BEHAVIORAL AND BRAIN SCIENCES (1999) **22,** 991–1060
Printed in the United States of America

Lexical entries and rules of language: A multidisciplinary study of German inflection

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Abstract: Following much work in linguistic theory, it is hypothesized that the language faculty has a modular structure and consists of two basic components, a lexicon of (structured) entries and a computational system of combinatorial operations to form larger linguistic expressions from lexical entries. This target article provides evidence for the dual nature of the language faculty by describing recent results of a multidisciplinary investigation of German inflection. We have examined: (1) its linguistic representation, focussing on noun plurals and verb inflection (participles), (2) processes involved in the way adults produce and comprehend inflected words, (3) brain potentials generated during the processing of inflected words, and (4) the way children acquire and use inflection. It will be shown that the evidence from all these sources converges and supports the distinction between lexical entries and combinatorial operations.

Our experimental results indicate that adults have access to two distinct processing routes, one accessing (irregularly) inflected entries from the mental lexicon and another involving morphological decomposition of (regularly) inflected words into stem+affix representations. These two processing routes correspond to the dual structure of the linguistic system. Results from event-related potentials confirm this linguistic distinction at the level of brain structures. In children's language, we have also found these two processes to be clearly dissociated; regular and irregular inflection are used under different circumstances, and the constraints under which children apply them are identical to those of the adult linguistic system.

Our findings will be explained in terms of a linguistic model that maintains the distinction between the lexicon and the computational system but replaces the traditional view of the lexicon as a simple list of idiosyncrasies with the notion of internally structured lexical representations.

Keywords: child language acquisition; development of inflection; grammar; human language processing; neuroscience of language; psycholinguistics

1. Combinatorial operations and lexical entries

A core property of human language is the unlimited possibility of expression despite limited resources. Speakers and hearers have the ability to create sentences and other linguistic expressions they have never heard before, even though their vocabularies, memories, attention spans, and so forth are limited. This property of human language can be explained by assuming a dual architecture of the language faculty with two separate components, a *lexicon* consisting of a list of lexical entries and a *computational component* for combining lexical entries. The lexicon is finite and specifies for each entry its category membership ("N(oun)," "V(erb)," etc.) and idiosyncratic information regarding its form and meaning. The computational component is conceived of as a finite set of rule-like operations that take lexical entries as inputs to form larger linguistic expressions, such as phrases and sentences. Because combinatorial operations apply recursively, they can generate an infinite number of expressions of arbitrary length. Moreover, as combinatorial operations manipulate abstract symbolic categories such as V and N rather than sounds or meanings directly, they can produce unusual sequences of words (*Colourless green ideas*), novel sentences, and even sentences that are structurally well formed but completely meaningless (*Mopy squitters blipped ruttily op en glurk*). In this way, the distinction between lexical entries and combinatorial rules explains the "discrete infinity" of human language (Chomsky 1995). It should be pointed out that the assumption of a dual structure of the language faculty does not hinge on the adoption of a particular linguistic theory or formalism, and that, consequently, the interpretation of our empirical findings hinges only on whether the phenomena are to be accounted for by combinatorial operations (such as rules of language) or by (access to) lexical entries.

Familiar arguments in favour of combinatorial operations for language and a mental grammar come from syntactic phenomena such as strict recursion and long-distance dependencies. Consider, for example, long-distance de-

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https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

pendencies like in wh-questions: *Who did he say that John loved?* Syntactic analyses of wh-questions posit computational mechanisms, for example, wh-movement (Chomsky 1981; 1995), to derive structural representations of such strings. In addition, a complex of constraints acting in tandem ensures that strings such as **Who did he say that John loved Mary,* in which an object expression follows the verb *love* (even though *love* normally takes direct objects), come out as ungrammatical. In this way, computational mechanisms such as constraints on movement correctly account for the syntactic properties of wh-questions.

Distinctions between lexical entries and combinatorial operations have also been made in psycho- and neurolinguistic research, with respect to the processing of language in real time, the acquisition of language by children, and the representation of language in the brain. Linguistically, morphological roots have lexical entries, but sentences typically do not (proverbs, clichés, etc., however, may be exceptions in this respect). Hence, whereas the processing of roots has traditionally been viewed as a search process with the goal of finding an entry in the mental lexicon, sentence processing involves the construction of a syntactic representation in accordance with grammatical principles (see Boland & Cutler 1996, however, for some critical discussion). In research on the acquisition of language, a distinction is made between two different kinds of mechanisms: Children may represent newly acquired linguistic material unanalyzed in lexical entries, or they may use combinatorial rules to construct grammatical rules (Berko 1958; Pinker 1984). Finally, the two components of the language faculty seem to elicit different brain potentials. Electrophysiological measures of neural activity have shown, for example, that semantically anomalous words elicit a characteristic brain response, the so-called N400 (Kutas & Hillyard 1980, and subsequent work), and that syntactic anomalies produce other effects (see sect. 4.5 below). Other brain-imaging studies suggest that different parts of the brain are active for lexical (Petersen & Fiez 1993; Petersen et al. 1989) and grammatical processing (Indefrey et al. 1996; Stromswold et al. 1996).

The view of the dual nature of the language faculty has recently come under attack from a group of researchers who seek to develop associative single-mechanism models of language, and subscribe to a school of cognitive science known as connectionism (Elman et al. 1996; Quartz & Sejnowski 1997; Rumelhart & McClelland 1986). A conception of knowledge of language is advocated here that tries to make do without the machinery of internally represented, symbol-manipulating combinatorial operations. Instead, it is argued that what looks like the application of symbolic principles or rules can be better represented in terms of associative networks operating without any directly implemented combinatorial principles. Associative networks consist of units called nodes and weighted connections between those nodes. All kinds of inputs and outputs are represented in the same way in these systems, that is, as patterns of activation over these nodes. For some linguistic phenomena that have traditionally been viewed as following from rules of language, for example, the English past tense (Halle & Mohanan 1985), associative single-mechanism networks have been proposed that are claimed to provide adequate accounts of inflection without invoking any kind of combinatorial operations. The most widely known example is Rumelhart and McClelland's (1986) pattern-associator network of past tense inflection in English, which contains no inflectional rules but can mimic rule-like behaviour and makes errors reminiscent of those made by children; see Hare et al. (1995), MacWhinney and Leinbach (1991), and Plunkett and Marchman (1991; 1993) for more recent networks of the English past tense. Some researchers have taken these simulations to mean that the knowledge of language would be better represented in terms of connectionist networks with associatively linked units rather than in terms of grammars (Bates & Elman 1993; Churchland 1995; Elman et al. 1996; Seidenberg 1997). It is claimed that if a reasonable account of linguistic phenomena can be given by a single type of mental mechanism, then – all other things being equal – there would be no need for a dual architecture or for separate cognitive systems such as the "lexicon" and the "computational system."

Apparently, however, things are not (yet) equal. Connectionist contributions to syntax have been limited (see Elman et al. 1996), and associative models of language seem to be incapable of properly implementing syntactic phenomena (Fodor et al. 1974; Fodor & Pylyshyn 1988; Marcus 1999). To take a famous example, Elman's (1993) network of subject-verb agreement in English was set up to do word prediction, take in sequences of words from a training set, and predict possible continuations. But when Marcus (1999) tested this model on words that were outside the training set, he found that it could not generalize in the way that humans do. Thus, it remains to be seen whether associative models will ever be able to handle successfully complex syntactic phenomena such as strict recursion and long-distance dependencies. Connectionist networks of the English past tense have also been shown to have severe deficiencies (Marcus 1999; Marcus et al. 1995; Pinker & Prince 1988), and it has been argued that they do not make a case for abandoning the idea of a dual structure of the language faculty including a mental grammar; see section 2 for some discussion.

The research strategy I will adopt here is to produce empirical evidence that might bear on the controversy between dual and single-mechanism models of language. My colleagues and I have studied (German) inflection in intensive detail from the perspective of different disciplines investigating its linguistic structure and historical development, how it evolves in child language acquisition, how it is produced and comprehended in real time, how it is processed in the brain, and finally, how it is affected by language disorders. We believe that such a multidisciplinary approach contributes to a better understanding of the mechanisms involved. The present target article shows that the results from these different investigations converge and that they provide new evidence for the dual nature of the language faculty.

2. The past tense debate

With respect to language, most of the empirical evidence in the connectionist-symbolist debate comes from the study of the English past tense, including studies on child language acquisition (e.g., Bybee & Slobin 1982; Marcus et al. 1992), adult language processing (e.g., Stanners et al. 1979; Stemberger & MacWhinney 1986), brain-imaging studies and event-related potentials (Jaeger et al. 1996; Münte et al.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

1998; Ullman et al. 1997a), connectionist simulations (e.g., Elman et al. 1996), and language disorders (e.g., Clahsen & Almazán 1998; Gopnik 1994; Marslen-Wilson & Tyler 1997). With respect to aphasia, for example, several researchers have pointed out contrasts between regular and irregular inflection in agrammatic production (Grodzinsky 1990; Kean 1977; Lapointe 1983). Perhaps the strongest evidence to date for a regular-irregular dissociation in the English past tense system comes from a cross-modal priming study with English-speaking aphasics (Marslen-Wilson & Tyler 1997). In this study, one subgroup of subjects exhibited (partial) priming effects for irregulars, but had lost (full) priming of regular verbs; another patient showed exactly the opposite pattern. Thus, there seems to exist a double dissociation between regular and irregular past tense forms in these patients, which indicates that the processes underlying regular and irregular inflection can be selectively impaired and therefore belong to different cognitive systems. We found similar dissociations for developmental disorders in children (Clahsen & Almazán 1998). We have investigated four English-speaking children with Williams syndrome (WS) (chronological age 11,2–15,5, mental age 5,4–7,6) and compared them to 2 control groups matched for mental age: normal subjects and specifically language impaired (SLI) subjects. Our findings indicate no impairments of the WS subjects on complex syntactic tasks, such as the interpretation of reversible passives and of sentences with reflexive anaphors, and on regular past tense formation; on these three phenomena, the WS subjects achieved the same level of performance as unimpaired controls, with a mean correctness score of 91%. On irregular verbs, however, the WS subjects performed much more poorly, with only 42% correct compared to 78% correct for the mental age normal controls. In SLI subjects, the results go the other way, with regular past tense forms producing higher error scores than irregular ones (see also Ullman & Gopnik 1994). It remains to be seen whether such double dissociations can be found for other inflectional phenomena and for languages other than English; see Penke (1998) for findings on selective impairments in the inflectional systems of German-speaking aphasics.

Several attempts have been made to simulate the properties of the English past tense in connectionist single-mechanism models. A detailed discussion of these models can be found in Marcus (1995; 1999), Marcus et al. (1995), and Pinker and Prince (1991). The following presents a brief review. Rumelhart and McClelland (1986) conducted a connectionist simulation of the acquisition of the English past tense system in which a pattern associator that directly takes a simplified quasi-phonological representation (= "Wickelfeatures") of the stem as input and computes a corresponding phonological representation of the past tense form as output. Correlations among pairs of features in the stem and the past are stored, and based on the strength of the association between the stem features and various output features in the training set, the model generalizes to new verbs. The challenge of this model is that it claims to represent the English past tense system including its acquisition in a unitary associative architecture without any recourse to morphological rules of inflection. However, Pinker and Prince (1988) and Marcus et al. (1992) pointed out several deficiencies in Rumelhart and McClelland's model. For example, the pattern associator can learn arbitrary input/output mappings, even those that are linguistically impossible, for example, string reversals. Marcus et al. (1992) also disconfirmed Rumelhart and McClelland's claims about vocabulary development and the assumed correlation with overregularization errors.

More recently, several new connectionist models have been proposed, each addressing one of the criticisms pointed out by Marcus et al. and Pinker and Prince. MacWhinney and Leinbach (1991), for example, built a network that can distinguish past tense forms of homophones (*ring – wring*), something the Rumelhart and McClelland pattern associator could not do; Daugherty and Hare's (1993) model correctly produces *-ed* forms of denominal verbs, even when they rhyme with existing irregulars; Hare et al.'s (1995) simulation can generate regular past tense forms of low-frequency verbs; the model proposed by Plunkett and Marchman (1993) mimics the U-shaped curve of the development of *-ed* in child language acquisition. All of these models have been claimed to create new problems, however, as pointed out by Marcus and collaborators (Marcus 1995; 1999; Marcus et al. 1995). For example, MacWhinney and Leinbach (1991) examined only a small number of verb pairs that by historical accident are homophonous and have different past tense forms in English, and they built features directly into their network for just these pairs (e.g., *to lie*). Although this correctly reproduced the facts for these verbs, it does not account for the fact that derived verbs, even if they are homophonous to existing irregulars, are always regularly inflected: *Napoleon rang the bell, and his soldiers ringed the city* (see Marcus et al. [1995, pp. 211f.] for further discussion of MacWhinney & Leinbach). Daugherty and Hare (1993) dealt with the inflection of denominals by adding extra input nodes that encode how a denominal verb is related to its head noun. This produced the correct output for these verbs, but Daugherty and Hare's network had to be particularly trained on verb forms such as *ringed (the city), spitted (the chicken),* and so forth, an unrealistic requirement given that speakers of English do not seem to depend on having heard such forms in the input (Kim et al. 1994, Marcus et al. 1995, p. 212). Hare et al. (1995) addressed the problem of generalizing a low-frequency default by representing the default affix as a discrete atomic label for a single output unit. But *-ed* is language-specific, and therefore hardwiring of *-ed* does not seem to be a realistic option. Moreover, as pointed out in Marcus (1999), semi-regular verbs such as *to sleep* and suppletive verbs such as *to go* pose problems for Hare et al.'s network, because the network's architecture systematically prevents massive stem changes (like *went)* and blends (like *slept)*. In contrast to claims made by Plunkett and Marchman (1993), Marcus (1995, p. 278) argued that their model's performance differs from actual children's development in important ways. For example, the Plunkett and Marchman model produced a U-shaped learning curve only after abrupt changes in the training regime, whereas in children's development there are no radical changes in the input. Moreover, irregularization errors (*flow → flew)* are extremely rare in children (Xu & Pinker 1995), but the Plunkett and Marchman model produced them more often than *-ed* overregularizations.

As is clear from this brief review, many of the criticisms of the original Rumelhart and McClelland model have been addressed in more recent connectionist networks of the English past tense. The proposed additions seem to have led to new problems, however. The fundamental deficiency

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of these models is that given enough training they can master the data of the training set, but in contrast to humans, their ability to generalize to novel items is limited and depends on particular statistical patterns in the input; see Marcus (1998) for further discussion.

Summarizing, we saw that despite all the evidence that has been accumulated on the English past tense, the representation and analysis of this system is still highly controversial and it is hard to see how the disagreements could be resolved. Perhaps the English past tense is not the most appropriate inflectional system for examining the distinction between memory- and rule-based representations for language. Compared to other languages, English is inflectionally poor. It has only one productive past tense suffix, the regular *-ed.* Also, regularity is confounded with both the presence of an overt affix and with type frequency: That is, regular verbs in English are much more type-frequent (= 95%) than irregular ones (= 5%) (see Marcus et al. 1995), and regular past tense forms contain a segmentable affix, whereas irregular forms typically do not have affixes.[1] These two confounding features leave room for several alternative interpretations of the same set of facts. Potential differences between forms such as *walk-ed* and *came,* for example, could be effects of frequency differences and/or effects of the presence or absence of an overt affix, rather than the result of different underlying representations.

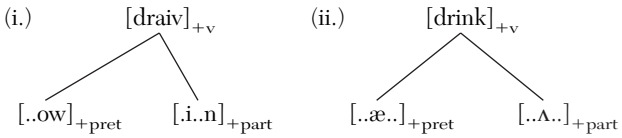
In our research we have examined two subsystems of German inflection, past participle inflection and noun plurals, from a multidisciplinary perspective. Like English past tense forms, German participles and noun plurals are easy to study, but, more importantly, they do not confront us with the confounding variables (in terms of word structure and frequency distribution) that make results on the English past tense so hard to interpret. We have investigated both verb and noun inflection to allow for generalizations across individual inflectional systems. The following sections will present results from these studies.

3. A dual-mechanism approach to German inflection

The basic idea of a dual-mechanism approach to inflection is the postulation of two qualitatively different clusters of inflectional phenomena, lexically based inflection versus inflection based on combinatorial rules, or – to use Pinker and Prince's (1991) terms – the distinction between irregular and regular (default) inflection. The latter is meant to capture the true productive aspects of inflectional morphology: regular (default) inflection can be easily decomposed into stem+affix and involves affixation processes that may operate on the outputs of other morphological operations (derivation, compounding); regular inflection readily extends to novel items. Lexically based inflection, on the other hand, epitomizes the idiosyncratic aspects of inflectional morphology as well as sublevel regularities of inflectional patterns with varying degrees of systematicity, such as the family resemblance patterns among irregular past tense forms of English (*sing – sang, ring – rang,* etc.). These irregular forms cannot necessarily be predicted from their corresponding base forms, and they are only tentatively extended to new forms.

We will adopt an approach to inflection in which the distinction between lexically based and rule-based inflection is made explicit and constitutes a design feature of the model, Minimalist Morphology (Wunderlich 1996; Wunderlich & Fabri 1995).[2] Minimalist Morphology distinguishes between regular inflection and lexically restricted inflection, and posits two qualitatively distinct linguistic mechanisms for them: structured lexical entries and affixation. Lexically restricted (irregular) inflection is not rule-based, but rather encoded in the lexical items themselves. Affixation on the other hand, is a combinatorial process that concatenates an affix with a lexical entry. Affixation is constrained only by a small set of general (probably universal) constraints, for example, that more specific lexical entries take precedence over less specific ones in affixation.[3]

With respect to the English past tense system, for example, Wunderlich and Fabri (1995) claim that regularly inflected forms such as *walked* are derived by affixation (add *-ed),* whereas irregular past tense forms are represented as subnodes of lexical entries. Consider, for illustration, the entries for verbs such as *drive* and *drink:*



Each node in a structured lexical entry represents a pair (<phonological string, morphological feature value>), and each subnode inherits all information of its mother, except for the features it replaces or adds. For example, the subnode $[..æ..]_{+pret}$ inherits the onset *dr-*, the coda *-nk,* and the categorial feature [+V] from the higher node. Subregularities among irregular past tense forms are captured through lexical templates in which stem segments are associated with segments from subnodes. For example, the $[..æ..]_{+pret}$ subnode occurs not only for *drink* but for several other verbs with the segments *-ing-* and *-ri-* in the base entry (*ring, sing, spring,* etc.), which therefore constitute a lexical template.

German participle formation involves two endings: *-n* appears on all participle forms of so-called strong (= irregular) verbs, and *-t* appears on participle forms of all other verbs[4] (see Appendix A1 for details). The participle *-t* suffix also applies to words for which lexical entries are not readily available, such as nonsense words (*faben, "gefabt"*), low-frequency words (*löten,* "to solder," "gelötet"), onomatopoeia (*brummen,* "to buzz," *gebrummt),* and verbs derived from adjectives or nouns (das *saubere* Haus, "the clean house"; wir *säubern* das Haus, "we clean the house"; wir haben das Haus *gesäubert,* "we cleaned the house"). In this regard, the participle *-t* behaves like the English past tense suffix *-ed.* By contrast, the participle *-n* does not apply under such circumstances. The participle *-n* co-occurs with phonologically unpredictable stem changes, whereas *-t* suffixation on weak (= regular) verbs does not involve any stem allomorphy (see Appendix A1 for examples). Hence, *-n* participle forms behave like irregular past tense forms in English. To capture these differences, Wunderlich and Fabri (1995) posit two distinct mechanisms for German participle formation, a *-t* affixation rule and lexical entries for irregular verbs (see Appendix A1 for further details).

German plurals are formed using five different endings (*-n, -s , -er, -e,* and *-0)* along with possible vowel changes

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(see Appendix A2 for examples). None of the five endings is statistically predominant, and the use of these endings with specific nouns is not readily captured by standard inflectional rules. Despite its overall irregularity, the German plural system has been shown to provide a default process that applies when irregular forms are not accessible. Marcus et al. (1995) demonstrate that according to their linguistic criteria, *-s* plurals fall into the default cluster, even though they are extremely rare in the German language compared to other plural forms. The *-s* plural applies when the phonological environment does not permit any other plural allomorph. It occurs on masculine, feminine, and neuter nouns, on words that exhibit the canonical stress pattern and on those that do not, on monosyllables and polysyllables, and on both vowel-final and consonant-final stems. The *-s* plural also generalizes to rootless and headless nouns, for example, to nominalized conjunctions such as *die Wenns und Abers,* "the Ifs and Buts," to eponyms and product names (*Fausts, Golfs,* etc.), and to nominalized verb phrases (VPs) (*die Rührmichnichtans,* "the Touch-me-nots"). This contrasts with other (irregular) plurals, which are restricted to particular morphophonological conditions. Given the Minimalist Morphology framework, we distinguish between two kinds of morphological processes involved in German noun plural formation, an *-s* affixation rule and lexical entries for irregular plurals (see Appendix A2 for linguistic details).

To sum up so far: We began by characterizing the dual nature of the language faculty according to which knowledge of language involves two distinct cognitive mechanisms, a symbol-manipulating system of combinatorial operations and lexical entries. We have chosen to examine the phenomenon of grammatical inflection from this perspective, focussing on two systems of German inflection, noun plurals and participle formation. A linguistic analysis of these inflectional systems was presented that made use of two kinds of linguistic representations, affixation and structured lexical entries. Affixation covers the regular aspects of inflection and belongs to the system of combinatorial operations. The irregular aspects of inflection are encoded in lexical entries. To capture subregularities of inflectional patterns, lexical entries were claimed to have internally structured representations ("default inheritance trees") and to be linked to related entries through lexical templates.

The view of the dual nature of the language faculty has implications beyond the level of linguistic analysis. If the idea of two distinct cognitive systems for language is real and fundamental, rather than just a convenient linguistic description or an epiphenomenon of frequency and similarity clusters in verbal memory, we would expect rule-based inflection to dissociate from lexically based inflection from different points of view, not just in analyses of inflectional systems in natural language grammars. We would expect to find corresponding dissociations, for example, in human language processing, with respect to neural structures in the brain, in the way children acquire these two types of phenomena over time, and so forth. We have used several experimental methods and different groups of subjects to investigate German inflection with respect to these domains, and as will be shown in subsequent sections, the evidence from these sources converges on the predicted dissociations, thus supporting the dual nature of the language faculty.

4. Adult language processing

In the previous section, we assumed that the language faculty has a dual architecture comprising combinatorial principles and a structured lexicon. This view raises two closely related psycho-/neuro-linguistic questions about (1) how these two mechanisms are used in speech production and comprehension, and (2) how they are represented in the brain. We will address these questions separately, taking the processing of German noun plurals and participles as the focus of our empirical investigation. Before turning to the empirical evidence, however, let us briefly consider how the mental grammar might be connected to processes involved in the production and comprehension of language.

4.1. Morphological processing models

The strongest and (to me) most interesting view concerning the grammar-processing relation is the correspondence hypothesis (originally proposed by Miller & Chomsky 1963), according to which the mental grammar is used directly in language processing. This means that grammatical rules and principles are mentally represented and that in recognition and production the language processor constructs such representations using the normal structures and operations of the grammar. The appeal of the correspondence hypothesis is that it provides an economical and straightforward account of how grammatical knowledge and processing are related: The parser is said to make basically the same distinctions as the grammar (Jackendoff 1997; Phillips 1996).

With respect to morphology, psycholinguists have examined the role of morphological structure in the processing of morphologically complex words and the question of whether there is any correspondence between the linguist's decomposition of a morphologically complex word and the way it is segmented by the speaker-hearer during online production and comprehension. Current morphological processing models provide conflicting answers to these questions, however. Some researchers (e.g., Butterworth 1983, Manelis & Tharp 1977) claim that the morphological structure of words plays no role in the way they are produced or perceived and that morphologically complex words are fully listed in memory. Recent connectionist models (MacWhinney & Leinbach 1991; Plunkett & Marchman 1993; Rumelhart & McClelland 1986, among others) are similar in spirit and can be viewed as implementations of full listing models. All inflected words, such as irregular and regular past tense forms of English, are said to be stored in terms of distributed representations in associative memory.[5] In contrast to this, the full parsing model of Taft and his collaborators claims that only stems have entries in the mental lexicon and that morphological variants need to be decomposed in processing before their stems can be accessed (see, e.g., Taft 1979). This model assumes global affix-stripping mechanisms for processing purposes that do not necessarily correspond to the morphological structure of a complex word. Several other models of morphological processing have incorporated whole word-based representations with morphological decomposition in so-called dual-route models (Frauenfelder & Schreuder 1992; Laudanna & Burani 1985; 1995; Schreuder & Baayen 1995). In these models, the language processor is said to make use of both full-form representations of morphologi-

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cally complex words and morphological decomposition. Word frequency and phonological transparency seem to be crucial factors in determining which of the routes is more efficient: Highly frequent, phonologically nontransparent words are more likely to have full-form representations than low-frequency transparent words. However, the extent to which these two processing routes depend on morphological structure is viewed as controversial (see, e.g., Baayen et al. 1997b).

According to the correspondence assumption, structural properties of inflected and (derived) words should converge with their processing properties, a sensible prediction if our ultimate goal is an integrated theory of brain and mental functions underlying language. Dual-mechanism morphology distinguishes between regular and irregular morphological processes, the former involving affixation and the latter, (structured) lexical entries. Hence, given the correspondence assumption, dual-mechanism morphology leads us to expect a parallel distinction in morphological processing: Inflected words that have stem+affix representations should be computed via their constituent morphemes, whereas inflected words that are represented in terms of (structured) lexical entries should exhibit associative memory effects in processing experiments. This means that for inflected words formed through affixation we would expect to find evidence for morphological decomposition in psycholinguistic experiments. By contrast, irregularly inflected words should produce effects that are characteristic of lexical entries in morphological processing experiments. It is an extremely strong (probably too strong) prediction that in any language one should find that linguistic and psycholinguistic properties of inflectional phenomena always converge into either of these two clusters. However, as Pinker and Prince (1991, p. 16) stress, "even partial confirmations across languages would offer new insight into the role of predictability, productivity, and statistical patterns in influencing grammar and linguistic performance." We will examine these predictions here, taking German noun plurals and participle formation as our test cases.

4.2. Generalizing inflectional processes

One crucial property of inflectional processes is that they can be easily applied to novel or unusual words under appropriate circumstances (see Bybee & Moder 1983 and Prasada & Pinker 1993, for English). The dual-mechanism model predicts that the generalization properties of regular and irregular inflection are different, however, depending on the linguistic mechanisms involved. Consider participle and noun plural formation in German. Irregular participle and noun plural forms are represented in structured lexical entries (such as those in [ii] and [iv] in Appendix A1 and A2). Hence, structured lexical entries should generalize only by analogy, that is, to novel words that are similar to existing ones. Regular *-t* participle and *-s* plural inflection, on the other hand, are based on affixation (see [i] and [iii] in Appendix A1 and A2), which may apply to a given syntactic category ("V" or "N"), irrespective of any kind of similarity to lexical entries. Hence, affixation-based generalization should apply elsewhere, even under a circumstance such as one in which similarity-driven analogies fail, for example to unusual sounding novel words.

The generalization properties of participle and plural formation processes have been investigated in different kinds of experiments involving inflected forms of novel and uncommon words; the results support the distinction between similarity-based and affixation-based generalization.

4.2.1. Generalization to nonsense words. Participle formation of nonsense words has been investigated in an elicited production experiment (Clahsen 1997). We constructed novel strong and weak verbs and presented subjects with both past tense and infinitive forms of these novel verbs. Note that past tense formation in German provides an unambiguous cue for determining verb-class membership: Weak verbs form their past tenses with *-te* and without vowel changes, whereas strong verbs all have vowel changes and never carry the *-te* suffix in the past tense (see [b] – [d] in Appendix A1). To begin, subjects were given each nonsense verb in the infinitive and the past tense form ("step 1"). They were then asked to use the past tense form from step 1 to fill in a blank in another sentence ("step 2"). Finally, they had to fill in a second blank, this time by providing the participle form of the nonsense verb ("step 3"); see the following illustration.

Step 1: Presentation of nonsense verb in infinitive and first person singular past tense
"Eines Tages kam mein Freund Peter zu mir und fragte mich, ob ich seinen Zatt *teiden* kann. Es war kein Problem für mich, und ich *tied* seinen Zatt."
(One day, my friend Peter came to me and asked me whether I could *teiden* [=infinitive] his Zatt. That was no problem for me, and I *tied* [= 1st person past tense] his Zatt. [Note that Zatt is a nonword as well.])

Step 2: Replication of past tense form
"Es war nicht das erste Mal, daß ich einen Zatt ———"
(It was not the first time that I ——— a Zatt.)

Step 3: Production of participle form
"Peter sagte: Danke, daß du meinen Zatt—— hast."
(Peter said: "Thank you that you have —— my Zatt.")

The experiment produced three main results (see Fig. 1). First, even in cases in which subjects correctly reproduced the strong past tense form in step 2, *-n* participle formation is used less often than expected: Only 31% (196/637) of the items that subjects reproduced in the strong past tense form in step 2 had the expected *-n* ending on the participle. Second, in contrast to *-n*, the *-t* suffix appeared in nearly all of the expected cases (97% of weak verbs, 665/685 cases), and more importantly, it was heavily extended to strong verbs: 69% (441/637) of the nonsense verbs that were correctly reproduced with strong past tense forms were suffixed with *-t* in the participle. Third, as shown in the third column of Figure 1, 91% (178/196) of the *-n* participles were produced on verbs that rhyme with existing strong verbs, for example, to *teiden – tied – getieden,* which is analogous to *scheiden – schied – geschieden,* "to separate."

These results show that the generalization properties of *-t* and *-n* participle formation are quite different: Whereas *-t* generalizes widely to all kinds of nonsense verbs, extensions of *-n* participle formation are narrowly restricted to novel verbs that are similar to existing ones. These differences correspond to the linguistic distinction between affixation and structured lexical entries: *-t* participles are affixation-based, constrained only by general principles, and hence may apply to any kind of verb; *-n* participles are sub-

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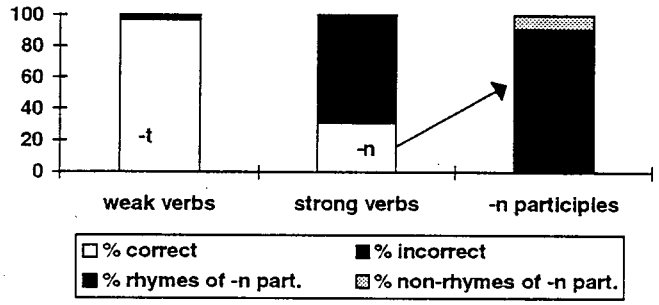


Figure 1. Generating participles of nonsense verbs. Suffixes used on different kinds of nonsense verbs. The first column shows that the *-t* suffix was used on 97% of the weak verbs. The second column shows that the *-n* suffix was used in 31% of the strong verbs. The third column shows that 91% of the *-n* participle forms were verbs that rhymed with existing strong verbs.

nodes of lexical entries that can be accessed only by analogy, and hence the similarity-based extensions to novel verbs found in this experiment.

Similar results have been obtained in a paper-and-pencil judgment experiment on plural formation of nonsense nouns (Marcus et al. 1995). The experimental items were 12 monosyllabic novel nouns that rhymed with existing German nouns that take irregular plural forms, for example, *Pund* on analogy with *Hund – Hunde,* "dog – dogs," and 12 nonrhymes. Each item was first presented in a context sentence in its singular form, followed by eight test sentences, each containing all possible plural forms. Subjects were asked to rate each sentence on a 5-point scale for acceptability.

We found that irregular plural forms were judged as significantly better for nouns that rhymed with existing (irregular) nouns than for nonrhymes ($p < .001$), whereas *-s* plural forms were judged as significantly worse in the Rhyme condition than in the Non-Rhyme condition ($p < .01$). Thus extensions of irregular plural formation are sensitive to similarity, whereas *-s* plurals are applied elsewhere, even to nouns that are not similar to any existing German word.

4.2.2. Matching sentences containing nonsense participles. We argued above that *-t* participle formation involves affixation, whereas the *-n* ending is part of lexical entries. The experiment to be reported here investigates effects of violations of affixation processes (Clahsen et al. 1997). According to our linguistic analysis, participles of weak (regular) verbs are formed by *(-t)* affixation. We would therefore expect incorrectly inflected participles of regular verbs to produce affixation-violation effects; for *-n* participle formation, however, there should be no such effects, because *-n* participle forms are not affixation-based.

To investigate affixation-violation effects, we adopted the sentence-matching technique from Chambers and Forster (1975) and Freedman and Forster (1985). In this task, subjects are presented with two stimuli on a screen and must decide as quickly and accurately as possible whether these two stimuli are the same or different. It has been shown that the reaction times (RTs) in this task are sensitive to grammatical well-formedness: well-formed words and sentences have shorter RTs than ill-formed control items. Chambers and Forster (1975), for example, found that subjects responded more quickly to word pairs such as HOUSE/HOUSE than to nonwords such as HSEUO/HSEUO, even though the nonword stimuli were of the same length as the word pairs. Similar effects were found for various kinds of morphosyntactic violations, for example, subject-verb agreement errors, illegal subjects, ungrammatical word-order patterns, and so forth (Clahsen et al. 1995; Forster 1987; Forster & Stevenson 1987; Freedman & Forster 1985). In our experiment, we used the matching technique to determine whether regular and irregular inflection behave differently with respect to violations of affixation.

To prepare the subjects for our matching experiment, they were first given a booklet and asked to learn a set of 20 nonsense verbs in the infinitive and corresponding past tense forms, 10 with weak past tense forms (e.g., *praupen – praupte)*, and 10 with strong ones (e.g., *flauden – flied)*. After the subjects had learned the nonsense words at home, successful learning was tested using a cloze test.[6] Only those subjects who correctly reproduced the past tense forms of all nonsense verbs performed the matching task in which they were confronted with *-t* and *-n* participle forms of the nonsense verbs they had learned before (e.g., *gepraupt – gepraupen, geflauden – geflaudet)*. There were four types of test items as shown in Figure 2: nonsense words learned as weak or strong verbs, and participles presented with *-t* or *-n* in the matching task.

We found that weak novel verbs incorrectly presented with *-n* produced longer RTs than the grammatical control condition, that is, weak verbs correctly suffixed with *-t* (1,643 msec vs. 1,483 msec, $p < .001$). For strong novel participle forms, however, there was no such effect; rather, *-t* suffixation, which is ungrammatical for existing strong verbs, produced slightly faster RTs than *-n* participle formation (1,513 msec vs. 1,552 msec, $p = .43$). These results can be explained in terms of a dual-mechanism analysis of German participle formation in which *-t* (but not *-n)* participles are affixation-based. Given the *-t* affixation process, an *-n* participle form of a (novel) weak verb involves a violation of an affixation process and hence the observed un-

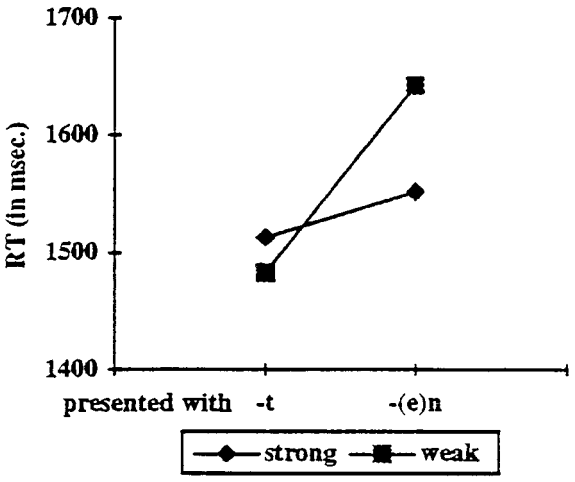


Figure 2. Sentence-matching times for novel participles. Nonsense items that were learned as weak verbs produced shorter mean response times when they were presented with the correct *-t* suffix compared to being presented with the (incorrect) *-(e)n* suffix. Nonsense items that were learned as strong verbs did not produce shorter response times when they were presented with the correct *-(e)n* suffix.

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grammaticality effect in the matching task. By contrast, a *-t* participle form of a novel strong verb does not violate any affixation process or constraint, because *-t* affixation may apply to any verb and because according to the linguistic analysis proposed here, there is no corresponding *-n* affixation process. Consequently, in the matching task *-t* participles of novel strong verbs do not produce longer RTs than *-n* participles of such verbs.

4.2.3. Judging participle and plural forms of unusual words. Words derived from other categories, as well as words directly borrowed from other languages, are unusual in that they do not have canonical lexical entries. Consider, for example, verbs derived from nouns. A denominal verb such as *to spit (the chicken)* in the sense of "to put the chicken on a spit" has a complex internal representation; it is based on the lexical entry of a noun, *(the) spit,* and is headed by a derivational affix that determines the category of the whole word (Olsen 1990; Wunderlich 1986). Hence, in terms of their linguistic structure denominal verbs do not have lexical entries (as verbs), but are instead computed by category-changing affixation.[7] When such derived words are inflected for the past tense, access to lexical entries of verbs is blocked, even though they may sound similar to existing verbs, and the regular default affix is used (*Paul spitted the chicken).* The ungrammaticality of irregular past tense forms in such circumstances follows from the fact that the lexical entry for the irregular verb form *spat* is specified for particular syntactic categories (= "V" in the case of verbs), which derived words such as *"spit (the chicken)"* cannot access given their morphological structure, that is, [V[N spit] -Ø]. The same applies to plurals of nouns derived from proper names and from borrowings, as in expressions such as *the Helmuts (= Helmut Kohl and Helmut Schmidt) like cappuccinos.* Linguistically, the items *Helmut* and *cappuccino* are stretches of sounds that do not have lexical entries. Rather, they bear a nonspecific label "X," which needs to be converted into a proper syntactic category, yielding structures such as $[[\text{Helmut}]_X\text{-Ø}]_N$ and $[[\text{cappuccino}]_X\text{-Ø}]_N$, which are similar to those of denominal verbs.

In two acceptability rating experiments, one on participles and one on noun plurals, we studied how speakers of German inflect such noncanonical words (Marcus et al. 1995). In the participle study, subjects were presented with novel denominal verbs, each of which appeared in two test sentences, one with a *-t* and one with an *-n* participle form. Subjects were asked to judge each test sentence on a 7-point scale for acceptability. To control for similarity-based generalizations, we made all the denominal verbs used in the experiment homophonous to existing strong verbs. Hence, if these novel denominals were inflected by analogy to existing lexical entries rather than by affixation, *-n* participle forms should have higher ratings than *-t* participles.

What we found, however, was that subjects judged *-t* participles of novel denominal verbs as significantly better than *-n* participles (mean ratings: 3.3 vs. 2.1, $p < .001$), even though the items were homophonous to existing strong verbs. Similar results were achieved on plural formation of derived nouns (Marcus et al. 1995). Recall from section 4.2.1 that similarity-based generalizations were found for plurals of nonsense nouns: Items that rhyme with existing nouns taking irregular plurals may be irregularly inflected by analogy. However, when the same items were presented to the subjects as proper names or borrowings, the preference for irregular plural formation disappeared: *-s* plurals of borrowings were judged as significantly better than *-s* plurals of the same items used as simple nonsense nouns ($p < .005$), and *-s* plurals of proper names were judged as significantly better than irregular plurals, even for items that rhyme with existing irregulars ($p < .001$). So, the novel item *pund,* for example, which is analogous to *Hund – Hunde,* "dog – dogs," has a clearly preferred plural form (= *pund-s)* when used as a proper name.

These results correspond to the linguistic distinction between affixation and structured lexical entries. Irregular participle and irregular plural forms are based on lexical entries, and these entries are specified for particular syntactic categories that derived words cannot access given their morphological structure. Affixation, however, can be applied to any element of a given category, and hence the clear preference for *-t* participles of denominal verbs and *-s* plurals of derived nouns.

4.3. Frequency effects in visual lexical decision

Several researchers have used lexical decision experiments (LDEs) to test inflected words for memory effects. LDEs are word/nonword discrimination tasks with RT as the dependent variable. Lexical decision times on noninflected simplex words have been consistently shown to be affected by word frequency: Subjects take less time to decide that high-frequency items are existing words than they do for low-frequency items (see Balota 1994 for review). This is conceived of as a memory effect: As memory traces get stronger with additional exposures, high-frequency entries can be more readily accessed than low-frequency ones. LDEs on inflected words have produced conflicting results. On the one hand, a number of studies have found an effect of root frequency (the sum of all forms with a given root) for words equated in word-form frequencies; Taft (1979) showed in an LDE that it takes less time to recognize a word like *sized,* which has a high root frequency and a low word-form frequency, than it does to recognize a word like *raked,* which has both a low root and a low word-form frequency. On the other hand, some studies have found word-form frequency effects in LDEs, even for what looks like regularly inflected words (Baayen et al. 1997a; 1997b), suggesting that regularly inflected forms are (sometimes) stored in memory. It is not entirely clear, however, whether the inflectional phenomena tested in these studies (Dutch and Italian plural formation) involve regular default processes; see Clahsen et al. (1997) for some discussion.

Given the dual-mechanism analysis of inflection, word-form frequency effects should be more likely to occur for irregularly inflected forms, than for regulars. This is because irregular forms are based on lexical entries, whereas affixation-based forms are typically computed on-line. I will report results from visual LDEs on German participle and noun plural formation in which this prediction was tested (Clahsen et al. 1997).

In the participle LDE, we compared 20 *-n* participles of different subclasses of strong verbs with 20 *-t* participles of weak verbs. The *-t* and *-n* participles were divided into two subgroups, each according to the (word-form) frequencies of the participle forms in the CELEX database (Baayen et al. 1993), a high-frequency group (with a mean participle frequency of approximately 60/million) and a low-frequency group (with a mean participle frequency of 13/mil-

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lion). The items were also matched for stem frequency, and this was held constant across the high- and low-frequency conditions, to isolate word-form frequency as the decisive factor (see Clahsen et al. 1997, Fig. 3).

We found word-form frequency effects for participles of different subclasses of strong verbs, but not for *-t* participles of weak verbs. Figure 3 presents the mean lexical decision times for *-n* participles of verbs of the strong-3 subclass (see Appendix A1[d]) in comparison to *-t* participles of weak verbs. Figure 3 shows that lexical decision times for high-frequency *-n* participles are significantly shorter than those for low frequency *-n* participles ($p < .001$). Participles of weak verbs, by contrast, do not produce a frequency effect in the lexical decision task.

In the plural study, we compared lexical decision times of *-er* plurals with those of *-s* plurals. Similar to *-s* plurals, *-er* plurals are relatively infrequent in German (see Appendix A2, Table 5), but the linguistic structures involved are claimed to differ: *-s* plurals are based on affixation, and *-er* plurals have lexical entries. Thus, we would expect lexical decision times for *-er* plurals (but not for *-s* plurals) to be affected by the frequency of the plural form. Subjects were tested in a visual LDE on 20 *-er* and 20 *-s* plurals, each divided into two subgroups according to their word-form frequencies in the CELEX database.

We found a strong frequency effect for *-er* plurals: Lexical decision times for high-frequency plural forms are 84 msec shorter than those of low-frequency *-er* plurals (mean RTs: 671 vs. 587 msec, $p < .001$). Regular *-s* plurals, however, produce similar lexical decision times, irrespective of whether they are low or high in frequency (mean RTs 650 vs. 654 msec, $p = .62$). These results show that *-er,* but not *-s* plural forms, are affected by their word-form frequencies.

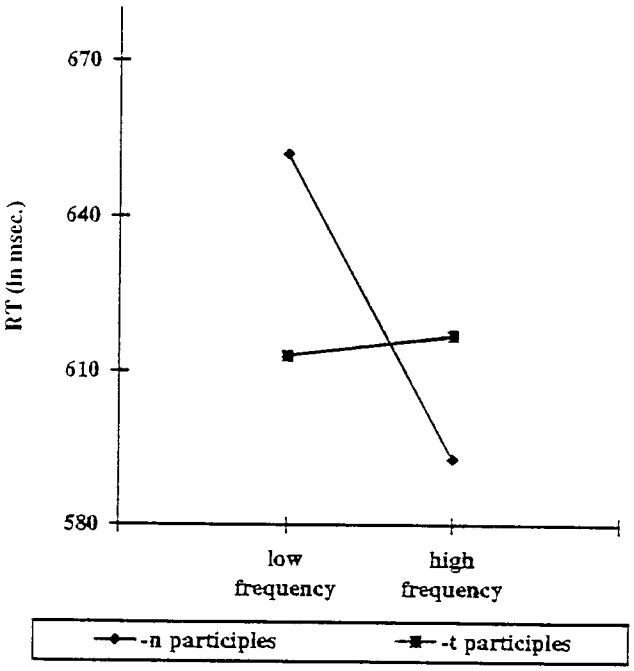


Figure 3. Lexical decision times for participles. High-frequency irregular *(-n)* participles produced shorter mean reaction times than low-frequency *-n* participles. For regular *(-t)* participle forms there is no such frequency effect.

The results of the two LDEs can be explained in terms of the different linguistic representations involved: *-er* plurals and *-n* participles have lexical entries, and hence high-frequency forms can be accessed more quickly than low-frequency ones. For *-t* participles and *-s* plurals, however, there are no full-form representations, as these are derived from affixation. Stems and affixes may have separate entries in the mental lexicon, and the speed with which they can be accessed might be affected by frequency. Affixation-based words as a whole, however, are not mapped directly onto corresponding entries, and hence the lack of a frequency effect for *-s* plural and *-t* participle forms in the two LDEs.

4.4. Cross-modal morphological priming

In priming experiments, two stimuli are presented to subjects, and the researcher manipulates the relation between them. Most research has been done on semantic and phonological priming to investigate the relationships among the meanings and the sound patterns of words in the mental lexicon (see Balota 1994 and Lively et al. 1994 for literature reviews).

Morphological priming effects were found in several studies investigating the English past tense. In their seminal study, Stanners et al. (1979) found that when subjects were presented with a sequence of two identical words for lexical decision, for example, *walk* followed by *walk,* the response times to the second occurrence of *walk* were usually faster than to its first occurrence. The repetition of a word is taken to facilitate access to its lexical entry. It is interesting that Stanners et al. found the same facilitation for earlier presentation of a regularly inflected past tense form (*walked* → *walk)*, that is, this condition produced the same amount of priming as prior presentation of the stem itself.

All subsequent experiments have confirmed Stanners et al.'s finding of full priming for regularly inflected words (Fowler et al. 1985; Kempley & Morton 1982; Marslen-Wilson et al. 1993; Napps 1989). However, with respect to irregulars, the results are much less clear. Where Stanners et al. had seen reduced facilitation for irregulars, Kempley and Morton (1982) found no priming at all, and Fowler et al. (1985) and Forster et al. (1987) found full priming. Marslen-Wilson et al. (1993) investigated two subclasses of irregular past tense forms, verbs such as *burnt – burn* and *felt – feel* with vowel changes and *-t* as the final consonant, and verbs such as *sang – sing, gave – give* with vowel changes only. They compared these irregular types with regular past tense forms in a cross-modal priming task. Only the regular past tense forms produced full priming. The past tense forms of semi-regular verbs (*burn – burnt, feel – felt)* yielded no priming, whereas those of pure vowel-change verbs such as *give – gave* actually led to an interference effect, with response times being significantly slower than following unrelated primes. The interference effect might be taken to reflect the presence of two lexical representations for *give* and *gave,* for example, which inhibit one another.

Taken together, the finding that regular past tense forms consistently produced full priming in all studies is compatible with the view that regular past tense forms are morphologically decomposed. Thus, the segmentation of *walked* into a stem (*walk)* plus affix (*-ed)* leads to activation of a lexical entry for the stem (*walk)*, which serves as a prime for the target stem (*walk)* in the lexical decision task;

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Table 1. *Example stimulus set–participles*

	Primes			Targets
	Identity	Morph. Related	Control	
-t participles	plane "(I) plan"	geplant "planned"	schätze "(I) estimate"	plane
-n participles	schlafe "(I) sleep"	geschlafen "slept"	beuge "(I) bend"	schlafe

hence the full priming for regulars. There is, however, an alternative interpretation as to why regular past tense forms in English produce full priming. Rueckl et al. (1997) argued that regular past tense forms are orthographically and phonologically more similar to their base forms than irregular 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. This interpretation would make full priming effects for *-ed* forms compatible with single-mechanism associative models of the mental lexicon. Thus, it is not entirely clear how full priming for regular past tense forms in English should be interpreted. In addition to that, there remains the question of why irregulars have yielded such inconsistent results across studies.

Again, the confounding variables of the English past tense system make it hard to interpret experimental findings. As shown below, German inflection allows us to construct priming experiments without such confounding variables. In two experiments, we investigated German participle and noun plural inflections for morphological priming effects (Sonnenstuhl et al. 1999) by adopting the cross-modal immediate repetition priming technique from Marslen-Wilson et al. (1993; 1994) and Marslen-Wilson and Tyler (1997). In this task, subjects hear a spoken prime (such as *Ponys,* "ponies," or *gekauft,* "bought") immediately followed by a visually presented form of the noun (e.g., *Pony)* or verb (*kaufe* "buy-1st person singular") on which subjects have to make a lexical decision. Because the task is *cross-modal,* any priming effects from these experiments are attributable to the lexical representations themselves, rather than to effects of modality-specific access procedures.

Full and partial priming effects were determined by comparing RTs in three conditions (see Tables 1 and 2 for example stimulus sets):

I. Identical primes and targets

II. Morphologically related primes and targets

III. Different primes and targets

In the control condition (III), primes and targets are neither semantically nor phonologically related, whereas in condition (I) they are identical. These two conditions provide the baseline lexical decision times (with no priming for III and full priming for I) to which the RTs of the experimental condition (II) can be compared. According to the dual-mechanism approach, we would expect only full priming, that is, (I = II) < III, for *-t* participles and *-s* plurals, but not for *-n* participles and irregular plurals. The reason is that *-t* participles and *-s* plurals are decomposed into stem+affix, which both have a lexical representation of their own; hence the repetition of the same stem in conditions I and II should facilitate accessing the corresponding lexical entries. Irregular plural forms and *-n* participles, however, are represented on subnodes of (structured) lexical entries. This means that irregular plural and participle forms activate their corresponding base entries only indirectly, via subtrees (see [i] and [ii] in section 3 and [ii] and [iv] in Appendix A1 and A2); they should therefore produce less facilitation than identical primes (I < II < III). In other words, we predict full priming for *-t* participles and *-s* plurals and partial priming for the irregulars.

We compared priming effects of participle forms of regular verbs with those of irregular participles of the "strong-3" class (see [d] in Appendix A1). Note that all verbs that belong to this class, for example, *laufen – lief – gelaufen* "run – ran – run," have stem changes in the past tense form, but not in the participle. This differs from English past tense forms where stem changes are a confounding variable for potential priming differences between regular and irregular inflection. This problem does not occur in the German study. We constructed 21 sets of triplets for each participle type (*-t* vs. *-n)*, where the 1st sg. present tense forms were always the target, presented visually for lexical decision, at the offset of one of three kinds of auditory primes, "Identical" (I), "Morphologically Related" (II), or "Different" (III). The control items for condition (III) were matched to the primes I and II for frequency and syllable length (see Table 1 for an example stimulus set), and weak and strong-3 verbs were matched with respect to their lemma frequencies.

Three experimental versions were constructed, so that each target word occurred only once for each subject. There were 66 subjects tested, 22 for each version. In addition to the experimental and control items, we included an additional 534 pairs of filler items, to make sure that the target was a nonword in half of the trials and that the proportion of related items is lower than 15% overall (see Sonnenstuhl et al. 1999 for details).

The results are shown in Figure 4 for two types of verbs, weak verbs that take the *-t* participle suffix and strong-3

Table 2. *Example stimulus set–plurals*

	Primes			Targets
	Identity	Morph. Related	Control	
-s plurals	Pony "pony"	Ponys "ponies"	Hefe "yeast"	Pony
-er plurals	Nest "nest"	Nester "nests"	Ferse "heel"	Nest

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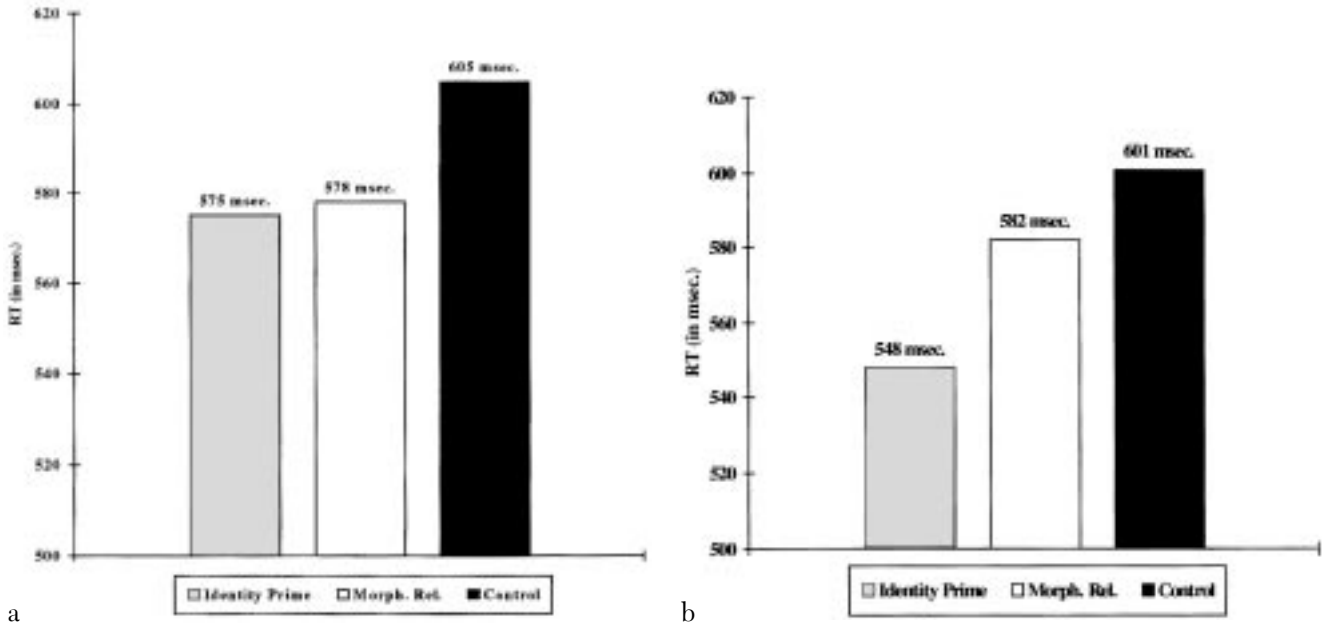


Figure 4. Cross-modal lexical priming of participles. Figure 4a presents mean lexical decision times on visual targets for *-t* participles, identical repetitions, and unrelated controls. The morphological prime (= regular *-t* participles) produced a full priming effect compared to unrelated controls which is similar to an identical repetition. Figure 4b presents mean lexical decision times for irregular *-n* participles, identical repetitions, and unrelated controls. In this case, the morphological prime, that is, the irregular *-n* participles, produced a partial priming effect, that is, longer reaction times than an identical repetition.

verbs with the participle *-n*. For both types of verbs, the "Identity" condition produces shorter RTs than the two control conditions. With respect to the "Morphologically Related" condition, however, there are pronounced differences between *-t* and *-n* participles. Regular (*-t*) participles produce significant morphological priming (578 vs. 605 msec, $p < .001$), and the size of the effect (= 27 msec) is similar to the size of the effect in the Identity condition (= 30 msec). RTs after presentation of *-t* participles do not differ significantly from those of the Identity condition (575 vs. 578 msec, $p = .67$). Irregular participles exhibit a different pattern of results. As shown in Figure 4b, prior presentation of an *-n* participle form produces shorter RTs than prior presentation of an entirely different verb (582 vs. 601 msec), but in contrast to *-t* participles, the effect for *-n* participles is nonsignificant ($p = .17$) and RTs in the Morphological Prime condition are significantly longer than in the Identity condition (582 vs. 548 msec, $p < .0001$). These results confirm the prediction that only regular *-t* participles produce full priming effects; irregular *-n* participles, on the other hand, only lead to partial priming.

In the second cross-modal priming experiment, we compared *-s* plurals with *-er* plurals. Even though these two plural forms have similar (i.e., low) type frequencies in German (see Appendix A3, Table 5), their lexical representations are claimed to be radically different: *-s* plurals are affixation-based, *-er* plurals are part of lexical entries. Hence, *-s* plurals should produce full and *-er* plurals partial priming effects. The design was the same as in the participle experiment. Thirty sets of triplets were constructed for each plural type (*-s* vs. *-er*). Three kinds of auditory primes, "Identical," "Morphologically Related," and "Different," were used; primes were matched to control items for frequency and syllable length.[8] Uninflected singular forms presented visually for lexical decision were used as targets (see Table 2 for an example stimulus set).[9] In addition to the experimental and control items, we included 220 additional pairs of word-word filler items and another 280 pairs of word-nonword items. There were 3 experimental versions, and 22 subjects were tested for each version. The results are shown in Figures 5a and 5b.

Again, as in the participle experiment, regular and irregular inflections behave differently with respect to morphological priming. For *-s* plurals, there is strong morphological priming compared to the control condition (565 vs. 645 msec, $p < .0001$), and the effect does not differ significantly from the Identity condition (565 vs. 558 msec, $p = .34$). For *-er* plurals, however, the priming effect is much weaker; RTs are shorter than in the control condition (550 vs. 568 msec, $p < .01$), but significantly longer than in the Identity condition (550 vs. 531 msec, $p < .01$). Finally, the overall lexical decision times for nouns that take *-s* plurals are considerably longer for each of the three conditions than the corresponding RTs for nouns that take *-er* plurals. These differences are the result of the frequency differences between these two classes of nouns (see n. 8).

Taken together, the results of our cross-modal priming experiments are parallel for participles and noun plurals. In both experiments, regular inflection (*-s* plurals and *-t* participles) exhibit full priming effects, whereas irregularly inflected word forms (*-er* plurals and *-n* participles) produced only partial priming. These findings correspond to the linguistic differences between regular and irregular inflection posited by dual-mechanism morphology: *-s* plurals and *-t* participles are decomposed into stem+affix and therefore priming toward other corresponding word-forms can be directly mediated via the stem. Irregular plurals and participles, however, are represented on subnodes of lexical entries, and from there they can less directly prime their corresponding base forms than *-s* plural and *-t* participle forms.

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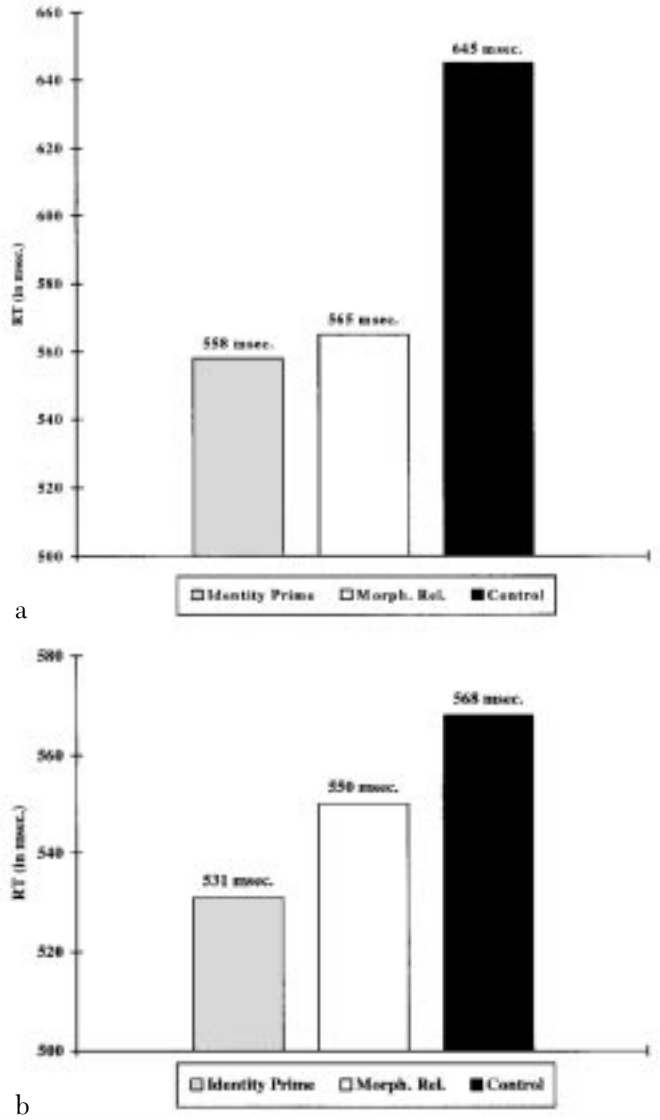


Figure 5. Cross-modal lexical priming of plurals. Figure 5a shows mean lexical decision times on visual targets for *-s* plurals, identity primes, and unrelated controls. Regular *-s* plurals produced a full priming effect. Figure 5b shows mean lexical decision times for *-er* plurals, identity primes, and unrelated controls. Irregular plurals produced longer reaction times than the identity primes.

4.5. Neuro-imaging studies on inflection

Recently, some researchers have begun to investigate the brain structures involved in morphological processing by using modern neuro-imaging techniques (Jaeger et al. 1996; Ullman et al. 1997a). In these studies, different areas of the brain have been shown to be active for regular and irregular inflection, but even though the results show some overlap, they do not yet provide us with a coherent picture of brain activations in processing inflected words. Moreover, because the techniques used (functional magnetic resonance imaging and positron emission tomography) provide high spatial resolution but relatively low temporal resolution, they do not directly tap into the rapid processes that are involved in inflecting words.

In our research on German inflection, my colleagues and I have applied the event-related potentials (ERP) method to investigate the brain structures that are involved in morphological processing and representation. In ERP-studies, the electrical activity produced by the neurons in the brain is recorded from various points on the scalp while the subject is performing some task, such as reading a sentence. The major goal of ERP studies is to isolate those electrical components that are correlated with a particular task or stimulus. In addition to this, an ERP-study provides an online measure of language processing in real time. Previous ERP-studies have led to the identification of components involved in semantic and syntactic processing; see Kutas and Van Petten (1994) and Osterhout and Holcomb (1995) for overviews.

One of the most promising experimental designs for ERP-research on language is the so-called violation paradigm. Kutas and Hillyard (1980) used this paradigm in their seminal study on the N400. They found that this ERP component was elicited by semantic violations, for example, a semantically inappropriate sentence-final word. Subsequent research has shown that the violation paradigm has proven to be extremely reliable in evoking N400 responses (see Kutas & Van Petten 1994). The violation paradigm has also been applied to study ERP components in morpho-syntactic phenomena such as violations of case, number, and tense in different languages, English (Kutas & Hilyard 1983 and Osterhout & Holcomb 1992, among others), Dutch (Hagoort & Brown 1994), Spanish (Kutas & Kluender 1994), German (Friederici et al. 1996; Münte et al. 1999), and Turkish (Münte et al. 1995). Two ERP effects have been observed in these kinds of violations: a positivity with a latency of about 600 msec variably called P600, and a left anterior frontal negativity called LAN. Although the exact status of the two effects is still controversial, it is safe to say that morpho-syntactic violations reliably elicit similar brain responses across different languages. In our research, we have adopted the violation paradigm to examine ERP components in morphological processing and representation. From a dual-mechanism perspective, one would expect to find different ERP effects for regular and irregular inflection. Given previous ERP research, we can make the more specific prediction that violations of regular affixation should produce ERP effects similar to those of other morpho-syntactic violations, that is, a P600 and/or a left anterior negativity (LAN); misapplications of irregular inflectional patterns should not elicit such components, however. We tested these predictions in two ERP studies, one on noun plurals and one on participles.

In the study on noun plurals (Weyerts et al. 1997), ERPs were recorded as German-speaking subjects read sentences containing nouns with correct and incorrect plural forms. Four groups of stimuli were constructed (see example stimulus set in Table 3): nouns that normally take *-n* as a plural marker together with the correct ending, as well as with the incorrect *-s* plural marker, the latter resulting in a "regularization" of an actual irregular plural (**Muskels*), and nouns that normally have *-s* plurals with the correct ending, as well as with the incorrect "irregularized" *-n* ending (**Karussellen*).

The electrical activity was recorded from 19 standard points on the scalp while subjects were silently reading these sentences. The ERP-recordings produced 19 sets of graphs such as those shown in Figure 6. The figures show the electrical activity recorded during the entire recording period, starting 100 msec before stimulus presentation and

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Table 3. *Example stimulus set*

		Nouns that take *-s* plurals	Nouns that take *-n* plurals
Correct		Karussells "carousel"	Muskeln "muscles"
Incorrect:	regularization	X	*Muskels
	irregularization	*Karussellen	X

ending after 800 msec. The electrical activity is measured in microvolts. The plus and minus signs beside the axes indicate the difference of the measured voltages from the baseline condition. The baseline condition is the mean electrical activity measured 100 msec prior to the presentation of the stimulus word; "+" means that the measured voltages are positive with respect to the baseline and "-" means that they are negative with respect to the baseline. The ERP-effects to be reported were evident from several different electrodes. For ease of exposition, however, I will present only the recordings of the electrodes F7 and Cz here. The electrode F7 is placed over the left frontal part of the brain ("Broca's area") and Cz at the central site; see Weyerts et al. (1997) for the results of the full electrode set. Figure 6 presents grand average ERPs for masculine/neuter nouns (e.g., *der Muskel,* see Table 3) that take *-n* plurals in German as opposed to nouns that take *-s* plurals (see "regular" in Fig. 6).

These graphs show that 200–400 msec after the presentation of the plural forms, the waveforms for incorrect plurals started to differ from the correct ones: from that point onward incorrect noun plurals were associated with a more negative waveform. It is interesting, however, that the scalp distribution of these negativities for the two kinds of morphological violations was rather different: For *-s* plural regularizations (= "incorrect masc./neuter" in Fig. 6), a focal left frontotemporal effect was seen with its maximum at the F7-site, whereas the differences at Cz are nonsignificant in this condition. In contrast to that, irregularizations (= "incorrect regular" in Fig. 6) produced an N400, that is, a central phasic negativity with its maximum at Cz; for this condition, the differences at F7 are nonsignificant. Thus, this experiment has produced different ERP-responses to violations of regular and irregular inflection.

The same ERP design was used for the participle study (Penke et al. 1997). Correct regular and irregular participles were compared with incorrect ones; the latter had *-(e)n* on verbs that actually take *-t* participles (**getanz-en* "dancen"), or *-(e)t* on verbs that require *-(e)n* (**gelad-et* "loaded"). The critical words were presented in three different versions to three different groups of subjects, as part of a simple sentence, in a word list, and embedded in a story. For each version separate ERPs were recorded. The ERP responses were consistent across the three versions of the experiment: Incorrect irregular participles (**gelad-et*) elicited a left frontotemporal negativity and incorrect regulars (**getanz-en*) produced no differences to the correct ones. The results are illustrated in Figure 7. Here we see waveforms for regular and irregular participles at the F7 site. Figure 7 shows that regularizations, that is, irregular

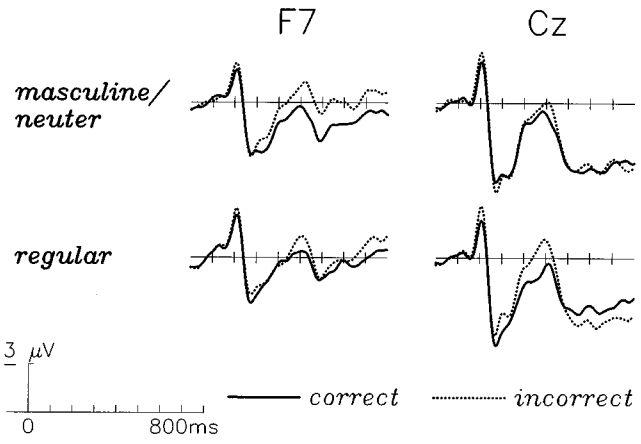


Figure 6. Event-related potentials of noun plurals. Comparison of ERPs for masculine/neuter nouns that take (irregular) *-n* plurals and for nouns that take regular *-s* plurals. Left column: Correctness effect at the left frontotemporal (F7) site for the two plural conditions. A significant negativity for incorrect plurals is present only for masculine/neuter. Right column: Correctness effect at the central (Cz) site for the 2 plural conditions. A phasic and earlier negativity for incorrect plurals is present only for nouns taking the regular *-s* ending as correct plural marker. Horizontal scale: tickmarks at 100 to 800 msec, vertical line at 0 msec (stimulus-onset): -3 to +3 μV.

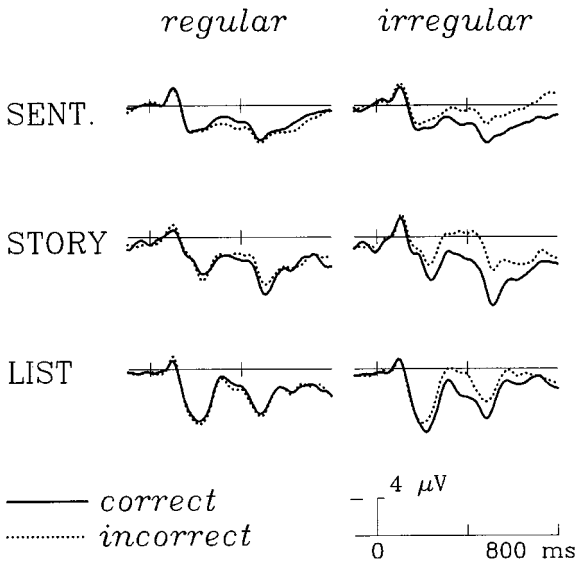


Figure 7. Event-related potentials of participles. Comparison of regular and irregular participles according to ending (*-t* versus *-n*) for the F7 site presented in three experimental versions, as part of a simple sentence, in a word list, and embedded in a story. Only the incorrect irregulars (those with the *-t* ending) are associated with a left anterior temporal negativity in all three experimental versions. Horizontal scale: tickmarks at 400 and 800 msec, vertical line at 0 msec (stimulus-onset): -4 to +4 μV.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

verbs incorrectly inflected with the *-t* participle ending, are associated with a left anterior temporal negativity in all three experimental versions.[10]

The most salient and consistent ERP result is that regularizations were associated with a negative waveform with a focal left anterior temporal distribution starting at about 200 msec, an effect that has been discovered in previous ERP-studies and that has been called LAN. LAN-effects have been reported when affixation (e.g., for subject-verb agreement) is incorrectly applied (Münte et al. 1993; Osterhout & Mobley 1995), when phrase-structure rules are violated (Friederici & Mecklinger 1996; Neville et al. 1991), and in the case of illegal filler-gap constructions (Kutas & Kluender 1994; Neville et al. 1991; but see McKinnon & Osterhout 1996). We found the LAN for incorrect irregulars in each of the three participle experiments and even more strikingly in a different inflectional system, noun plurals. In linguistic terms, regularizations are violations of affixation, that is, misapplications of the participle *-t* or the plural *-s* to (irregular) verbs or nouns that would normally block the affixation process, to produce illegal stem+affix combinations such as **gelad-et* and **Muskel-s.* A LAN was found only in such cases. Thus, the LAN found under these conditions can be interpreted as reflecting processes involved in morphological structure building.[11]

Irregularizations do not involve violations of affixation, but may instead be conceived of as unexpected or anomalous words. The ERP-results support this interpretation as the central negativity we found for (plural) irregularizations does indeed resemble the so-called N400 effect that occurs (among other cases) in response to pronounceable nonwords (Kutas & Hillyard 1980; Rugg 1987).

Hence, our results indicate that the brain responds differently to violations of regular and irregular inflectional processes. Regularizations elicited signals that are typical of morpho-syntactic rule violations, whereas irregularizations produced waveforms that are typical of the reaction to anomalous words. These differences correspond to the linguistic distinction between affixation-based and lexically based inflection.

4.6. Associative models of German inflection

In this section, we will discuss associative single-mechanism models of German inflection. Three recent studies have proposed connectionist implementations of German plurals and participles, Nakisa et al. (1999), Westermann and Goebel (1995b), and Goebel and Indefrey (1999). In addition, Bybee (1995b) and Köpcke (1988; 1993) have suggested ways in which associative schemas might handle the data on German inflection.

Nakisa et al. (1999) have made an attempt to implement the German plural system in single-mechanism pattern associator networks of different kinds. They took 8,598 plural forms from the CELEX database, split them roughly in half, and used one half as a training set and the other as a testing set. For the latter, their pattern associators produced between 70% and 82% correct plurals depending on the learning algorithm and network architecture chosen. Nakisa and collaborators consider this success rate to be "remarkably high." In addition to pure similarity-based simulations, they also carried out a simulation in which the plural *-s* was removed from the pattern associator and was applied only to singular items that were phonologically distant from other singular items in their sample. This was meant to be an implementation of a dual-mechanism model and the special status of *-s* in the German plural system. Nakisa et al. found that this simulation failed to perform any better than their single-mechanism pattern associators. They concluded that the mental process of regular inflection can be simulated in a single-mechanism associative network by exploiting the statistics of the input, contra to claims made by proponents of the dual-mechanism model.

The reasoning behind their conclusion is puzzling, however. We are led to believe that rules of inflection can be eliminated from the mental grammar, because after extensive training a pattern associator gets a majority of the existing German plural forms right. That the model does well is not in fact surprising, given that more than 90% of the existing plural forms of German are irregular ones (see Appendix A3, Table 5). One might even ask why the network produces a relatively large number of incorrect plurals, with 20% to 30% errors certainly not a negligible quantity. The fact that the simulation in which the *-s* plural was hardwired to apply to phonologically distant nouns did not outperform the pure pattern associators does not come as a surprise because it is based on an assumption that is descriptively inadequate for German, namely, that all existing nouns that take *-s* plurals are phonologically distant from all other nouns. Moreover, for this simulation Nakisa et al. removed all nouns that take *-s* plurals from the training set, thereby creating unrealistic training materials that consisted of irregular plurals only. The crucial question then is whether any of the single-mechanism models they proposed can simulate the differences between regular and irregular plurals. Consider, for example, the generalization properties of *-s* plurals reported in section 4.2. We found that the plural *-s* applies under default circumstances, that is, when access to lexical memory is ruled out, in cases such as nonsense words that are dissimilar to existing words, derived forms, and words that do not have canonical lexical entries. However, in contrast to what German speakers do, Nakisa et al.'s pattern associators would extend *-n* and, to a lesser extent, *-e* plurals under such circumstances, simply because these happen to be the most frequent plural forms in the training set.[12] Moreover, their simulations do not explain the experimental findings reported in previous sections, for example, the fact that irregular plurals, but not-*s* plurals, produced a word-form frequency effect in lexical decision. In sum, Nakisa et al.'s simulations do not present us with a descriptively adequate single-mechanism model of the linguistic and psycholinguistic properties of German noun plurals.

What seems more promising are implementations of German inflection in modular connectionist networks as suggested by Goebel and collaborators. Westermann and Goebel (1995) present a network for participle formation that consists of two separate components, a combinatorial system capable of representing sequences of feature vectors and an associative phonological lexicon. They stress that the architecture of their network is in accordance with the dual-mechanism model of inflection. The network was trained on a corpus of 538 verb tokens using a backpropagation algorithm, and it is shown that the network's generalizations of *-n* and *-t* participle formation are similar to those we found in experiments with German speakers: Extensions of *-n* participle formation are similarity-based, whereas *-t* participle formation is generalized under no-

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

similarity conditions, that is, to items that do not resemble any existing verbs.

Goebel and Indefrey (1999) made use of the same kind of network architecture to model the German plural system. Their training corpus consisted of 6,364 noun types taken from the vocabulary of 5- to 6-year-old children. After having achieved good performance for the items of the training set, the generalization properties of the network were tested on the set of experimental items used in our plural judgement study (Marcus et al. 1995). Goebel and Indefrey's model was partially successful, particularly with respect to irregular plural forms. The model extended *-e* plurals to novel items with masculine gender and generalized *-n* plurals to novel feminines, both reflecting strong tendencies among the irregular plural forms of German. The generalization properties of *-s* plurals, however, were not properly captured by their network. The model applied *-s* to novel nouns that end in the full vowel *-O,* that is, to items that are similar to existing *-s* plurals. The crucial point, however, is what the model does to items that are dissimilar to existing nouns. Recall that speakers of German prefer *-s* pluralizations in such cases (Marcus et al. 1995). Goebel and Indefrey's connectionist network, by contrast, failed to generalize *-s* under no-similarity conditions. Thus, this model does not capture the generalization properties of *-s* plurals. Goebel and Indefrey speculate that it is the extremely low frequency of *-s* plurals combined with their default properties which makes it impossible for the network to generalize *-s* in the way speakers of German do.

Schema-based approaches to inflection, such as Bybee (1991; 1995b) and Köpcke (1988; 1993), share with connectionist approaches the view that "all types of morphological patterns can be acquired by the same process – the storage of items, the creation of connections among them, and the formation of patterns that range over sets of connections" (Bybee 1991, p. 87). It is also argued that potential differences between morphological schemas result from their frequency distribution – a big class is more productive and forms a stronger schema than a small class. Bybee (1995b) analyzed German participle formation from this perspective. She argued that *-t* suffixation applies to the largest number of verb stems and that when subjects are required to inflect nonsense words, they prefer to follow the majority pattern yielding overapplications of the participle *-t.* For German noun plurals, Köpcke (1988; 1993) presented an analysis in terms of associative schemas. The schemas are envisioned as capturing the similarities among the existing nouns that take a plural suffix; nothing has a special status as the default. To support this account, Köpcke presented results from an elicited-production task in which German adults had to pluralize novel noun stems that varied by gender (masculine, feminine, and neuter) and syllabic structure (suffixed, schwa-final, vowel-final, pseudosuffixed, or monosyllabic). He found that each type of word has a preferred suffix. For example, feminine schwa-final nouns nearly always took *-(e)n,* and monosyllabic nouns tended to take *-e* if neuter or masculine, *-(e)n* if feminine. This is presented as evidence for the view that the German plural system can best be handled in terms of associative schemas.

Schema-based models of German inflection are confronted with the same problem as connectionist pattern associators in that they do not account for the linguistic and experimental differences between regular and irregular inflection. In his experiment on noun plural formation, for example, Köpcke did not test whether there is a default pluralization process in German. He presented each noun in isolation, which made it possible for his subjects to form an analogy to an existing noun and its plural form. The plural judgement task reported in section 4.2.3 provides a way of ruling out such unwanted associations. The results show that in cases in which memory access is made impossible, speakers of German rely on the plural *-s,* indicating that (in contrast to what Köpcke and Bybee argued) the plural *-s* is a regular default in German.

Moreover, the default nature of regular affixes does not necessarily follow from their frequency distribution. This is obvious for the plural *-s* which applies to only 7% of nouns in German (see Table 5 in Appendix A3), whereas, for example, in English the plural *-s* is applied to more than 99% of all nouns. For verbs, there is also a clear difference between English and German in terms of the vocabulary distribution of regulars and irregulars, even though the difference is less dramatic than for plurals. Three different frequency measures revealed that (in contrast to English) regular and irregular verb forms have similar frequencies (see Appendix A3). With larger samples of verbs, the gap narrows, but regular *-t* participle forms in German always show lower frequencies than corresponding *-ed* past tense forms in English. This leaves schema-based theories unable to account for the fact that despite differences in frequency distribution, the generalization properties of the German *-s* plural and the *-t* participle are similar to the English *-s* plural and the past tense *-ed.*

The results from our lexical decision experiments reported in section 4.3 are also hard to explain in terms of schema-based models of inflection. We found that lexical decision times were shorter for high-frequency forms than for low-frequency forms, but this effect occurred only for irregular plurals and irregular participles, not for regular ones. Conversely, full priming effects were found for regular plurals and participles, but not for irregular ones. In the ERP experiments (sect. 4.5) and the sentence-matching experiments (sect. 4.2), violation effects were found for *-t* participle and *-s* plural affixation, but not for irregular inflection. These experimental effects cannot be derived from associative schemas such as those proposed by Köpcke (1988) and Bybee (1995b) for German inflection.

Summarizing, despite several attempts there is still no single-mechanism associative model that can handle the full set of facts of German plurals and participles. As the regular plural and participle affixes (*-s* and *-t)* do not generalize on the basis of frequency or similarity, it is hard to imagine how any conventional single-mechanism pattern associator could ever get the facts of German inflection right.

4.7. Preliminary summary

The findings reported above demonstrate clear processing differences between *-t* participle and *-s* plural formation on the one hand and *-n* participle and irregular noun plurals on the other hand. Table 4 summarizes the main results.

These findings receive, at most, a partial explanation from single-mechanism accounts of inflection in which no distinction is made between affixation-based and lexicon-based inflection. If all inflected words were stored in memory, as assumed in full-listing models of morphological pro-

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Table 4. *Summary of processing properties of plurals and participles*

-t participles, *-s* plurals	*-n* participles, non *-s* plurals
• generalize to novel and derived words, irrespective of similarity,	• similarity-based generalizations only
• show no frequency effect in visual lexical decision	• faster lexical decision times for high-frequency forms
• fully prime their base forms in the cross-modal priming task	• reduced priming of base forms;
• elicit affixation-violation effects in the sentence-matching task and in ERPs	• no affixation-violation effects

cessing, we would not expect to find processing differences between regular and irregular inflection; but such effects exist, as shown in previous sections, and they are left unexplained by these kinds of models. We also argued that associative networks do not properly capture the generalization properties of German inflection. In full-parsing models, on the other hand, all inflected words are assumed to be morphologically decomposed into stem+affix. If this is correct, we would expect to find rule-violation effects in the sentence-matching task and the ERP-studies for inflected words in general; legal stem+affix combinations, for example, should elicit shorter sentence-matching latencies than illegal ones. Our findings show that this is true for regular inflection, but not for irregularly inflected word-forms. This difference cannot be explained by the full-parsing model.

Two theoretical assumptions, I suggest, have to be made to explain the set of results in Table 4. First, the processor may choose between accessing an inflected word from the mental lexicon or decomposing it into stem+affix. Second, these two processing routes correspond to the morphological structure of inflected words: Those represented in terms of lexical entries are processed by accessing full-form representations, whereas affixation-based inflected words are processed by decomposing them into stem+affix combinations. The empirical results show that the structural properties and the processing properties of German participles and noun plurals converge into either the regular or the irregular cluster, thus providing support for the dual-mechanism model.

The fact that German (and English) exhibit linguistic and experimental differences between regular and irregular inflection raises the question of how general this distinction holds across languages. In two recent studies, we have investigated Italian past tense and participle inflections with respect to this question (Gross et al. 1998; Say 1998; see also Orsolini & Marslen-Wilson 1997). In contrast to Germanic languages, Italian verbs fall into three basic morphological classes, called conjugations, and it is not clear how a dual-mechanism model might account for a three-way inflectional system. To examine the generalization properties of the three conjugation classes in Italian, Say (1998) performed an elicited production experiment, adopting the design of the elicitation task on German participles reported in section 4.2. Say found that first conjugation stem forms generalize freely to all types of novel verbs, regardless of phonological content, whereas third and second conjugation stems generalize only to those novel verbs that were similar to existing verbs of these types. Moreover, a frequency effect was found for third and second conjugation verbs, but not for first conjugation verbs: The former generalize more easily to novel verbs that were similar to existing high-frequency verbs than to those based on low-frequency existing verbs.

Thus, only the first conjugation stem formation process showed characteristics of a default; the second and third conjugation stem forms, on the other hand, showed nondefault behaviour, namely, frequency and similarity effects in their generalization properties. In addition to stem formation processes, we examined the role of affixation processes in Italian verb forms using the ERP violation paradigm (Gross et al. 1998); the design was adopted from our studies on German inflection (see sect. 4.5). We found that incorrect irregulars resulting from overapplications of regular inflection, for example, **prendato* ("*tooked") instead of the correct *preso* ("taken"), elicited a widespread negativity. By contrast, incorrect theme vowels, for example, **parlito* instead of *parlato* ("spoken") and **dormato* instead of *dormito* ("slept"), produced no such effect. This difference replicates previous ERP results on German participle and plural inflection.

Further experimentation is required before any strong cross-linguistic claims on the processing of inflection can be made. This caveat notwithstanding, we think that the results mentioned above do indeed suggest that across different types of languages the mind/brain honours the regular/irregular distinction posited by dual-mechanism models of inflection, through, for example, different generalization properties and different brain potentials for the two morphological clusters.

5. Child language acquisition

The idea that the language faculty of an adult speaker consists of two qualitatively different components, a system of combinatorial operations and a lexicon, raises the question of how this dual structure emerges in child language development. One approach for addressing this question is in the spirit of Piagetian constructivism; children may construct mental representations for language on the basis of their linguistic experience and general-purpose learning mechanisms (Bates et al. 1988; Elman et al. 1996; Karmiloff-Smith 1992). However, even though much research has been devoted to this approach, it is still a puzzle how general mechanisms plus input should yield successful learning of the essentials of the adult grammar, such as its dual architecture, its combinatorial mapping between semantics and linguistic forms, abstract morpho-syntactic representations, its symbolic categories and features (e.g., "V[erb]," "N[oun],"

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etc.) One potential solution to this puzzle might be to try to eliminate such apparently unlearnable notions from representations of adult grammars and to implement an adult's knowledge of language in connectionist networks that do not contain grammatical categories and operations of the familiar kind (Elman et al. 1996, Rumelhart & McClelland 1986). The reasoning would make perfect sense: If there were no such things as dual architecture, combinatorial rules, "Ns" and "Vs", and so forth in the adult grammar, then we would not have to worry about how children learn them. But Pinker and Prince (1988) and Marcus (1999) have shown that these kinds of connectionist networks have severe deficiencies, and argue that eliminative connectionism must be rejected. As Marcus (1999) puts it, "connectionism cannot save constructivism." Moreover, as pointed out in the previous section, research on language and language processing in adults has produced substantial evidence in favour of the dual-mechanism view and related notions that cannot be handled by single-mechanism networks (see sect. 4.6). These findings would be left unexplained if grammatical categories and operations were eliminated from mental representations. This leads us back to the original question: How does the adult linguistic system emerge?

An alternative way of addressing this question is in terms of the "continuity hypothesis," which claims that the structure of the language faculty does not change over time but that development results from other factors (Hyams 1986; Pinker 1984; Weissenborn 1992, among others). The specific idea my colleagues and I have pursued in our language acquisition studies is that grammatical development may result from increases in the child's lexicon, that is, from the set of lexical and morphological items the child has acquired (Clahsen 1990; 1992; Clahsen et al. 1993; 1994; 1996a). Hence, even though the child's language faculty is said to be qualitatively identical to that of adults, the lexicon takes time to develop. Inflectional affixes, for example, are often unstressed, monosyllabic, not uttered in isolation, and perceptually nonsalient. For these reasons, the child may find it difficult to pick them up from the input, and, consequently, those elements of the child's language faculty that operate on inflectional affixes, such as principles of affixation, cannot become effective, though they are (latently) available throughout. In this way, the grammar of the particular language the child is acquiring develops gradually, through the interaction of available abstract knowledge (e.g., about combinatorial principles) and the child's learning of the lexicon. Evidence for continuity and lexical learning has come mainly from studies on the acquisition of syntax. Here, we will examine the development of inflection from this perspective.

5.1. Overregularization and the development of inflection

The most detailed information about children's inflectional systems comes from studies of the English past tense (Marcus et al. 1992 and references cited there). This research has produced three major findings. First, only one type of inflectional error is produced: overapplications of the regular past tense affix *-ed* to irregular stems (**go-ed,* etc.). Overapplications of irregular patterns (**brang, *wope, *talken*) are much less frequent and systematic (Xu & Pinker 1995). Second, overregularizations are rare at all ages (typically less than 10%) and their occurrence is preceded by a stage at which all overtly marked past tense forms are correct. Third, overregularizations are sensitive to frequency and similarity: Children make these errors more often for low-frequency irregular verbs, and they make fewer overregularization errors for irregular verbs that fall into families with more numerous and higher-frequency members (see also Bybee & Slobin 1982). Marcus et al. (1992) take these findings as evidence for the view that children (like adults) possess two distinct mechanisms for inflection, a symbol-manipulating rule system for regulars and lexical entries for irregulars. Only when the child fails to get access to a lexical entry for an irregular form is the regular rule applied, resulting in occasional overregularization errors. However, due to the confounding factors in the English past tense system, some researchers have argued for an alternative explanation, namely, that children overregularize *-ed* not because *-ed* is rule-based, but simply because children have heard it used with so many different English verbs (Plunkett & Marchman 1991; 1993, among others). Associative models of language may indeed appear quite successful in this case and it has been argued that they accurately model English-speaking children's overregularizations of *-ed.*[13] But this success depends on an artifact of the English past tense system, namely the extremely high frequency of *-ed* forms. The two inflectional systems we have studied, German participle and noun plural formation, exhibit different vocabulary statistics (see Appendix A3) to the English past tense; results from these studies should help assess the role of input frequencies for children's overregularizations.

5.1.1. Participle formation in German child language. We investigated the development of participle formation in longitudinal data from 9 children between the ages of 1,4 and 3,9 and two elicited production experiments covering the age period of 3,6 to 8,10 (Clahsen & Rothweiler 1993; Weyerts 1997; Weyerts & Clahsen 1994). We found that children across all age groups overapply the participle *-t* to strong verbs, but that they rarely overapply the participle *-n* to mixed or weak verbs. In the longitudinal data, there were 116 incorrect endings in children's participles, 93% of these were *-t* errors. Thus, children typically produce errors such as **gekommt* ("come," participle) instead of *gekommen,* but not **geschneien* ("snow," participle) instead of *geschneit* ("snowed"). Overregularizations of the participle *-t* are rare in the longitudinal data (mean rate = 10%), and there is an early stage prior to the occurrence of *-t* errors at which all participle forms used by the child are correct. Consider, for illustration, Figure 8, which presents a longitudinal graph for one child, Simone. On the x-axis, the period of observation, ranging from 1,10 to 3,9, is divided into 14 individual corpora that each covered approximately 1 month; the y-axis shows the rates of *-t* overregularizations for each age point. Figure 8 shows that the period from age 2,1 onward (= Corpus 3) with a relatively steady *-t* overregularization rate of 5% to 10% is preceded by a period, Corpora 1 and 2, with no overregularizations.

The preference for *-t* overregularizations was also confirmed experimentally. In an elicited production experiment with 70 children (age range: 3,6 to 8,10), 152 incorrect endings on participles of existing verbs were produced, 90% of them *-t* errors. Among the *-t* overregularizations, we found a clear frequency effect: Strong verbs that have low

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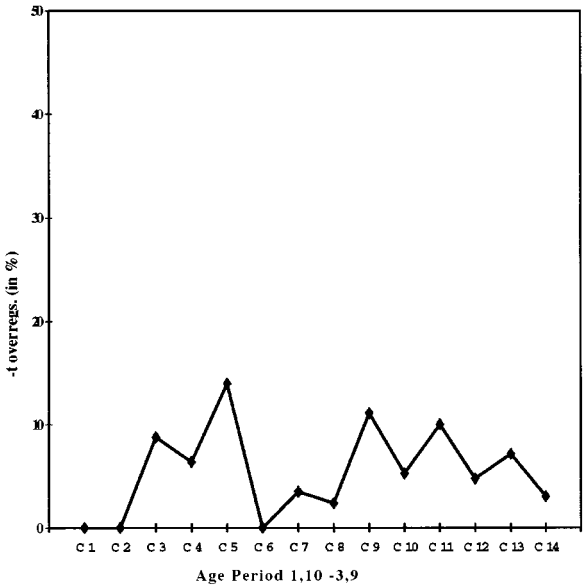


Figure 8. Overregularizations of the -t participle suffix. Longitudinal data covering the age period from 1,10 to 3,9 divided into 14 corpora. Overregularization rates for *-t* were calculated against the total number of correctly inflected irregular participles. From 2,1 onward there is a relatively constant overregularization rate of 5% to 10% compared to 90% to 95% correctly inflected participles of irregular verbs. This is preceded by a stage without any *-t* overregularizations.

token frequencies elicit significantly more *-t* overregularization errors in participle formation than strong verbs with high token frequencies. This frequency effect indicates that participles of strong verbs form lexical entries, and that the participle *-t* applies in cases of unsuccessful lexical access. In another experiment, we elicited participles of nonsense verbs. Of the 454 forms with one of the two participle endings produced by the children, 93% had *-t*. Thus, children apply *-t* participle formation under default circumstances to verbs that do not have lexical entries.

5.1.2. Children's noun plurals. We have examined various aspects of plural formation in German-speaking children (Bartke 1998; Bartke et al. 1996; Clahsen et al. 1992; 1996b). Here we focus on the question of whether there are any similarities in the way children and adults generalize inflectional processes. Recall from section 4.2 that for adults, *-s* plural affixation is applied under default circumstances and generalizes widely, for example, to unfamiliar or unusual sounding words and to proper names. Extensions of irregular plural forms, however, are restricted to items that are similar to existing ones. To test the generalization properties of plural formation in children, we administered an elicited production experiment with 66 children (age: 3,1 to 8,11) and an acceptability judgment experiment with 37 children (age: 3,6 to 6,6), in which the circumstances under which adults generalize regular and irregular plural formation processes were controlled.

In the first experiment (Clahsen et al. 1996b), 16 objects were used denoting low-frequency nouns in German such as *Feder* ("feather"), *Tuch* ("towel"), *Fassung* ("socket"), and so forth. The nouns tested require adults to use the plural allomorphs *-er, -en, -s,* and *-0* in four cases each and the plural *-e* in two cases. The children were asked to name each object, and were then prompted to produce plural forms by being presented with four instances of each object. We found an overall overregularization rate of 18.5% (n = 141), which is considerably higher than the rates reported for spontaneous speech and reflects the fact that some of the experimental items were unfamiliar to the children. Within the overregularizations the different affixes were used with different frequencies: 58.5% (n = 76) of the overregularizations were with *-s* plural; 26.2.% (n = 34) with *-e,* 14.6% (n = 19) with *-(e)n,* and only 0.8 % (n = 1) with *-er.* Thus, children (like adults) are more likely to inflect unfamilar words with the *-s* affix than with any other plural form.

In a second experiment (Bartke et al. 1996), we examined children's acceptability judgments on plural forms of nonsense words. To control for similarity-based generalizations, two kinds of nonsense words were constructed: "Rhymes," items such as *pund, kach,* and so on that rhyme with existing German nouns that take irregular plurals (*Hund – Hunde,* "dog – dogs," *Dach – Dächer,* "roof – roofs") and "Non-Rhymes," items such as *pnähf, fneik,* and so forth that do not rhyme with existing German nouns. By using different context sentences, these items were introduced to the children in two conditions, as canonical root nouns and as proper names. Note that in linguistic terms, proper names are noncanonical words that do not have lexical entries and should therefore undergo *-s* affixation when pluralized. Recall from section 4.2 that adults do indeed prefer *-s* plural forms of proper names, irrespective of the word's sound properties. In the child experiment, each item was embedded in a story and illustrated by picture cards, followed by the presentation of the two plural forms, one with *-s* and one with *-(e)n,* the latter of which is the most frequent plural form in German. Children were encouraged to provide a third, alternative plural if they found neither *-s* nor *-(e)n* acceptable. Figure 9 presents the results.

Figure 9a shows that children's ratings for *-s* plurals were much better in the Non-Rhyme condition than in the Rhyme condition, and Figure 9b shows that, overall, *-s* plurals of names were judged as significantly better than *-n* plurals for both rhymes and nonrhymes. Thus children (like adults) prefer *-s* plurals for unusual-sounding words (nonrhymes) and for noncanonical words (proper names).

In sum, our results on participle and noun plural formation indicate that regular and irregular inflectional processes are dissociated in child language. The *-t* participle and the *-s* plural affixes are supplied under default circumstances. They are sometimes overextended to words that are irregular in the adult language, resulting in overregularization errors, and they occur when similarity-driven analogies fail, for example, in the case of unfamiliar, unusual-sounding, or otherwise noncanonical words. Overextensions of irregular patterns are more restricted; *-n* participle errors are extremely rare in German children, and irregular plural forms seem to be overapplied only by analogy. The generalization properties of regular and irregular inflection in children are identical to those found for adults (see sect. 4.2), indicating that the dual structure of the language faculty is already in place early on. What seems to change over time is only the child's vocabulary, that is, the inventory of lexical entries. We have isolated an early developmental stage at which children do not produce any overapplication errors. At this stage, the inflectional affixes have not yet been isolated, and all inflected word forms (including those that are regular in the adult language) have

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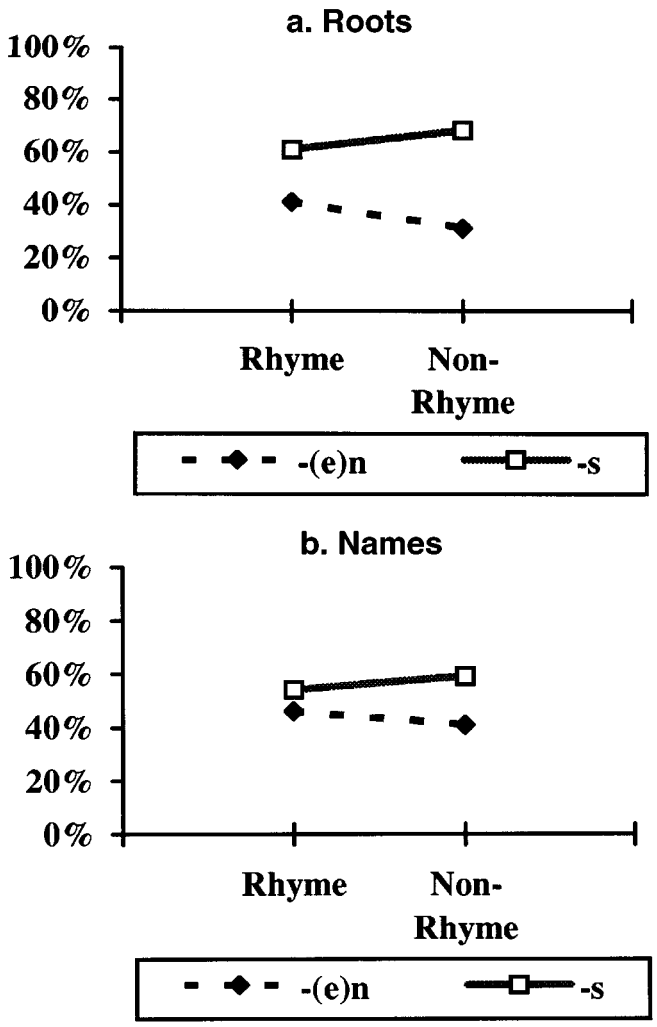


Figure 9. Children's ratings of plural forms. Preferences for -s plurals versus *-(e)n* plurals on rhyme and nonrhyme roots and names. For nonrhyme roots (top), children preferred *-s* pluralizations to *-(e)n* plural forms, whereas there was no clear preference for rhyme roots. For names (bottom), on the other hand, children preferred *-s* pluralizations in both the rhyme and the nonrhyme condition.

lexical entries for children; the affixation component cannot yet operate at this stage and must await the child's identification of suitable affixes. Once separate lexical entries for the *-t* participle and the *-s* plural suffixes have been created, the affixation component can become effective, and children apply affixation under the same circumstances as adults. It follows that the child does not have to learn inflectional rules; instead, children create lexical entries for affixes in much the same way that they learn new words and represent them in the form of new entries; subsequently, combinatorial mechanisms such as affixation can operate. Thus, under this view, the driving force in children's grammatical development is their gradual acquisition of new lexical and morphological items; the architecture, however, including its dual structure seems to be intrinsic to children's as well as adults' language faculty.

5.2. Constraints on word formation processes

To continue our investigation about whether the architecture of the child's language faculty is identical to that of the adult or whether it undergoes substantial developmental changes, we have studied relationships between two different word-formation processes, compounding and inflection, in children and adults (Clahsen et al. 1992; 1996b).

In English, irregular plural nouns such as *teeth, mice,* and so forth can appear as initial parts or nonheads in compounds, whereas plural nouns formed by adding the suffix *-s* are not used in this position, (e.g, *teeth marks* versus **nails marks; mice eater* versus **rats eater).* The same is true for German inflection. The sole plural forms that occur as nonhead elements inside compounds are the irregulars, and never the plural *-s.* Hence the distribution of plurals-inside-compounds coincides with the distinction made in Minimalist Morphology between structured lexical entries and affixation. Lexical compounding is a process that concatenates lexical entries. It follows that irregular plurals (because they have lexical entries) can be fed into the compounding process, whereas affixation-based forms such as *-s* plurals (which do not have lexical entries) cannot be included in the compounding process. There are several other linguistic analyses to capture these facts (Borer 1988; Di Sciullio & Williams 1987; Kiparsky 1982; Wiese 1996). The idea that is common to these different analyses is that feeding relationships between plural inflection and compounding are determined by a grammatical ordering constraint. It is hard to see how children could learn this constraint directly from input data. From the perspective of "continuity" and "lexical learning" one would rather expect design features of the language faculty not to change over time. What does change over time is the identification and categorization of lexical entries from the input. Thus, children may differ from adults with respect to the lexical representations of plural forms, but whatever the child's default plural form is, as could be measured through children's overregularization errors, for example, the ordering constraint should not be violated. What we predict, then, is a correlation between overregularization and plurals-inside-compounds: Plural forms that are used in overregularizations should be omitted from the nonhead elements of compounds. This would indicate that even though children's plural forms might be incorrect in terms of adult grammar, the ordering constraint on plurals-inside-compounds would be operative in the child's linguistic system.

Gordon (1985) has confirmed this prediction for child's English using an elicited-production task, which prompted children to first produce a plural form of a given item X (e.g., *mouse → mice)* and, subsequently, a synthetic compound of the X-eater type (e.g., *mouse-eater* or *mice-eater).* Gordon found that in about 98% of the novel compounds produced by the children the plural *-s* is not used on the nonhead element; this even holds for the youngest children (i.e., the 3-year-olds). Overregularizations like **mouses* sometimes occurred as a simple noun but never within a compound such as **mouses-eater.* Furthermore, it was found that as soon as the children have acquired irregular plurals they sometimes use them inside compounds (as in *mice-eater).* Thus children behaved essentially like adults: They were willing to say *mice-eater* and unwilling to say **rats-eater.* Gordon interprets these results as support for the early availability of the morphological ordering constraint in children. There is an alternative explanation of Gordon's findings, however, which is independently motivated by developmental principles of word formation suggested by Clark (1993). She found that 3,0 to 6,11 children

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tend to strip off all previous verb and noun affixes before they form a novel compound. Thus, when asked to form a compound out of a phrase such as "a boy who bounces balls," children strip off the 3rd sg. *-s* as well as the plural *-s* to form the compound *ball-bouncer*. Clark (1993) argued that this reflects a general developmental strategy that she called the "simplicity of form" principle: Young children use simple building blocks to form new words, that is, they tend to use unadorned elements with no affixes in forming new words. The simplicity principle predicts that children should produce compounds constructed with bare nouns or bare noun and verb bases such as N+N compounds (*rat-man*), V+N compounds (*twist-knob*), and so on. Gordon's findings on compounding in English-speaking children might also be explained in this way. According to the simplicity principle, children strip off the regular plural *-s* inside compounds, but maintain the irregular plural form, simply because in irregulars there is no separate affix to be stripped off; compare, for example, *rat-s* versus *mice*. In this way, Gordon's results could be accounted for without any reliance on abstract morphological principles such as the ordering constraint mentioned above.

This issue is hard to resolve by looking only at English, because of its confound between regular inflection and suffixation: Whereas regular plurals are marked with a suffix, irregular plurals are not. We therefore need to examine a language in which both regular and irregular plurals have endings. The German plural is precisely such a system. If children's linguistic abilities are regulated by a simplicity-of-form principle, they should omit plural affixes from compounds, regardless of whether they are regular or irregular. In contrast, a morphological theory that draws a structural distinction between regular and irregular inflection would predict that children tend to omit regulars but maintain irregulars inside compounds.

We have examined spontaneous speech samples (Clahsen et al. 1992) and data from two elicited production experiments (Clahsen et al. 1996b) with respect to this prediction. In the spontaneous speech samples, children used *-e, -er,* and *-n* plural forms in nominal compounds (e.g., *Bild-er-buch,* "picture-book," *Hund-e-hütte,* "kennel"), but never *-s*. This conforms to the adult language. Moreover, we found that some children use *-n* in overregularizations and that these children leave out the plural *-n* inside compounds, even in cases in which it is required in German. There was a statistically significant correlation ($r = .69$, $p < .005$) between the rates at which different children overregularized *-n* and the rates at which those children omitted *-n* from compounds, indicating that the more often children overregularized, the more often they omitted *-n* in compounds. Thus, children may temporarily misinterpret *-n* as a default plural form, but the ordering constraint is operative throughout, and hence the correlation between overapplication of *-n* and omission of *-n* plurals from compounds.

To test these findings experimentally, we have adopted the elicited production task originally developed for English by Gordon (1985). Subjects were 66 German-speaking children aged 3,1 to 8,11. For each child, we compared the rate of compound omission for plurals that were overregularized with the rate of compound omission for plurals that were not overregularized. We found that the omission rate for plurals inside compounds was greater for overregularized affixes than for non-overregularized affixes (means .88 vs .56, $t[49] = 9.01$, $p = .0001$). This shows that default plurals are omitted more often from compounds than nondefault forms. The same result was obtained in the second experiment in which novel root compounds consisting of 2 nouns were elicited from 41 children (age range: 4,2 – 8,11). The result again demonstrates a close connection between overregularization and compound-internal omissions of plural forms. Plural forms that are used in overregularizations are likely to be omitted inside compounds (mean 92%), whereas plural forms that are not overapplied are significantly less likely to be dropped inside compounds ([mean 31%], $t[18] = 7.68$, $p = .0001$).

In sum, we observed correlations between overregularization of plural affixes and omission inside compounds in various sources of data, for different kinds of compounds, for existing compounds in children's spontaneous speech, and for novel compounds in the two experiments. These results show that German children do not globally omit plural affixes from compounds. Rather they restrict default plural inflection from compounds significantly more often than they restrict nondefault inflection. The results suggest that the observed interaction between compounding and inflection follows from the internal organization of the children's language faculty.

6. Concluding remarks

The idea that the language faculty comprises two separate components, a lexicon of (potentially structured) entries and a system of symbolic operations for combining lexical entries, underlies much work in the study of language, in linguistic theory, and related psycholinguistic research. Recently, however, this view of the language faculty has been challenged by proponents of associative approaches to language who claim that the knowledge of language can better and more economically be represented in terms of single-mechanism systems of associatively stored units (Rumelhart & McClelland 1986 and subsequent work). Against this background, this target article offers a case study of one system of human language (German inflection), the results of which bear on the controversy between dual- and single-mechanism models of language.

We examined noun plurals and participle formation, because these subsystems of German inflection are relatively easy to study and, at the same time, much less confounded by other factors than, for example, the English past tense. German inflection was investigated from a multidisciplinary perspective using different experimental methods and different groups of subjects. It was shown that the evidence from these sources converges and supports the dual nature of the language faculty.

The particular version of a dual-mechanism model of inflection I adopted (Minimalist Morphology) distinguishes between affixation (for regular inflectional processes) and structured lexical entries (for irregular inflection). In this model, the basic distinction between the lexicon and the combinatorial system is maintained, but not the traditional (structuralist) notion of the lexicon as a simple list of exceptions (Bloomfield 1933 and subsequent work). Instead, lexical entries are assumed to have internally structured representations. A linguistic analysis of noun plurals and participle formation was presented that made use of the notions of affixation and structured lexical entries (see Ap-

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pendix A1 and A2). If the dual architecture comprising combinatorial principles and a structured lexicon is a core property of the language faculty, then this distinction should do more than just provide for convenient linguistic descriptions; we would expect to find corresponding dissociations in human language processing, with respect to the brain structures involved in processing and in child language development. We therefore investigated how German noun plurals and participles are processed by adults and acquired by children.

The results from the various adult experiments demonstrate that the processing properties of inflected words correspond to their morphological structure: Inflected words that have stem+affix representations are typically computed via their constituent morphemes, whereas inflected words that are represented in terms of (structured) lexical entries show frequency and similarity effects in processing experiments. Moreover, in event-related potentials incorrect applications of affixation elicited a brain response that is typical of morpho-syntactic rule violations; incorrect irregulars, however, produced a different ERP-waveform. These findings suggest that affixation-based inflection involves brain structures distinct from those involved in processing lexically based inflection.

In our studies on children's inflections, we focussed on two phenomena: the generalization properties of regular and irregular inflection, and constraints on word-formation processes, specifically the feeding relationships between plural inflection and compounding. We found that children perform very much like adults with respect to these phenomena and that, in child language, regular and irregular inflectional processes are dissociated in the same way as in the adult system: Regulars are overapplied under default circumstances and are omitted from compounds, whereas irregulars are extended by analogy only, and may occur inside compounds. These findings suggest that the architecture of the linguistic system, including its dual structure, does not change very much over time. Observed differences between children's and adults' language and developmental patterns can rather be explained in terms of the child's gradual acquisition of lexical entries. Taken together, these results support the view of a dual structure of the language faculty.

APPENDIX: PARTICIPLE FORMATION AND NOUN PLURALS IN GERMAN

Appendix A1. Linguistic properties of participles

In descriptive grammars, past participle formation is made dependent on three (arbitrary) verb classes, weak, strong, and mixed. These verb classes are relevant not only for the formation of participles, but also for past tense and subjunctive forms of verbs. Participles of *weak verbs* are suffixed with *-t* and do not show any stem changes (see [a]), in the participles or past tense forms. The past tense forms of weak verbs are suffixed with *-te* (see [a]). *Strong verbs* undergo *-n* participle suffixation and involve stem changes in the past tense, and at times in the participle as well (see [b, c, d]). Three minor strong verb classes can be distinguished: strong-1 (= same vowel change for the past tense and the participle, "A-B-B" in [b]), strong-2 (= two different vowel changes for the past tense and the participle, "A-B-C" in [c]), and strong-3 (= vowel change in the past tense only, "A-B-A" in [d]). *Mixed verbs* represent a small class consisting of 13 verbs. Participles of these verbs are suffixed with *-t* but also exhibit stem changes (see [e]).

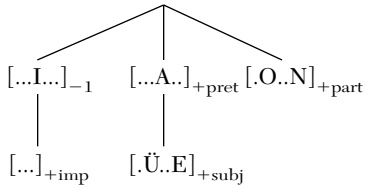
The distribution of the *ge-* prefix is prosodically determined: *ge-* occurs only in participles whose verbal stem is stressed on the first syllable (see [a] vs. [b]), irrespective of whether the verb is strong, weak, or mixed. The choice of the prefix is irrelevant for the morphological distinction between regular and irregular inflection.

a.	káufen	kaufte	gekauft	(*Weak*)
	to buy	bought	bought	
b.	vertréiben	vertrieb	vertrieben	(*Strong-1: A-B-B*)
	to expel	expelled	expelled	
c.	gehen	ging	gegangen	(*Strong-2: A-B-C*)
	to go	went	gone	
d.	laufen	lief	gelaufen	(*Strong-3: A-B-A*)
	to run	ran	run	
e.	brennen	brannte	gebrannt	(*Mixed*)
	to burn	burnt	burnt	

Appendix A1.1. Participle formation in Minimalist Morphology. Wunderlich and Fabri (1995) posit two distinct mechanisms for German participle formation, the affixation process in (i) and several lexical templates such as those in (ii) for the verb *werfen* "to throw."

(i) /-t/; [+V] → [ ]$_{+part}$

(ii) [wErf] "to throw"



Affixation applies to elements of a given syntactic category, in this case to verbs, irrespective of their phonological or semantic properties and computes a corresponding participle form as its output. It is thus the default process of participle formation in German. All other participle forms are represented in terms of structured lexical entries such as the one in (ii). Hence, a strong verb like *werfen* ("to throw") has one base node (= *werf*) and several subnodes (e.g., *warf* for past tense formation and *worfen* for participles), whereas the lexical entries of weak verbs do not contain any subnodes. A weak verb like *schauen* ("to look"), for example, has just one base node (= *schau-*), and the participle inherits the feature structure of this general entry.

A characteristic property of strong verbs in German is that their participle forms (as well as the past tense and subjunctive forms) are to varying degrees similar to their corresponding base forms. Typically, only the length and quality of the vowel change and in some cases the coda of the root as well (see Appendix A1 [b] and [c]). This is captured in structured lexical entries through two theoretical notions, *underspecification* and *default inheritance.* Subnodes of trees such as (ii) may change the information from dominating nodes in two ways (indicated by capital letters in [ii]: they either add new information to the dominating node, as, for example the "E" in the subjunctive node and the "N" in the participle node of (ii), or they may substitute information from the higher node, as in the case of the various vowel changes ("I," "A," "O," "Ü" in [ii]). All other information at a particular subnode (indicated by dots in [ii]) is inherited from the higher node. Hence structured lexical entries are not part of a simple list but fall into families, based on shared subnodes. The subnodes of the entry in (ii), for example, are shared by several other irregular verbs (*sterben,* "to die," *verderben,* "to spoil," *helfen,* "to help"). In this way, structured lexical entries are maximally underspecified, and, at the same time, account for the overall similarity of irregularly inflected verb forms to their base forms and for the family resemblance structure of irregular verb forms.

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Appendix A2. Linguistic properties of noun plurals

With respect to German plural formation, there are five different endings (*-n, -s , -er, -e,* and *-0)* along with possible vowel changes (see examples below). There exist, at best, preferred tendencies of plural formation interacting with the gender system. The most systematic account of German noun plurals in descriptive grammar has resulted in 10 rules/schemas and 15 lists of exceptions (Mugdan 1977). For example, masculine and neuter nouns ending with final schwa syllables such as *-er* and *-el* usually form the plural with zero, yet plural forms such as *Bauern,* "farmers," *Vettern,* "cousins," *Muskeln,* "muscles," and *Pantoffeln,* "slippers," exist as well. Even families of rhyming words exhibit exceptions, such as *Kind-Kinder, Rind-Rinder,* but *Wind-Winde.*

a. *-0* (± UML)	der Daumen	die Daumen	"the thumb/thumbs"
	die Mutter	die Mütter	"the mother/mothers"
	der Apfel	die Äpfel	"the apple/apples"
b. *-e* (± UML)	der Hund	die Hunde	"the dog/dogs"
	die Kuh	die Kühe	"the cow/cows"
c. *-er* (±UML)	der Wald	die Wälder	"the forest/forests"
	das Huhn	die Hühner	"the hen/hens"
d. *-(e)n*	die Strasse	die Strassen	"the street/streets"
	die Frau	die Frauen	"the woman/women"
e. *-s*	das Auto	die Autos	"the car/cars"
	der Park	die Parks	"the park/parks"

Appendix A2.1. Noun plurals in Minimalist Morphology. In applying Wunderlich and Fabri's (1995) analysis of participles to noun plurals, we would posit the *-s* affixation rule in (iii), and structured lexical entries for nouns that take irregular plural forms, as for example, *Blatt-Blätter,* "leaf – leaves."

(iii) /s/; [+N] → [ ]$_{+plur}$

(iv) [Blatt] "leaf"
|
[..ä..ER]$_{+plur}$

Similar to (i) for participles, (iii) is a default operation that applies to any element of the syntactic category N(oun) to generate a corresponding plural form. The lexical entries representing the irregular plural forms of German have fewer subnodes than the strong verbs, but are otherwise quite similar. As shown in (iv), they may alter the base entry, that is, umlaut the vowel, and/or add information to the base (= ER). Again, as in the case of the participles, irregular noun plurals are highly similar to their base forms, and irregular noun plurals fall into families of similar-sounding items. For example, nouns such as *Blatt, Rad, Bad,* and so forth all form their plurals with umlaut "ä" and -ER. Hence, in terms of the present analysis, the template for the entry in (iv) is shared by several other lexical entries. In this way, the notion of underspecified entries plus default inheritance captures the subregularities within German plural formation.

Appendix A3. Frequency distribution

The frequency counts of noun plurals shown in Table 5 come from three sources summarized in Marcus et al. (1995) and Bartke et al. (1996). First, Janda (1990) examined a corpus of 600,000 words in taped interviews (Pfeffer 1964), of which the 200 most common German nouns (with token frequencies of from 100 to 2,500 per million) were analyzed with respect to the distribution of their plural forms (Janda 1990). Second was the more extensive CELEX database (Baayen et al. 1993), consisting of approximately 381,000 types taken from a corpora of 6,000,000 tokens, most from written text of a variety of discourse types and 600,000 from speech; CELEX contains 4,571 noun stems; the plural form frequency distribution of these is shown in Table 5. Third, we tabulated measures of adult's speech to children using nine cross-sectional corpora collected by Klaus R. Wagner. Each corpus represents speech recordings taken from a single child on a single day, with the children's ages ranging from 1,5 to 10,7; see Wagner (1981).

Table 5 shows that the frequency distribution in these different corpora converges on one major point: The plural *-s* is extremely rare both in terms of token and type frequencies. Despite the infrequency of *-s,* there are several reasons for suggesting that *-s* is the default plural affix in adult German (see sect. 3 in the main text).

With respect to participles, several frequency counts show that *-t* and *-n* participles have similar frequencies (see Clahsen 1997 and Marcus et al. 1995 for details). According to Ruoff (1981), 1,000 verb types account for 96% of all verb tokens in German. The token frequencies are as follows: 47% strong verb tokens, 32% verb tokens of the mixed class, and 17% weak verb tokens. The type frequencies among these 1,000 verbs are as follows: 502 strong verb types, 50 verb types of the mixed class, and 448 weak verb types. Thus, in terms of type and token frequencies, verbs requiring the participle affix *-t* are similar to verbs requiring the participle affix *-n.* This contrasts with the vocabulary distribution in English, where among the 1,000 most frequent verbs 86% are regular and only 14% irregular (Marcus et al. 1995). A second relevant source is Meier (1964) who counted the most frequent word forms in German texts. Among the 1,200 most frequent word forms are 23 strong past participles with the *-n* affix, 3 participles of the mixed class with the *-t* affix, and 8 participles of weak verbs with the *-t* affix. Again, there is no frequency preference for the *-t* affix. Finally, we analyzed four different child language corpora with respect to the type frequencies of participles in the speech addressed to the children (Clahsen 1997). The children were between 1,5 and 2,1, and the corpora contained approximately 40,000 words. We found similar type frequencies for *-t* and *-n* participle forms, 45% for the former, and 55% for the latter on average.[14]

Hence, on the three counts used, the frequency distribution of weak and strong verb forms in German is rather similar. Only if we include larger samples that contain verbs with extremely low token frequencies, such as CELEX with a total of nearly 6 million tokens, do weak verbs outnumber strong verbs. Our CELEX

Table 5. *Plurals and the proportions of nouns inflected with them*

Affix	Adult speech; 200 most common words	Adult writing and speech (CELEX) Tokens (Types)	Children's Input Tokens (Types)
-0	12	Not counted	Not counted
-e	35	28% (22%)	30% (33%)
-er	10	5% (2%)	15% (8%)
-en	42	65% (68%)	49% (53%)
-s	1	2% (7%)	6% (5%)

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

counts revealed type frequencies of 78% for weak and 20% for strong verbs, but even these figures are less extreme than corresponding counts for English verbs (Marcus et al. 1995).

ACKNOWLEDGMENTS

The research reported in this paper is supported by the Deutsche Forschungsgemeinschaft (DFG) (German Research Council; grants Cl 97/1.1-1.3, Cl 97/5.1-5.3, and SFB 282/B7). The collaboration with Steve Pinker and Gary Marcus is supported by grants from the Deutscher Akademischer Austauschdienst (DAAD) (German Academic Exchange Service) and the American Council of Learned Societies (ACLS). The collaboration with Thomas Münte is supported by a NATO Collaborative Research Grant.

I wish to thank my collaborators on these projects for their contributions: Susanne Bartke, Sonja Eisenbeiss, Gary Marcus, Thomas Münte, Knut Olawsky, Martina Penke, Steve Pinker, Monika Rothweiler, Ingrid Sonnenstuhl, Helga Weyerts, Richard Wiese, and Dieter Wunderlich. I am also grateful to various colleagues at the University of Essex for helpful discussions and comments on earlier versions, in particular to Martin Atkinson, Jenny Dalalakis, Claudia Felser, Iggy Roca, Tessa Say, and Andrew Spencer.

NOTES

1. One might argue that the participle ending *-en* of irregular verbs such as *written* and the past tense ending *-t* in verbs such as *bent, felt,* and so forth are actually suffixes, and even analyze no-change verbs such as *hit, put,* and *shot* as containing a past tense *-t* suffix, which has become invisible through degemination. However, despite these cases, irregular past tense forms do not normally contain segmentable endings in English.

2. The basic distinction between two types of inflectional clusters could also be derived from other linguistic frameworks, for example, from Halle and Marantz's (1993) Distributed Morphology in terms of the distinction between "vocabulary insertion" and "phonological readjustment" or from Corbett and Fraser's (1993) Network Morphology in terms of the notion of "global" versus "nested" defaults, or from Jackendoff (1997) in terms of the distinction he draws between "lexical rules" (for irregulars) and "combinatorial rules" (for regular inflection). It does not seem to matter (for our current purposes at least) which of these linguistic implementations is chosen and we will therefore not discuss these alternatives here. Minimalist Morphology does, however, differ from standard Generative Phonology treatments of inflection (see, e.g., Halle & Mohanan [1985] and related work) in which minor rules are proposed – for example "Lowering Ablaut" to derive irregular forms such as *sang* from the stem *sing.*

3. There is an antecedent within linguistic theory for the notion of structured lexical entries, namely Chomsky's (1970) notion of lexical redundancy rules.

4. Note that the *ge-* prefix, as in *kaufen – ge*+kauft, "buy – bought" and *laufen – ge*+laufen, "run" occurs in regular and irregular verbs and that its distribution is determined by the stress pattern of verbal stems (see Appendix A1 for details). Because the choice of the prefix is irrelevant for the morphological distinction between regular and irregular inflection, we will not further investigate *ge-* here.

5. Clearly, however, inflectional patterns of languages like Turkish and Inuktitut, where each verb has tens of thousands of forms are difficult to handle for a full listing model. Hankamer (1989) calculated that a full listing of the different forms of Turkish words would likely exceed the storage limits of the entire brain.

6. The sentences used in the cloze test were structurally similar to those in the booklet from which the subjects had to learn the nonsense verbs, but they contained different lexical material. The second sentence of each pair had a gap in the verb position that the subjects had to fill with the preterite form of one of the nonsense verbs learned from the booklet; see Clahsen et al. (1997).

7. Another way of capturing this phenomenon is to posit that denominal verbs are headless or exocentric (Selkirk 1982; Williams 1981).

8. It should be mentioned, however, that nouns that take *-s* plurals tend to be less frequent in German than nouns that take *-er* plurals. Consequently, the nouns we had to use for *-er* plurals in our experiment are more frequent than those with *-s* plurals; CELEX mean lemma frequencies are 72 million for *-s* plurals and 897 million for *-er* plurals. We would expect this difference to lead to shorter lexical decision times for nouns that take *-er* plurals, simply because these nouns are more frequent than nouns that take *-s* plurals. Potential priming effects, however, are not determined by directly comparing *-s* and *-er* plurals, but by comparing morphological primes with appropriate frequency-matched identity and control conditions. As this is done separately for *-s* plurals and for *-er* plurals, the different lemma frequencies mentioned above should not affect the priming results.

9. Note that in the *-er* condition we had to include several nouns (n = 23) that have an umlaut (in addition to *-er)* in their plural form. This was necessary because otherwise there would not have been enough (non-umlauted) *-er* plurals that could be used for this experiment. To assess the role of umlauts in the processing of German nouns, we independently performed a cross-modal priming experiment on diminutives prior to the experiment on *-s* versus *-er* plurals reported here (Sonnenstuhl et al. 1999). We examined diminutives with umlauted stems, for example, *Bäum-chen,* "small tree" (*Baum* "tree"), and diminutives without umlauts, for example, *Kleid-chen,* "small dress" (*Kleid* "dress"), using the same design as in our other priming experiments. We found that both types of diminutives produced a strong priming effect, irrespective of whether or not they contained umlauts. Diminutives with umlauts (= *Bäum-chen*) led to a priming effect of 26 msec compared to unrelated control items; the same effect was found for diminutives without umlauts (= *Kleid-chen*). Moreover, the RTs on both types of diminutives were not significantly different from the RTs to the identity condition. Thus, this experiment produced full priming for diminutive forms, even for those with umlauts. This shows that umlauting does not impede morphological priming in this task.

10. The N400 component found in the plural study for irregularizations was only seen in the participle study for nonce verbs, but not for incorrect regular participles. This might be explained by a linguistic difference between these two kinds of items: plural irregularizations (**Karussellen)* produce nonwords, hence the N400, but in irregularized participles (**durch-getanzen)* the item is identical to an existing verb form, the infinitive (= tanzen, "to dance"), and therefore does not elicit an N400.

11. Some researchers have interpreted the LAN as reflecting working memory operations, with the LAN being elicited by words that occur at positions that put a high load on the working memory system (King & Kutas 1995; Kutas & Kluender 1994). It is not clear how the present set of ERP data could be explained in terms of working memory processes. I would therefore maintain the linguistic interpretation of the LAN suggested in the main text.

12. See correction in Response section R1.5, paragraph 1.

13. This view has been criticized, however; see section 4.6. Marcus et al. (1992) and Marcus (1995) have shown that predictions derived from frequency-based models of the acquisition of the English past tense are not empirically valid. For example, it is not the case that children overregularize more often when they are acquiring regular verbs more rapidly.

14. In contrast to these frequency counts, Bybee (1995b) claimed that *-t* participle suffixation applies to the largest number of verb stems and therefore has a higher type frequency than *-n* participle forms. Bybee's frequency counts, however, are based only on a set of 1,258 so-called basic verbs ("*Grundverben*") from Ruoff (1981); see Clahsen (1997) for some arguments against restricting type frequency counts to Grundverben.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

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And what about the Chinese?

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Abstract: We discuss other recent studies on the acquisition of the German plural that do not support the dual-mechanism model. The attested overgeneralizations are not by default only, nor completely random, but predictable from subregularities based on the grammatical gender and the phonology of the noun. In addition, the dual-mechanism model creates a number of problems for acquisition (theory) rather than solving existing ones.

We do not believe that Clahsen's model of language acquisition is a workable one, empirically or theoretically. The main problems may be illustrated via one of his central examples, the German plural. Clahsen claims that eight of the nine plural markers of German may be acquired on the basis of frequency or similarity, whereas the *-s* plural participates in some mysterious rule system that Mother Nature has designed. It takes much ontogenetic time for the rule system to kick in in this case, because the *-s* plural is not so frequent, and some (unspecified) critical mass of exemplars of this and the other plurals (as well as evidence about the relationship between plural morphology and nominal compounding) is needed before the rule system can become operative.

But a much more plausible explanation is that children are learning morphological patterns with the German plural, just as they are learning many other morphological patterns. Over time, the *-s* plural does take on something of a special status because it has the least phonological constraints on it, so it is applied in something like a "default" manner, when no other plural marker seems appropriate. The wider applicability of the *-s* plural may account for its being processed in a brain area different from the area used for other plurals, and also for some of the adult reaction time data, but it does not imply that there are two general ways of processing language that are operative from the beginning: by rote and by rule (Pinker 1991).

The facts are as follows. Several studies show that children overgeneralize several different plural markers, not just the *-s,* and the way this happens is not random. For example, in a cross-sectional study, Ewers (1999) found that most often 3-year-olds overgeneralize the highly frequent *-(e)n* plural, with overgeneralizations of the *-s* plural becoming more frequent only in 4 and 5 year olds. Similarly, Gawlitzek-Maiwald (1994, p. 243) found that overgeneralization with *-(e)n* when nouns are feminine was the dominant pattern throughout development, even for adults. Using nonce nouns, she also found that children and adults overregularize a number of different plurals, and that *-s* overregularization occurs in those contexts where gender- and Auslaut-based rules would predict them (see also Köpcke 1998; Bittner & Köpcke 1999). And there is individual variability in all of this, as would be expected with such an unpredictable system. In general, both Gawlitzek-Maiwald (1994, p. 243) and Köpcke (1998, pp. 314ff.) conclude that children's overgeneralizations are neither random nor by default only but reflect areas of uncertainty in the German plural. (Similar results are obtained when looking at the acquisition of German past participles; see Lindner 1998.)

With just the small set of morphological examples presented by Clahsen (plural and past tense), perhaps the two explanations cannot be satisfactorily compared and evaluated. But what if we look more broadly at other areas of morphology? If a dual mechanism was a fact about the organization of language and language processing, we should find it at work in all inflectional categories in all languages, independent of the nature of allomorphy found in each given case. But how could this work in the case of portmanteau morphemes, which fuse several distinctions together, such as the German fusing of gender and case for nouns? For many languages, portmanteau morphemes such as these are virtually all that exist, and, insofar as different languages mark different things, are all possible notions that could be morphologically marked in a human language lying dormant in the genes of all human beings, with regular rules ready to be applied in case the language has a unique grammatical marker for it? In languages such as Chinese, in which there is very little morphology at all, is this mechanism just sitting there quietly in the brains of one-fifth of all the people on earth, doing nothing?

Moreover, these problems aside, it is still unclear how the purported mechanism is actually to work in even the most straightforward cases. That is, concretely, how does the child create affixes for regular morphology? Clahsen claims that an increase in vocabulary size (=lexical learning) leads the child to identify a default rule in which stem and affix are differentiated, for example, stem + *-s* for the "regular" German plural. But how does the child know to do this for the *-s* plural but not for the *-en* plural, which is actually more frequent? Why should repeated hearing of "irregular" plurals strengthen holistic retrieval cues, whereas repeated hearing of "regular" plurals does not but leads to the creation of an affix – *given that the child has no way of knowing ahead of time which is which?* Clahsen's answer is: Because children cannot know which is the regular form from the beginning, they must simply memorize regulars and irregulars alike. Then, at some later point, they must reanalyze some of these holistically stored forms into stem + affix (i.e., the regulars) but not others (i.e., the irregulars). However, the problem of identification is still with us. How exactly does the child know which are which? In the case of the German plural, the child has to notice that the *-s* plural has less restrictions of use and that certain inflected forms but not others tend to enter into nominal compounding. Does this same identification algorithm work for all other affixes in all other languages, especially insofar as even in German this relation is not systematic enough to trigger the default (see Gawlitzek-Maiwald 1994)? Does it change when languages change historically from one productive (=default) morpheme to another?

It thus seems to us that there is no good evidence that children process the German *-s* plural in a qualitatively different way from other plural endings or other inflectional markers. Children do quite well in acquiring the irregular aspects of language, so why should they need help to acquire regular morphology? With all the problems discussed above, the dual-mechanism model does not facilitate acquisition or processing but provides an unwieldy cognitive apparatus useful at best for a very limited set of exceptionally regular morphological markers. The dual-mechanism model is simply one more way to try to save a Chomskian innate Universal Grammar from the messy facts of real languages, which clearly do not conform to a distinct split into words and strictly compositional rules.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Productivity and exponence

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Abstract: The experimental results reported in Clahsen's target article clearly distinguish regular from irregular processes and suggest a basic difference between items that are productively formed and items which are stored in the lexicon. However, these results do not directly implicate any particular combinatory operation (such as affixation), nor do they distinguish inflectional items from other productive formations.

Clahsen's target article presents interesting support for a cognitive architecture that formally distinguishes lexical entries from combinatory operations. The results summarised here highlight a fundamental difference between regular and irregular morphology that can be readily understood if regular forms are defined by combinatory operations, and irregular forms are retrieved from the lexicon.

Yet, although the priming and imaging studies clearly distinguish regular from irregular processes, these studies are compatible with various ideas about the nature of combinatory operations and the organisation of lexical information. It is thus useful to factor out the claims and assumptions in the present article that represent inessential implementation details or reflect parochial features of German in order to isolate the conclusions that are directly supported by the experimental results.

Three issues of particular linguistic interest are enumerated below and briefly elaborated in the following paragraphs.

1. The contrast between regular and irregular processes is consistent with the claim that regular formations, unlike irregulars, access and manipulate stem entries of a lexeme. However, in the absence of studies showing independent affix priming, there is no direct support for the view that affixes also have lexical entries that are accessed in the formation of regulars. Hence the present studies are neutral between the "item and arrangement" model advocated by the author and an "item and process" model of the sort developed by Anderson (1992).

2. The declared focus on inflectional phenomena is too narrow and arguably misplaced, given that the verbal participles discussed in the article behave in significant respects like derivational stems. The studies thus motivate a central opposition between productive formations, whether inflectional or derivational, and the irregular items stored in the permanent lexicon.

3. The account of the contrast between regular and irregular forms rests on two main claims: (a) "that a given lexeme [entry] may have more than one stem" (Aronoff 1994, p. 41), and (b) that irregular stems of a lexeme may be accessed independently of the basic stem. The inflectional or derivational status of irregular forms is again of subsidiary importance, though there are grounds for treating them as derivational. Moreover, although the inheritance-based entries in section 3 exhibit a concise and efficient format for organising lexical information, none of the studies reported here bears on the choice between this format and alternatives in which irregular forms are exhaustively listed. The key point is that retrieval of irregular forms does not require access to – and concomitant activation of – the basic stem.

Productivity and affixation. The idea that irregular processes involve frozen alternations that are stored in lexical entries enjoys relatively widespread theoretical and experimental support. The conflation of "productive" with "affixal" processes is an entirely different matter; it is neither the case that all productive processes are affixal nor the case that all forms that can be "decomposed into stem + affix" reflect productive processes. The subtractive processes that define nominative nouns in Lardil (Hale 1967), perfective verbs in Papago (Zepeda 1983), or the "incomplete phase" in Rotuman (Churchward 1940) involve productive operations that cannot be described as affixal without trivialising the notion of affixation. Conversely, German plurals such as *Hunde,* "dogs," which can be assigned the transparent stem + affix analysis *Hunde*+e, are nevertheless frozen irregular forms.

The opposition between affixation and structured entries thus reflects a parochial property of modern German, namely, that all productive paradigmatic morphology is affixal. Insofar as this overlap is clearly contingent rather than necessary, either productivity or affixation can be identified as the property that determines the experimental contrasts between regular and irregular formations:

1. The essential property of regular formations is that they are formed *productively* by symbolic operations, whether affixal or nonaffixal, whereas irregulars are listed and retrieved.

2. The essential property of regular formations is that they are formed by *affixation,* in contrast to productive nonaffixal formations and nonproductive irregular forms.

Both theses are possible a priori, but the null hypothesis from a linguistic perspective is surely that productive processes will pattern together and that the primary opposition in German is accordingly between productive formations and frozen forms that are listed in the lexicon.

Inflection and derivation. A second confounding factor in German concerns the relation between productivity and inflection. Although the distribution of the *-s* plural exponent establishes its productivity in German, it is the distribution of plural *forms* in *-s* that determines the inflectional status of *-s.* Irregular plurals are found in a range of derived formations, including compounds *Gäst*+e+buch, "guestbook," derived nominals *Mütter*+schaft, "motherhood," and adjectives *löcher*+ig, "full of holes." Plurals in *-s* do not occur within such derived forms; despite the fact that [*s*] is found within compounds in German, "[c]ompounds such as **Auto*+s+versicherung, "car insurance," or **LKW*+s+gebühr, "truck fee," do not exist" (Wiese 1996, p. 146). The conventional view that derivation precedes inflection accounts for this contrast, if *-s* is treated as inflectional. This account also suggests that irregular plurals are derivational stems that, like basic stems, may be mapped onto identical inflected items.

This account extends as well to plurals such as *Rakete*+n "rockets," and *Frau*+en, "women," which occur in compounds such as *Rakete*+n+stufe, "rocket stage," or *Frau*+en+chor, "female choir." The view that compounding applies to derivational stems reconciles the existence of these compounds with the arguments of Penke et al. (1999) and Wunderlich (this issue) that feminine plurals in *-n* are productive derivational forms. In contrast, these compounds are problematic if only "irregular plurals (because they have lexical entries) can be fed into the compounding process" (sect. 5.2, para. 2).

Parallel considerations support a derivational treatment of participial verb forms in German, which feed productive derivational word-formation processes. The regular past participle *gereist,* "travelled," can be converted into a lexical adjective, which may occur attributively or undergo subsequent lexical compounding, as in *ein vielgereister Kanzler,* "a much-travelled chancellor." The resulting compound may, like any other adjective, be nominalised, as in *die Vielgereiste,* "the much-travelled ones." The irregular participle *betrunken,* "drunk," exhibits similar conversions in *der schwerbetrunkene Mann,* "the heavily-drunk man," and *die Schwerbetrunkene.* The fact that past participles, unlike finite forms, feed such canonically derivational processes suggests that the operations that define regular participles in *-t* are likewise derivational rather than inflectional.

Structures and operations. In sum, while inflectional paradigmatic processes are often productive (in German), not all productive paradigmatic processes are inflectional. The contrast between inflectional processes and irregular patterns can again be viewed as a special case of the general distinction between productive operations and stored forms. The relevant opposition here is not between inflectional and noninflectional phenomena but rather between items that are stored in the permanent lexicon and elements that are defined from items in the lexicon by productive, possibly inflectional, operations.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Although the choice of German eliminates confounding frequency effects in English, German retains other confounding factors. Filtering these out strengthens the main line of argumentation in this article by isolating the core properties that distinguish regular from irregular forms.

Lexical storage and regular processes

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Abstract: Clahsen's claim that output forms of productive processes are never listed in the lexicon is a consequence of the rule/list fallacy, empirically incorrect, and not necessary for the hypothesis that the human language faculty has a dual structure, that is, a lexicon and a set of rules.

The basic claim made by Clahsen is that there are processing differences between regular and irregular inflection and that this is evidence in favour of a model of the human language faculty that consists of two basic modules, a lexicon and a set of rules. Irregular forms are listed in the lexicon, and regular forms are produced by rule. Although I accept this basic distinction of two modules, I believe that Clahsen's identification of irregularity and storage is incorrect: There are several reasons for assuming that, in addition to irregular forms, regular forms can, and sometimes must, be listed in the lexicon.

To begin, Clahsen's reasoning suffers from the "rule/list fallacy" (Langacker 1987, p. 29), the idea that listing forms and also accounting for them by rule are mutually exclusive. This is by no means necessarily true, and I will argue below that this position is incorrect. The capacity of the human memory is so vast that the storage of regular forms of high frequency is possible, and quite advantageous in terms of speed of processing. So, why would the language user not be so efficient as to store highly frequent regular forms if this speeds up processing?

Second, there are many examples of regular, productive morphological rules that nevertheless require lexical listing of words of the corresponding form. For instance, the pluralisation of Dutch nouns consists of the addition of one of two competing suffixes, *-s* or *-en* (*e* stands for schwa). The choice between these two suffixes is made as follows: *-s* after a stem ending in an unstressed syllable, *-en* after a stem ending in a stressed syllable. The effect is that a Dutch plural noun will always end in a trochaic foot (Booij 1998). However, there are several classes of exceptions to this pattern. For instance, English loan words such as *tram* and *flat* have plural nouns in *-s* (*trams, flats*), although we would expect the plural forms *trammen* and *flatten,* the forms produced by many Dutch children during the process of language acquisition. That is, although affixation with *-s* is a regular rule, we also have to list a number of plural nouns in *-s* in the lexicon, the positive exceptions to this rule. This observation does not cause severe problems for Clahsen's model, but shows that the same affix can sometimes be attached by rule to a stem, whereas in other cases it may be part of a lexical entry.

A serious problem for Clahsen's claim that the existence of a productive, regular process implies that its outputs are not listed in the lexicon is the observation that words might be regular from the formal point of view, but semantically idiosyncratic. For instance, many Dutch past participles are formally regular but semantically irregular. Examples are *gezet* (stem *zet,* "to put") "fat" and *gesmeerd* (stem *smeer,* "to smear") "fast, fluent." These words have to be listed because their meaning is unpredictable from that of the stem and the affix; thus, formal regularity does not preclude the necessity of a word being listed.

There is another kind of linguistic evidence that can be used for deciding on the storage of a word, and it is not used by Clahsen: phonological change. The relevance of this kind of evidence can be illustrated again with data from Dutch. Dutch exhibits the effects of Prokosch's Law for Germanic languages, the rule that stressed syllables must be heavy. The consequence of this law in Early Middle Dutch was that short vowels were lengthened in open syllables, which arose through affixation with the plural suffix *-en.* Thus, Dutch got alternations such as

(1) da[a]g "day" d[a:]gen "days"
w[e]g "way" w[e:]gen "ways"
sch[i]p "ship" sch[e:]pen "ships"

Although these plural forms with long vowels in their first syllables were completely regular, they must have been stored as such, because, after the loss of this process of open-syllable vowel lengthening, these plural forms kept their long vowels. This is possible only if these forms were stored as such at the time that they were still regular. There are many more examples in the historical linguistics literature of relics of once-regular phonological processes, relics that could survive only because the relevant words have been lexically stored.

Hence it is in my opinion unnecessary, in order to defend a dual structure of the language faculty, to make the claim that the output forms of regular, productive rules are never stored. On the contrary, this claim is patently false.

There is another specific claim that relates to this problematic aspect of Clahsen's position. Clahsen argues that it is true for English and German that only irregular inflected forms can feed word-formation processes such as compounding. Clahsen invokes this argument to support the claim that regular inflection is in a module of the grammar different from that of irregular inflection and that word formation takes its input forms from the lexicon only. Even if this claim were correct for English and German, it cannot follow from the universal organization of the human language faculty, because there are many languages in which regular inflection feeds word formation. This empirical issue has been discussed in relation to the so-called split morphology hypothesis of Perlmutter (1988); in another paper (Booij 1993) I have provided ample evidence against the claim that regular inflection does not feed word formation. For example, regular Dutch past participles (regular regarding both form and meaning) can freely feed deadjectival nominal affixation with *-e* "-ness," as in (*het*) *vertelde* "what has been told." Moreover, as has been argued by Booij (1977), word formation processes are fed not only by listed words but also by possible words, that is, words for which there is no evidence that they are listed. Hence, the presupposition that word formation is fed by inputs from the lexicon only is incorrect.

In sum, Clahsen's evidence should be taken to support the claim that there is a fundamental distinction between lexicon and rules. However, this by no means implies that regular inflected forms cannot be stored in that lexicon. Moreover, even outputs of inflectional rules that are not stored may feed word formation.

Use impacts morphological representation

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Abstract: The distinction between regular and irregular morphology is not clear-cut enough to suggest two distinct modular structures. Instead, regularity is tied directly to the type frequency of a pattern. Evidence from experiments as well as from naturally occurring sound change suggests that even regular forms have lexical storage. Finally, the development trajectory entailed by the dual-processing model is much more complex than that entailed by associative network models.

The separation of usage from structure is a traditional practice in linguistics dating back to Saussure's (1916/1973) distinction between *langue* and *parole.* Clahsen subscribes to this dichotomy,

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

seeing linguistic analysis as totally driven by innate structures rather than by linguistic experience. In recent years, many linguists have made great headway by considering an alternative hypothesis, which is that language structure is built up from patterns of language use. For instance, our understanding of the nature of ergativity (DuBois 1987), subjects and passive (Givón 1979), relative clauses (Fox 1987; Fox & Thompson 1990), and tense, aspect, and modality systems (Bybee et al. 1994) has been greatly expanded by attention to the way language use conditions grammatical change over time. These studies demonstrate that no innate structures are necessary to explain the grammar of human language.

The difficulty Clahsen encounters in trying to argue for innate modular components to account for structural differences is that properties of usage often correspond to the proposed properties of structure, and disentangling the two is a major challenge. For instance, the regular "rules" of morphology usually have high type frequency; that is, they apply to a large number of different forms. Clahsen has addressed this challenge by trying to show that there are regular rules that do not have high type frequency. However, there are problems with his proposals, as described below.

First, Clahsen takes the German *-t* participle and *-s* plurals as cases in which frequency and structure do not correspond, claiming that both of these affixes constitute the "regular" alternative but have a lower type frequency than competing "irregular" allomorphs. However, neither of these cases is clear-cut: (1) the claim that "three different frequency measures revealed that (in contrast to English) regular and irregular verb forms have similar frequencies" is based on counting German verbs differently from the way English verbs are counted (sect. 4.6, para. 8). For English we count *write* as one irregular verb even though it occurs with different particles in *write out, write up, write down,* but Clahsen counts the comparable structures in German with *schreiben,* "to write," such as *aus-schreiben* "to write out, announce," as a different verb from *schreiben.* Insofar as many "irregulars" occur with the prefixed particles (or separable prefixes), this greatly inflates the number of irregulars (Bybee 1995b). In addition, when considering the claim that type frequency conditions productivity, it is important to note that the irregulars cannot be grouped into one class because they have a number of different types of vowel changes (in English as well as in German). Thus the type frequency of the English *-ed* past tense or the German *-t* participle is much higher than the type frequency of any particular class of irregulars. (2) The *-s* plurals do have a very low type frequency compared to any other class of noun plurals. As would be predicted from their low type frequency, they are not free of lexically based similarity effects, contrary to the claim made by Clahsen (see Table 4). Köpcke (1988) showed in a nonce-probe task that subjects tended to use the *-s* plural on nouns that resembled existing *-s* plurals, in particular those ending in full vowels, such as *Autos* and *Pizzas.*

Second, considerable evidence is accumulating to show that even regularly inflected forms show word frequency effects, which suggests that high-frequency regulars are stored in the lexicon rather than derived by rule. Stemberger and MacWhinney (1986) show that high-frequency regular forms are less prone to error than low-frequency regulars, in both naturally occurring and experimentally induced errors. Losiewicz (1992) found that the *-ed* affix on low-frequency regular past tense verbs was significantly longer in acoustic duration than the same affix on high-frequency regulars. Bybee (1999) found that the rate of deletion of final /t/ and /d/ on regular English past tense verbs was higher for high-frequency verbs than for low-frequency verbs. All of these frequency effects are compatible with the hypothesis that high-frequency regulars are stored in the lexicon and accessed directly, whereas low-frequency regulars require some access to the regular affixation schema, in other words, that it is frequency of use that determines the nature of storage and access, not structure.

Finally, consider the development stages entailed by the dual-processing model. Presumably, at first, all items are stored in memory, for otherwise it would be impossible to segment them into stem and suffix. That is, *play – played, spill – spilled,* and a large number of parallel items must be stored and associated in memory before the suffix can be discovered. Once the suffix is segmented, the question arises of how children identify it as "regular," if it is not because of the strength it gains from type frequency. In Clahsen's model the normal forms of the language are not sufficient for this categorization; the child has to wait until he or she has heard strange forms such as *ringed* (as in *they ringed the city*). Having established the rule, the child not only reorganizes thoroughly by moving the rule to a different module, but he or she must now ensure that it does not apply to irregulars, by also establishing the blocking device that prevents this (Marcus et al. 1992). This is not the end of the reorganization. The regular forms that were previously stored must now be purged from memory so that only irregulars remain.

The alternative is much simpler and to my mind more plausible: The child learns specific words, some with affixes, some without. They are stored in memory and a network of associations among them begins to develop. These associations eventually reveal recurrent subparts, such as *play* in *plays, playing, played* and *-ed* in *played, spilled, wanted.* Subparts that occur in more combinations (that is, have a high type frequency) are reinforced more, both because their occurrence in more combinations makes them more segmentable, and because their reuse increases their levels of resting activation, making them more accessible. Words with high frequency are more autonomous from the networks of associations, which means that if they are irregular they can resist regularization (Bybee 1985; 1995b). No blocking devices or major reorganizations into modules are needed, just a growing network of associations with individual items differentiated by accessibility, which is a result of how often they occur in the child's experience with language.

The tension between "combinatorial" and "class-default" regularity

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Abstract: Clahsen shows that "combinatorial" inflection is processed differently from "irregular" inflection. However, combinatorially regular affixes need not coincide with "class-default" affixes, that is, affixes shared by more than one inflection class and all of whose rivals are peculiar to one class. This creates a tension that may help to explain the persistence of inflection class systems.

Clahsen argues persuasively that regular affixation is processed differently from irregular affixation. However, it is necessary to distinguish between regular affixes in Clahsen's sense (affixes that are typically used in nonce formations or with nonsense stems) and what I call "class-default" affixes (affixes all of whose rivals are "class-identifiers," peculiar to one inflection class). This qualification does not contradict but rather complements Clahsen's distinction between "combinatorial" and noncombinatorial affixation. It may help to explain why inflection class systems are so robust diachronically and so readily learnable by native speakers, despite being communicatively and cognitively so pointless – facts that are rather puzzling if most inflection class diversity is classed simply as "lexical," without differentiation. At the same time, it reinforces the importance of distinguishing between affixal and nonaffixal inflection (Carstairs-McCarthy 1994, pp. 757–59), a distinction that is generally downplayed in the connectionist approaches that Clahsen criticizes and is not prominent in Clahsen's own treatment either.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Consider a set of six inflection classes representable schematically as in (1), where the letters *a–g* stand for distinct affixes and where "Cell 1" and "Cell 2" stand for distinct combinations of morphosyntactic properties.

(1)	Class A	Class B	Class C	Class D	Class E	Class F
Cell 1	*a*	*a*	*a*	*b*	*a*	*c*
Cell 2	*d*	*e*	*f*	*g*	*g*	*g*

In cell 1, affixes *b* and *c* are peculiar to one inflection class and may therefore be called "class-identifiers"; their only rival is affix *a*, which may be called the "class-default" for cell 1. Similarly, in cell 2, *d, e,* and *f* are class-identifiers and *g* is the class-default. Now, in an inflectional pattern such as this, which class (if any) is likely to display affixes that are "combinatorial," not "lexical," in Clahsen's sense? One may be inclined to guess that the answer must be class E, which in both cells exhibits the class-default affix (*a* and *g*, respectively). However, there is no logical necessity for this. The class to which nonce words, nonwords, and so on conform could be any of the six.

The pattern in (1) is in fact essentially that of masculine nouns in standard written German, with cell 1 and cell 2 interpreted as genitive singular and nominative plural, respectively.

(2)	Class A	Class B	Class C	Class D	Class E	Class F
Gen Sg	*-es*	*-es*	*-es*	*-en*	*-es*	*-ens*
Nom Pl	*-e*	*-er*	*-s*	*-en*	*-en*	*-en*
Example	Tag "day"	Wald "forest"	Park "park"	Held "hero"	Dorn "thorn"	Name "name"

German, therefore, supplies an answer to the question just posed. The inflection class displaying "combinatorial" inflection is class C, not class E, even though the plural suffix for class C is a class-identifier (*-s*), not the class-default (*-en*). So, for a given cell in the paradigm, the affix that is most productive need not be the one that is most general in the sense of being shared among two or more inflection classes. Whether this should be of concern to Clahsen depends of course on whether anything of interest hangs on "class-default" status. The answer is yes: Quite solid evidence suggests that affixes that are otherwise synonymous must be either class-identifiers or class-defaults, so that no more than one of such rivals may be shared by more than one class (Carstairs-McCarthy 1994). This requirement is likely to be what underlies "paradigm economy" effects (Carstairs 1987).

There are, then, two distinct types of affixal "regularity": class-default status and "combinatorial" productivity. I suggest that the tension between these may be one of the factors that underlie the diachronic tenacity of inflection class systems. Superficially, it would seem natural for the "combinatorial" affix for some cell to tend to displace any one of its "lexical" rivals; after all, that should amount to a straightforward lexical simplification for the lexemes concerned. It would seem natural, for example, that in (1) the suffix *f* of class C, assuming that it is the combinatorial affix for cell 2 (corresponding to plural *-s* in German), should spread to other inflection classes, such as class D, yielding the pattern in (3).

(3)	Class A	Class B	Class C	Class D	Class E	Class F
Cell 1	*a*	*a*	*a*	*b*	*a*	*c*
Cell 2	*d*	*e*	*f*	*f*	*g*	*g*

However, (3) differs in a crucial respect from (1). As a result of this apparent simplification, cell 2 now has two affixes that are neither class-identifiers nor class-defaults, namely, *f* and *g*. That kind of unwelcome outcome may, I suggest, be a factor in inhibiting apparent inflectional simplifications of this kind.

The greatest risk that affixal simplification will lead to this kind of unwelcome outcome arises when "combinatorially" productive affixes are concentrated in an inflection class that is particularly idiosyncratic (that is, one that differs affixally from other classes in most or all cells). This is because, if one of those idiosyncratic affixes spreads to other classes, its status as a class-identifier is lost, and instead it trespasses on the class-default's role as the only affix shared by more than one class. The maintenance of nominal inflection classes in most branches of the Indo-European language family may thus be partly due to the fact that the class that was generally most productive (the *o*-stem class) was also suffixally the most idiosyncratic, bearing some suffixes that were originally pronominal rather than nominal. The psycholinguistic experimentation that Clahsen reports may seem remote from such diachronic issues, yet an adequate account of how inflection class systems behave must reconcile evidence from all relevant sources.

The processing of inflected forms

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Abstract: Clahsen proposes two distinct processing routes, for regularly and irregularly inflected forms, respectively, and thus is apparently making a psychological claim. We argue that his position, which embodies a strictly linguistic perspective, does not constitute a psychological processing model.

Clahsen's argument is based on the inflectional system of German, because German allows comparisons not possible in English. This fact highlights yet again the problem that too much psycholinguistic theorizing relies exclusively on English, a language that is in many respects atypical (Cutler 1997). Clahsen claims that the German data motivate distinct processing routes for regularly and irregularly inflected forms. This appears to be a psychological claim. We argue, however, that his account, arising from a strictly linguistic perspective, does not constitute a psychological model at all.

Models of processing make behavioral as well as informational distinctions. It is not enough in a processing model simply to note that two distinct types of information may play roles in processing some material. A processing model must distinguish between, for example, recognition and production processes or, within recognition, between (modality-specific) access representations and (modality-independent) central representations. In fact the latter is a common distinction in psychological models of morphological processing (McQueen & Cutler 1998). No such distinction is made by Clahsen, however. It is thus impossible to say where his claims about the decomposition of regulars apply in the lexical access process – only centrally, or also at the access level? Does Clahsen rule out the possibility of full-form access representations for regular inflections, even if there are no such central representations?

To illustrate our argument, we report the results of an experiment in which listeners wrote to dictation ambiguous English word forms (McQueen et al. 1992; Van Ooijen et al. 1992). The experiment was based on an earlier study by Taft (1978), who showed that listeners preferred to write monomorphemic rather than inflected forms for ambiguous items such as [best]; note that prior studies (Bond 1973) have shown such items to be fully ambiguous between an inflected and a monomorphemic form (here, *based/baste*). We used Taft's task to compare regular and irregular inflections. The results, though clearly showing a processing difference between regularly and irregularly inflected forms, cannot easily be fitted into Clahsen's model.

The listeners were 32 native speakers of British English. They wrote 17 items involving a regular inflection and 19 items involving an irregular inflection, namely, regular: *billed/build* (.06), *paws/pause* (.06), *rays/raise* (.03), *sighed/side* (.03), *prints/prince*

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

(.44), *guessed/guest* (.13), *tents/tense* (.72), *passed/past* (.41), *paced/paste* (.34), *missed/mist* (.34), *knows/nose* (.09), *tied/tide* (.31), *guys/guise* (.19), *packed/pact* (.88), *based/baste* (.72), *days/daze* (.19), *stayed/staid* (.53); and irregular: *bred/bread* (.09), *won/one* (.19), *lain/lane* (.22), *blew/blue* (.04), *rode/road* (.31), *sought/sort* (.97), *knew/new* (.03), *caught/court* (.94), *read/red* (.13), *fought/fort* (.80), *seen/scene* (.81), *led/lead* (.25), *flew/flu* (.75), *heard/herd* (.72), *made/maid* (.47), *sent/scent* (.78), *thrown/throne* (.81), *feet/feat* (.84), *taught/taut* (.91). The numbers in parentheses are the proportions of inflected form responses to each item. The test also included 56 further items: homophones involving two monomorphemic forms (e.g., *beat/beet*), homophones involving function words (*would/wood*), and nonhomophones, both inflected and monomorphemic, in a single list recorded by a speaker of southern British English.

For the regular-inflection homophones (e.g., *based/baste*), listeners wrote the inflected form (*based*) on 32% of trials and the monomorphemic form (*baste*) on 68% of trials, a significant difference ($z = 8.27$, $p < .001$). For the irregular-inflection homophones (e.g., *blew/blue*), listeners wrote the inflected form (*blew*) on 53% of trials and the monomorphemic form (*blue*) on 47% of trials, a difference that was not significant ($z = -1.42$). There was therefore a qualitative difference between the regular- and irregular-inflection homophones. This is not the whole story, however. Another major determiner of listeners' choice was word frequency. Over all 36 items, the proportion of inflected choices correlated significantly with three different frequency measures (from a British English frequency count; Johansson & Hofland 1989): the inflected form's log frequency, $r(35) = .34$, $p < .02$; the monomorphemic form's log frequency, $r(35) = -.30$, $p < .04$; and the difference in these frequencies, $r(35) = .48$, $p < .001$.

Our items were in fact chosen so that there were subsets in which either the inflected or the monomorphemic form was higher in frequency. For the irregular-inflection homophones, listeners tended to write down whichever form was more frequent: The inflected form was chosen on 37% of trials when it was lower in frequency (e.g., *blew/blue*) and on 70% of trials when it was higher in frequency (e.g., *heard/herd*). However, for the regular-inflection homophones, there was a bias towards the monomorphemic form even when the inflected form was more frequent: The inflected form was chosen on only 24% of trials when it was lower in frequency (e.g., *billed/build*) and on only 40% of trials when it was higher in frequency (e.g., *based/baste*).

This striking difference between regular and irregular inflections was significant. In an analysis of covariance in which the log frequencies of both the inflected and the monomorphemic forms were used as covariates, there was a significant effect of regularity, with reliably more inflected choices with the irregular-inflection homophones than with the regular-inflection homophones: $F(1,32) = 5.59$, $MSe = .0749$, $p < .03$. This regularity effect was also significant in an analysis of covariance with the difference in log frequencies as covariate: $F(1,33) = 5.35$, $MSe = .0378$, $p < .03$.

These results support the hypothesis that there is a processing distinction between regularly and irregularly inflected forms. We believe that the lack of separate central representations for regular inflections underlies the distinction. With a homophone involving an irregular inflection, listeners have (aside from the frequency bias) a straight choice between two simple representations, but, with a homophone involving a regular inflection, the choice is between one simple representation (the monomorphemic form) and something more complex for the inflected form (whatever one's preferred account of how decomposed forms are represented).

Our point here, however, is that this interpretation already goes beyond the framework offered by Clahsen. We think that the effect entails central representations because (1) the correlation for the regular-inflection homophones alone between log inflected form frequency and proportion of inflected choices was not significant, and (2) other evidence indicates that spoken regularly inflected forms have full-form access representations (Baayen et al., in preparation). However, because Clahsen does not distinguish between access and central representations, we are unable to offer him these data as support for his model.

Investigating lexical entries and rules: A typological perspective

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Abstract: Research into entries and rules based on English is hampered by the fact that crucial factors coincide. Clahsen avoids this problem and demonstrates his claims by working on German. Seen against the background of the immense variety of the world's languages, this successful move is potentially the first of many possible ones: Several languages offer promising configurations of the factors relevant to Clahsen, and others present new challenges.

Clahsen makes the point cogently that many investigations into the respective roles of entries and rules are vitiated by being based on a language in which regularity, overt suffixation, and high type frequency coincide (see sects. 2, 4.4, and 5.2). Clahsen and his collaborators are able to tease apart the confounding factors by working on German rather than English. By leaving the overcrowded section of the laboratory, as it were, to work on a quieter bench, they make considerable progress. If we take a typological perspective, viewing the variety offered by the world's 6,000 or so languages, then Clahsen has moved a relatively short distance: German and English are closely related, and, when compared to Mayali, Tsakhur, Yup'ik, or Japanese, they appear almost identical. There is thus a wonderfully large laboratory on offer, much of it virtually unused. The purpose of this commentary is therefore to suggest that Clahsen's successful move can be repeated many times, with the prospect both of further progress in the issue he addresses and of new challenges. This theme will be illustrated from one of the problems Clahsen investigates, namely, the category of number, although similar points could be made with relation to the other problem, tense.

Clahsen is concerned largely with binary oppositions; for instance, German and English are limited to a singular–plural opposition of number. This is a common system, but many languages have three number values: singular, dual (for two), and plural (more than two); Yup'ik is an example. Some have an additional value, a trial (for three, as in Larike) or a paucal (for a small number, as in Paamese). The largest systems have five number values (as in Sursurga). These large systems are found with pronouns rather than nouns, but duals on nouns are common. Given a singular-dual-plural system, the question of regularity becomes more complex than in English or German, insofar as a lexical item may be regular in respect of one number opposition but irregular in respect of another (see, e.g., Priestly 1993 on Slovene, p. 401). These larger systems also bring with them interesting frequency effects: Singulars are normally more frequent than plurals, but the reverse holds for certain lexical items, such as *teeth*; when a dual is available, it is typically the least frequent value, though for some lexical items it is the most frequent. (The existence of dual-dominant nouns is of relevance for the work on singular- and plural-dominant nouns by Baayen, Levelt, and Haveman, reported in Levelt et al. 1999, sect. 5.3.5)

German and English are also similar in that number is an obligatory category. If I say *It seems there's a dog in the park* when I know there are several, then I am being at best misleading. However, in many languages, such as Japanese, an equivalent example with *dog* would be fully appropriate when more than one is involved; the plural would be used if the speaker wanted to draw

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

special attention to the quantity, but it is not obligatory. This difference has implications for frequency of use of the different number values, for the input for language acquisition, and in some languages for the degree of agreement among speakers on the form of the plural. While typically there is a shared form for singular and nonspecific or "general," a language may have a unique form for nouns that is outside the number system; this is found in Bayso (Corbett & Hayward 1987).

German clearly outdoes English in terms of the degrees of irregularity, and this is important for Clahsen. From a broader perspective, however, German nouns fall into a moderate number of (relatively) neat classes when compared to Nilotic languages, such as Shilluk. Gilley (1992, p. 81) quotes Kohnen, who following 30 years of study concluded that "A general rule for the formation of plurals in Shilluk cannot be given" (1933, p. 19). After detailed analysis, Gilley concurs. For many nouns one form is the base to which a suffix is added (whether to form the singular or the plural), whereas for some nouns both forms have a suffix. The real difficulties arise within the stem, which is typically of the shape consonant–vowel–consonant. There are some consonant alternations between singular and plural, and the vowel has four sources of variation, in terms of height, quality, tone, and length. It is as though the English plurals of the *foot – feet* and *mouse – mice* type made up a significant proportion of the lexicon (and with more possible types of alternation). Given the degree of unpredictable variation, Gilley (1992, p. 190) concludes that singulars and plurals in Shilluk cannot be derived from a single underlying representation and that two forms must be stored for each noun. Of course, it is difficult to prove a negative, but Gilley makes a good case. Yet Shilluk, with its remarkable degree of irregularity, provides some unconfirmed support for Clahsen's position (sect. 5.1). Gilley reports a suggestion that Shilluk children generalize the use of a suffix for the plural and then later learn the more complex forms (1992, pp. 130–31). Given the degree of irregularity, much greater than that of German, Shilluk suggests tantalizing questions regarding how far the balance between lexical entries and rules can be tipped in favour of one or other in particular languages.

In conclusion, Clahsen has shown again how beneficial it is to see English not as if it were Language but, rather, as just one (typologically rather odd) language. By moving the focus to German, he immediately clarifies the issues he wishes to address. There are many similar moves to be made, and, when we look at languages that are radically different from English and German, they can lead us to ask questions that English and German would not provoke. They offer new research space and new challenges. Unfortunately large parts of the laboratory are closing: According to Krauss (1992, p. 6), at the present rate, 50% of the world's 6,000 languages are likely to become extinct during the next 100 years.

Chomsky's new clothes

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Abstract: Clahsen's view on language is intimately linked with the Chomskian distinction between competence and performance. He uses performance to verify theoretical assumptions about the underlying structure of competence. Using mostly off-line tasks, he may fail to answer the question of how language is generated and perceived in natural situations.

In the old days of generative grammar, Chomsky introduced the distinction between the competence and performance of a human speaker/hearer. In Clahsen's account, competence is now labeled the language faculty consisting of innate, abstract, and modular organized linguistic knowledge, and performance is measured in a variety of tasks for language processing. The fit between the linguistically defined genotype of language and the empirically obtained phenotype of language use in the area of morphology could not be better, could it?

First, the purpose of the empirical studies presented is to verify the proposed dual architecture of the language faculty. What should data look like to have the slightest chance to revise the theory? Or is the theory a sort of biological ontology, resistant to falsification and modification?

Second, the variety of tasks Clahsen used in his endeavor to reflect and test the phenotypic appearance of two types of linguistic genes – the generative and the nongenerative ones – is impressive, indeed, but also restricted in a systematic way. Off-line tasks clearly predominate over on-line tasks. Do off-line tasks tap the same linguistic resources and procedures as on-line tasks do, or do they reflect "fallback procedures," as Butterworth (1983) has put it? For example, how does access to the meaning of words affect their lexical and morphological processing?

Let us compare visual lexical decision for isolated German participles and the minimal requirements for accessing the meaning of such participles in a natural situation, characterized as follows: a continuous language/text flow, no expectation of nonwords. Furthermore, participles do not occur alone (except for ellipsis) but are embedded in constructions that use auxiliaries: the passive (*Das Haus wurde gekauft,* "The house was bought") and the present/past perfect (*Sie hat/hatte ihn gesehen,* "She has/had seen him"). A hearer will accordingly expect a participle to occur when it is preceded by its accompanying auxiliary. (Of course, participles may be used in an adjectival function as in *Dies ist ein geschriebener Text,* "This is a written text." But Clahsen, Eisenbeiss, and Sonnenstuhl [1997] excluded these forms in their frequency counts, presumably because they bear – in German, unlike English – inflectional suffixes.) The participles used by Clahsen et al. (1997) all bear the prefix *ge-,* which further signals the occurrence of a past participle. For the identification of participles (and their meaning) such as *ge-glaub-t,* "believe-d," or *ge-schrieb-en,* "written," the phonemes or graphemes of the stem (*glaub* or *schrieb*) are accordingly sufficient and not all may be needed, depending on the specific uniqueness point. The suffixes *-t* or *-en* are redundant, in contrast to a lexical decision task where every bit of information is important in determining the yes/no response.

For a hearer in a natural situation it is only interesting to know which particular verb the speaker uses, because the grammatical information that a participle suffix signals is already specified by the earlier context. In the case of past participles, centering on the access to meaning may lead to different processing, as in lexical decision. Clearly, language users are able to perform a wide range of tasks, but perhaps all these various performances are due to different competences or, preferably, to the joint activity of several processes whose contributions must be analyzed carefully, not owing to one faculty.

Finally, what is the ultimate aim in studying language use? Should it provide a realistic model of how a speaker generates an utterance such as "Harald has written a very interesting article" and how a hearer perceives, parses, and interprets such an utterance? Or is it about collecting positive evidence for a faculty, called *language.* That is the question!

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Why collapse morphological concepts?

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Abstract: Clahsen's conception of inflectional rules – as being not only regular, but simultaneously only concatenative (combinatorial), general and productive, representing the default, not occurring in interfixation within German compounds, and identical to the first rules to be acquired in first-language acquisition – involves an unwarranted collapsing of morphological concepts.

Clahsen argues with multiple independent evidence for the superiority of a rule-plus-lexical-storage account over a connectionist account, a general enterprise with which I sympathize, not least because over a year's worth of attempts by Dorffner, myself, and our students to have connectionist networks acquire the full complexity of German past participles and noun plurals have failed (see also Sánchez Miret et al. 1997), in marked contrast to Dorffner's (see, e.g., Dorffner et al. 1966) successes with connectionist modelling of word acquisition. What I want to comment upon are unwarranted simplifications in collapsing morphological concepts that should be differentiated. I will stick to grammatical and acquisitional arguments.

In section 1, Clahsen assumes a computational component consisting of syntactic and morphological combining operations. This assumption has two flaws: (a) It separates phonological rules from rules of syntax and morphology, although they share the same basic criteria of regularity, productivity, default (and their symbolic character has been attacked by connectionists as well) and (b) it obscures essential differences between syntactic and morphological rules. Of particular interest for our discussion is the fact that it is only morphological (and phonological) rules that are not only combinatorial or concatenative but may also represent modifications such as umlaut (metaphony) or ablaut (apophony). In contrast to the views of Clahsen, the minimalist model of Wunderlich and Fabri (1995, p. 239), on which Clahsen relies (sect. 3), also allows for regular umlaut and ablaut (which is necessary for many languages). Although concatenative operations may be regarded as prototypical in morphology (which may be deduced from the preference for iconicity in language), the computational morphological component must not be reduced to this.

Next, Clahsen (starting with sects. 2 and 3) collapses regularity (i.e., accountability by a symbolic rule) with generality of application (see Dressler 1985, pp. 65–68, 89–103), although he himself mentions in note 2 the standard generative distinction between major rules (regular, general) and minor rules (regular, non-general; i.e., they hold only for a finite list of words). There is multiple evidence (beyond the Italian processing evidence cited by Clahsen in sect. 4.7) that minor rules capture generalizations different from analogies based on single items (not on rules; see Dressler & Ladányi 1998). This alternative amounts to a triple mechanism of major rules versus minor rules versus only lexical storage (see Dressler 1997a).

Clahsen's assumption (sects. 3, 4.2.3) – that an inflectional system has just one regular rule-derived class, which is at the same time the only fully productive one and represents the default – is somewhat "ethnocentric" (i.e., based on the experience of Western European languages). This collapsing of the criteria of default and productivity occurs with weak verbs in English, Dutch, German, and so on, and the French type *parler,* but it is unreasonable for verb inflection in, for example, Slavic languages, in which several fully productive verb classes compete. For example, Polish has seven such classes, none of which can be identified as the default (see Dressler 1997a; Dressler & Dziubalska-Kołaczyk 1998; Dressler et al. 1998).

This collapsing does not even work for German plural formation, regarding which I agree with Clahsen (starting with sect. 3) that the *-s* plural may be identified as the default (although a weak one). However, four other plural formations are also productive, insofar as they "readily extend[s] to novel items" (sect. 3); I illustrate these with examples in which I do not translate English loans and internationalisms occurring in English as well as in German.

(a) *-n*: the only rule applying to feminines and masculines in final schwa, as in *der Coyote,* pl. *die Coyote-n,* but it also applies to other feminines, as in *die Farm,* pl. *die Farm-en, die Pizza,* pl. *Pizz-en* or *Pizza-s*

(b) *-e*: a must with masculines and neuters ending in a sibilant (incl. sibilant affricates), as in the plurals *die Buss-e, Fax-e, Quizz-e,* but also in *das Oval,* pl. *die Oval-e, der Radar,* pl. *die Radar-e/s*

(c) *-e* with umlaut: *der General, Admiral, Mops* "pug," pl. *die Generäl-e, Admirä l-e, Möps-e* (nineteenth century still without umlaut; still earlier, *Admiral-s!*)

(d) zero plurals with nonfeminine nouns ending in schwa plus *n/r/l*: *der Laser,* pl. *die Laser*.

The only unproductive plurals are the pure umlaut plurals, *-er* plurals (the foil in sects. 4.3, 4.4) and learned Latinate plurals.

In section 5.2, Clahsen flatly identifies interfixes in compounds, such as in *Hund-e-hütte* "kennel" (lit. dog–interfix–hut), with plural affixes, although, more often than not, no plural meaning is discernible (e.g., usually, a kennel is for just one dog), and sometimes the actual plural affix is different (e.g., *Hahn-en-kampf,* "cock fight," vs. pl. *Hähn-e*; see Dressler & Merlini Barbaresi 1994, pp. 553–57; Fuhrhop 1996). His interpretation that only "irregular" (plural) suffixes occur as interfixes, whereas the default (plural) in *-s* is systematically excluded, cannot account for the fact that the productive, default Gen.Sg. masc./neuter *-s* does occur as interfix, as in *Gott-es-lohn* "God's reward" or Austrian G. *Schwein-s-braten* = BRD G. *Schwein-e-braten* "roast pork" (lit. pork–interfix–roast, pl. *Schwein-e,* Gen.Sg. *Schwein-s*).

The last simplification via collapsing concerns Clahsen's assumption (sect. 5) that children acquire first the default = regular = general = productive rule of each category. However, in contrast to Clahsen's claims in section 5.1.2, Austrian children acquire the *-n* and *-e* plural rules before the *-s* rule (Kilani-Schoch et al. 1997; Schaner-Wolles 1993; Sedlak et al. 1998; Vollmann et al. 1997), and this also holds true for other Germanophone children, as reported by Park (1978) and Gawlitzek-Maiwald (1994), whom Clahsen neither cites nor discusses. With regard to German past participles, Clahsen (sect. 5.1.1) does not mention the frequent findings (Vollmann et al. 1997) that not only do children first acquire the *-t* participle and overgeneralize it but they later also overgeneralize *-n* participles, which suggests the typical scenario of children first acquiring major rules and later minor rules. Thus, in addition to type and token frequency, generality, productivity, and default status too are relevant properties of a rule that render it attractive for being identified and acquired early by children. Iconicity and transparency are also important, however, for example, in inducing Polish children to start, typically, with one of the seven productive verb classes that is not the most general, productive, and frequent one (personal communication from K. Dziubalska-Kołaczyk).

In conclusion, I hope to have provided plausible reasons for not following Clahsen's general equation about inflectional rules: regular = concatenative (combinatorial) = general = productive = default = not occurring as interfix in German compounds = being the first rule to be acquired. Clahsen may have shown the superiority of his model to connectionist single-mechanism models, but not yet its superiority to triple-mechanism and dual-route processing models (which are mutually compatible; Dressler 1997a) nor to a constructivist approach to language acquisition, as practiced in our "Crosslinguistic project on pre- and protomorphology in language acquisition" (Dressler 1997b; Gillis 1998).

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Pitfalls in tracking the psychological reality of lexically based and rule-based inflection

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Abstract: Clahsen reports the results from two sets of word-recognition experiments with adult native speakers of German supporting the notion that the processing of regular (or default) inflection differs from the processing of irregular inflection. My commentary points to shortcomings in stimulus selection and inconsistencies in the pattern of results, revealing that the empirical support for the proposed dual mechanism is much weaker than Clahsen suggests.

In his target article, Clahsen continues a longstanding debate in linguistic theory and psycholinguistic research concerning the way in which regular and irregular inflections are represented in the language system. The dual-mechanism account for which he argues draws upon a conceptual framework of linguistic morphology. Regarding psycholinguistic morphology, the problem of whether morphologically complex words are processed by rule or by rote can be decided only experimentally. In other words, the processing question is an empirical one; to settle it we need compelling experimental evidence. To this point, however, Clahsen clearly failed to provide cogent evidence in favor of his theory, as will be demonstrated by a closer look at his experimental studies on processing differences between regular and irregular inflections in visual word recognition.

In section 4.3, Clahsen presents the results of two lexical decision experiments, in which manipulation of word-form frequency was taken as a diagnostic tool for uncovering the processes underlying the recognition of regularly inflected (*-t* participles, *-s* plurals) and irregularly inflected word forms (*-en* participles, *-er* plurals). Effects of word-form frequency (i.e., faster lexical decisions for high-frequency than for low-frequency forms) were found for irregularly inflected words but not for regularly inflected words. These results were interpreted as evidence that irregularly inflected words are listed in the mental lexicon as full forms, whereas regularly inflected words are listed by their stems, with morphologically complex forms derived by rule. In the following, I will show that the experiments are so poorly executed that little, if anything, can be concluded from them regarding processing differences due to lexical-based irregular inflection and rule-based regular inflection.

For the participle study, Clahsen makes us believe that stem frequency was kept constant across the high and low word-form frequency conditions. In fact, however, these parameters turned out to be highly correlated. As revealed by an analysis of the stem frequency of the experimental items given by Clahsen et al. (1997; appendix IV), high- and low-frequency regular participles had mean stem frequencies of 265 and 65 per million, the mean stem frequencies of high- and low-frequency irregular participles were 272 and 31 per million, with stem frequency information based on the German lemma frequency counts of the CELEX database (Baayen et al. 1993). In the psycholinguistic literature, effects of stem frequency have been interpreted as evidence that morphologically complex words are lexically accessed either by their stems (e.g., Taft 1979) or by both stem and full-form representations (McQueen & Cutler 1998). Thus, the present confound of stem and word-form frequency makes Clahsen's interpretation of the latency difference between high- and low-frequency irregular participles quite questionable. The lack of latency differences between high- and low-frequency regular participles, on the other hand, is puzzling, because a stem-based access mechanism would predict their processing times to be affected by stem frequency. However, as is held by most experimental psychologists, null effects are always difficult to interpret.

Problems also arise with the plural study. For the *-er* plural conditions, reaction time (RT) differences may be attributed to idiosyncratic differences in the structure of the stimuli rather than to the manipulation of word-form frequency. For example, half of the low-frequency *-er* plurals were derivationally affixed, whereas the high-frequency *-er* plural condition contained only one derivationally complex word (see Clahsen et al. 1997; Appendix VI). Admittedly, experimental evidence regarding processing costs from derivational complexity is ambiguous (for a review, see Burani & Laudanna 1992), but it cannot be excluded that mean RTs in the low-frequency condition were enhanced from the high proportion of derivational complex *-er* plurals. Word length constituted a further poorly controlled factor that is well known for its effects on lexical decision times. That is, the low-frequency condition included a substantially greater number of longer words than the high-frequency condition, which might have caused an increase of mean RTs in the former condition. Thus, both factors, either alone or in combination, could have contributed to the observed pattern of results. My concerns are not based on picking out some odd experimental stimuli of a large item pool. In fact, the item pool was small (10 items per condition) so that even a few odd items could produce systematic effects rather than simply increasing error variance.

When it comes to *-s* pluralization, Clahsen and also Clahsen et al. (1997) might have simply failed to mention that in German the suffix *-s* does not only occur as a plural marker but also as the genetive singular marker for all neuter nouns, for most masculine nouns, and even for a few feminine nouns. Of vital importance, however, is that he did not even mention that almost all stimuli used in the high- and low-frequency *-s* plural conditions were ambiguous with respect to number information; that is, 19 of the 20 plural forms also had a genetive singular reading (see Clahsen et al. 1997; Appendix VI). One might legitimately argue that the *-s* plural form is much more frequent than the corresponding genitive singular form. Moreover, when presented in isolation, for native German speakers, the genitive singular reading of *-s* plural nouns seems unlikely to be the first that comes into mind, if it does at all. Nevertheless, both readings must be coded in the mental lexicon, and both are likely to receive activation during lexical access. The effects on processing times, however, are less obvious and, owing to lack of empirical evidence, open to speculation. Thus, from a linguistic viewpoint, it might be interesting to contrast regular and irregular inflections by means of German *-er* and *-s* pluralization. From a psycholinguistic point of view, however, *-s* plural nouns do not provide a suitable testing ground, at least when they have an additional singular reading, and this is true for a great deal of German *-s* plural nouns and for about all of the experimental items used in the study under consideration.

It should be noted that the number problem is also evident in the event-related potential (ERP) study on plural nouns (sect. 4.5). For example, the "regularization" of several masculine/neuter nouns taking *-(e)n* plurals did result in real German words, namely, the genitive singular forms (e.g., des *Muskels*; Table 3), whereas the "irregularization" of all nouns taking *-s* plurals did result in nonwords (e.g., **Karusellen*; Table 3). Considering that the items were presented in a sentence, one might argue that the former were interpreted as an agreement error by the processing system, whereas the latter were taken as a lexical error. It is beyond the scope of this commentary to go into further detail here. Even so, I wish to indicate that the item list presented by Weyerts et al. (1997) is subject to a number of additional critical questions about stimulus selection and about possible confounds.

In section 4.4, Clahsen presents two experiments addressing the issue of processing differences between regular/irregular participles and plurals by means of the cross-modal priming procedure. The manipulation here was the relationship between prime and target, which was either morphological, identical, or unrelated. According to the dual-mechanism account, morphologically related prime–target pairs including a regularly inflected form were expected to result in full priming (i.e., equal priming to the identical condition), whereas morphologically related prime–target pairs including an irregularly inflected form should result in

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partial priming (i.e., less priming than identical priming). As claimed by Clahsen, the pattern of results completely met these predictions.

On closer look, however, the results are by no means as orderly as Clahsen suggests. Following the assumptions of the dual-mechanism account, it should be the morphologically related condition that reflects processing differences between regular and irregular inflections. Now, consider the data presented in Figure 4. There is a large RT difference in the identical priming condition between the regular and irregular verb sets, but the corresponding morphologically related conditions as well as their control conditions yield nearly identical RTs. Thus, the reason that regular and irregular participles produced full and partial priming, respectively, is because the regular verbs resulted in less identical priming (30 msec) than the irregular verbs (53 msec). Consequently, unless Clahsen has a model of why identical priming effects change across the regular and irregular item sets, his arguments regarding full and partial priming are less convincing, if they are at all.

When it comes to the data from plural nouns (Fig. 5), there is a different problem. Here, the control condition yielded much shorter RTs in the irregular *-er* plural set than in the regular *-s* plural set (77 msec). This could be explained in terms of frequency differences between the two item sets; the targets of the *-er* plural set were more frequent than those of the *-s* plural set. If this is so, then one would expect to find a similar RT difference between the identical conditions, because the same target sets were used across conditions. In fact, however, this difference was much less pronounced (27 msec). Moreover, the RT difference between the regular and irregular morphologically related conditions was actually the least in size (15 msec). Thus, again we are left with inconsistencies in the pattern of effects for which Clahsen fails to give an adequate account. It should also be taken into consideration that in this study the nouns taking *-s* plurals might be as "number ambiguous" as those in the experiments discussed above.

Lexical processing and representation of morphologically complex words have been a central theoretical and empirical issue in word recognition research for the past 20 years. Clahsen's psycholinguistic attempt to resolve this issue for regular/irregular inflections in terms of a generative machinery as part of the language processing system of native German speakers/hearers has to be considered as defeated.

Diachronic evidence for a dual-mechanism approach to inflection

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Abstract: The received view in historical linguistics is that there is always an inverse relation between token frequency and likelihood of analogical change. I have found evidence, however, of a sharp difference in frequency effects between regularization and nonregularizing analogical change. I argue that this difference can easily be accounted for by dual-mechanism models of inflection but is very problematic for pure associative-memory models.

The advocates of both single- and dual-mechanism models of morphological processing often mention the relevance of historical evidence to the issues they are addressing (e.g., sect. 1, para. 6). Very little has been done, however, in the way of systematic analysis of diachronic developments and assessment of their implications for the controversy at hand.

In ongoing work that looks at regularizations, irregularizations, and other kinds of morphological change in German verbs, I am finding a new kind of evidence that strongly supports the sort of dual-mechanism model advocated by Clahsen and others. I have focused especially on the token-frequency effects observable for different kinds of change. The rarely questioned orthodoxy in historical linguistics is that there is always an inverse relation between token frequency and the likelihood of any kind of morphologically motivated ("analogical") change. High-frequency items supposedly resist change because of the strength of the memory traces of the established forms, whereas low-frequency items have weak memory traces and are therefore vulnerable to the analogical influence of other items and classes (Bloomfield 1933, pp. 409–10; Bybee 1985, pp. 117–23; Paul 1877, p. 329). In a number of studies, I have found empirical evidence that is problematic for this view. In Fertig (1998), for example, I discuss the fact that many ultrahigh-frequency suppletive items, such as the verb "to be" in the Germanic languages, have actually undergone a tremendous amount of analogical change. The extreme irregularity of such items cannot be attributed simply to the survival of rote-memorized forms. Instead, we must recognize that new, analogical forms are frequently being created and adopted, but these new forms are just as irregular as the old forms that they replace.

In more recent work, I have found that the standard account of the relationship between token frequency and morphological change is accurate for just one kind of change: regularization. Large numbers of verbs that were irregular in medieval German have become regular weak verbs in the modern standard. Similar developments can be observed in nonstandard dialects. The vast majority of verbs affected by this development are, as expected, low-frequency lexical items. When we look at every kind of analogical change other than regularization, however, we find that it is often high-frequency items that are most affected. This is true of the irregularization of originally regular verbs as well as shifts from one irregular class or pattern to another.

Any approach to morphology that recognizes the role of memory traces for at least some forms can account for analogical change among high-frequency items by proposing that the memory trace of an innovative form can play a role in promoting an analogical change just as the memory trace of an older form plays a role in resisting change. Spontaneous, nonregularizing analogical innovations do occur in speech. If the analogical forces favoring a particular innovation are very strong and the overall token frequency of an item is high, then it is conceivable that a spontaneous innovation will occur often enough to establish its own memory trace. Once this memory trace is established, analogical change in favor of the new form could become a positive feedback process (snowball effect), because each production of the innovative form will further strengthen its memory trace and thus increase the likelihood of future productions of the same form.

Although pure associative memory models could accommodate this kind of account of analogical change in high-frequency items just as well as dual-mechanism models, the former cannot account for the sharp difference in token-frequency effect that we observe between regularization and other types of analogical change. According to single-mechanism models, analogical attraction exerted by forms stored in associative memory is responsible for all kinds of morphological change, including regularization. We would thus expect token-frequency effects to be the same for all kinds of analogical change.

The finding that regularization affects low-frequency forms whereas nonregularizing analogical change tends to affect high-frequency forms is perfectly compatible, however, with dual-mechanism models. The diachronic counterpart to the fundamental distinction that these models draw between regular and irregular morphology is a distinction between regularization and analogy. Regularization, in a dual-mechanism model, is a matter of falling back on a default rule when no stored form in memory can be accessed. It does not involve any attractive force at all, and the resulting regularized form is not stored in memory. Analogy, by contrast, involves the attractive force of a form or cluster of forms, or in Clahsen's model a "lexical template" (sect. 3, para. 4), stored in associative memory. True analogy always results in the creation of a new irregular form, a form that is itself stored in as-

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

sociative memory. Thus, memory traces of innovative forms could play a role only in cases of true analogy, not in cases of regularization.

Clahsen points out that the vast majority of innovations in child language are regularizations and that irregularizations and other kinds of analogical innovations are quite rare (sect. 5.1, para. 1). This may seem to be at odds with the claim that nonregularizing analogical change is very common in high-frequency items, but in fact this merely points to another aspect of the fundamental distinction between regularization and analogical change as diachronic processes. Under a dual-mechanism model, we would expect regularization to be especially common in cases of incomplete or imperfect learning. True analogy, on the other hand, requires that clusters of irregulars (or lexical templates) be established in associative memory, making child language perhaps the least likely place to find this kind of innovation. This reasoning calls for a reconsideration of the view, widespread among historical linguists, that incomplete learning is the driving force in all kinds of analogical change (see, e.g., Kiparsky 1992).

The dual-route account of German: Where it is not a schema theory, it is probably wrong

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Abstract: Clahsen's experimental data from generalization, frequency, and priming fail to support and even conflict with those aspects of his dual-route account that distinguish it from schema theories.

How different is Clahsen's from other accounts? Irregular lexical entries involve templates drawn on by groups of correspondingly patterning irregulars (sect. 3); the general "rule" is a template applying to an entire syntactic category; hence proximity to schema accounts is great. Bybee (1995b), for example, posits an entirely *open schema* "*V - /ed/*" that applies freely, plus more specific schemata for various irregular groups. Köpcke's (1993) detailed analysis of the German plural system distinguishes aspects best characterized as involving rules, such as the inflection of nouns derived from other syntactic categories, and those based on more or less detailed schemata, among them the /s/ plural which is phonologically particularly free (N.B., ascribing to Köpcke the claim that schemata are driven along by type frequency, as implied in section 4.6, is a gross misrepresentation of Köpcke's work). Clahsen's proposal differs from these as follows.

1. Clahsen allows no product-oriented analogies: Analogies seem to take place between stems only; there is no generalization based on output considerations. Thus the considerable evidence for product-oriented analogies (Bybee 1995b; Hahn & Nakisa 1999; Hahn et al. 1998; Köpcke 1993) goes against Clahsen's proposal.

2. What the rules are (if there are any): The /s/ plural in German is held to be not just a particularly open schema but to apply to an equivalence class "noun."

3. The claim that the general rule is extralexical and applies where lexical access is impossible.

Salient linguistic facts about German are ignored in the target article. Lexical access is deemed *impossible* for noncanonical roots (sect. 4.2.3) forcing, via point 3 above, the use of the /s/ plural. Proper names and nominalized verb phrases (VPs) are listed in this category, but /s/ plurals are not uniformly applied here. Hahn and Nakisa (1999) present data on female first names such as "Ulrike" or "Beate," which are frequently irregularized (+/n/) in analogy to a pattern governing feminine nouns ending in schwa. Some nominalized VPs such as "Vergissmeinicht" (forget-me-not) do not receive +/s/. Deverbal nouns, in an exceptionless rule, never do. This is linguistic evidence contra points 2 and 3 above; Clahsen's experimental data fail to establish an alternate picture.

Generalization. Among the studies listed (sect. 4.2.3) is one involving acceptability ratings of German plurals for nonwords first reported by Marcus et al. (1995). As argued by Hahn and Nakisa (1999), however, these experiments contain strong evidence *against* the dual-route account. One of the manipulations contrasts acceptibility ratings for the same nonword when presented as a lexical root and when presented as a borrowing or name. While the stimuli elicited comparatively high naturalness ratings for irregular plurals in the root condition, only the regular should be acceptable in the name condition. Names are not lexical roots, so they cannot access the lexicon, ruling out lexically based generalization and forcing use of the default rule. The data, however, do not support this. Although there is a significant increase in the regular ratings where words are presented as names, not roots, the ratings by no means have the clear-cut nature the account requires: The mean ratings for irregular forms vs. regulars are 4.3 versus 4.6 in the root condition and 2.9 versus 4.2 for names; this is a far cry from the predicted 1 (unnatural) versus 5 (perfectly natural) for the latter and contradicts the claim that lexical access is *impossible* in such conditions.

Even more problematic is the fact that Hahn and Nakisa (1999) show that these data contain statistically significant *differences* in the mean regular ratings depending on whether an item is presented as a surname or a different kind of name (such as the name of a book). This is incompatible with an affixation process that operates uniformly over a syntactic category "noun" and thus provides direct evidence against the account.

Frequency effects. Frequency effects in on-line tasks seem a poor test; word-form frequency effects for regulars seem perfectly compatible with rule application: Why should the speed at which the rule is accessed from the stem, for example, or the speed with which the actual phonological form is assembled *not* be subject to practice effects? Conversely, given that frequency effects tend to be small, a failure to find such effects can plausibly arise from sampling error, let alone the confluence of other variables known to affect lexical processing, such as age of acquisition or neighborhood density. In the reported studies, the lack of frequency effect for regulars is attributed to the fact that the appropriate inflected word forms are not stored as such, so their frequency cannot give rise to priming effects. However, in Clahsen's structured model of the lexicon *irregular* word forms are generally not universally stored as such either. They are "contained" in a subnode using underspecification, which gives rise to *lexical templates* that are shared by correspondingly patterning words (sect. 3); this proposal is deemed psycholinguistically relevant via the correspondence hypothesis. Given the considerable patterns among the stimuli used, template (type) frequency is expected, but not word-form frequency. The only explanation compatible with Clahsen's account is that these frequency effects arise from associated processing (e.g., access to subnode, output assembly) – a locus that seems equally available to regulars. Thus the results either conflict with Clahsen's model or are not directly indicative of lexical structure at all.

Priming. These studies are motivated by the fatal confounding factor in previous studies with English: Differential priming for regulars and irregulars might simply stem from differences in the amount of phonological similarity between inflected forms and stems in both categories. The German studies fail to overcome this difficulty. Both for participles and for plurals, the "irregular" primes have an *additional syllable* relative to their targets, whereas the "regular" primes and targets have the same syllabic structure. This gross difference in phonological similarity alone would predict, all other things equal, the observed pattern of results. The only necessary assumption is that priming in this study is mediated – somewhere along the way – by phonology. This assumption is plausible and compatible with the cross-modal nature of the task chosen to ensure that "any priming effects are attributable to lexical representations themselves" given that *some* representation of phonological form is part of anyone's account of the lexicon.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

In summary, examining the German plural system reveals that there is no support for those claims (points 2 and 3 above) that specifically distinguish Clahsen's account from schema theories. The latter theories, particularly Köpcke's, also have in their favor their in-depth analyses of plural morphology, which encompass both diachronic and synchronic, semantic and phonological considerations. German might have been the ideal test case for the dual-route account, but the results do not support it.

Some problems with the lexical status of nondefault inflection

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Abstract: Clahsen's characterization of nondefault inflection as based exclusively on lexical entries does not capture the full range of empirical data on German inflection. In the verb system differential effects of lexical frequency seem to be input-related rather than affecting morphological production. In the noun system, the generalization properties of *-n* and *-e* plurals exceed mere analogy-based productivity.

Clahsen presents an impressive series of studies showing processing differences between irregular and regular inflection in German. Whereas for the German noun system the distinction between regular and irregular plural allomorphs is somewhat problematic and is discussed below, this distinction is quite straightforward for the German verbal system, comprising strong and weak verbs similar to English. Clahsen reports data on lexical decision times showing a verb frequency-by-regularity interaction, with irregular verbs being faster for high-frequency forms (sect. 4.3). In the context of a positron emission tomography (PET) study on the inflection of German verbs (Indefrey et al. 1997) we obtained voice onset time data on the production of regular and irregular past tense and participle forms. Twelve subjects were visually presented with infinitive forms, which they inserted in neutral sentence frames requiring either past tense or participle verb forms (*Er kochte/las etwas,* "He cooked/read something"; *Er hat etwas gekocht/gelesen,"* He has cooked/read something"). The reaction time (RT) data (mean RTs [msecs]: high [frequency] regulars 564, low regulars 582, high irregulars 607, low irregulars 631) showed a strong main effect of regularity (ANOVA, F 27.96, p .000) and a marginal main effect of the spoken verb form frequency (F 3.97, p .072) but no interaction (F .02, p .895). This means that, in contrast to Clahsen's input-related data, a distinction in lexically based and rule-like processes is not supported for the production of regular and irregular verb forms.

For the German noun system, Clahsen considers the *-s* plural to be the only regular one among the five German plural allomorphs (sect. 3, para. 5; sect. 4.7, para. 1). Consequently, he interprets generalizations of *-n* and *-e* plurals to novel nouns as similarity-based both in his own data and in his discussion of the Goebel and Indefrey (1998) associative model of German plural inflection (sect. 4.6, para. 5). In contrast to Clahsen's view, we assume that both *-n* and *-e* plurals have to be considered as regular and productive allomorphs with gender-dependent application domains ($N_{+fem} > N - (e)n_{+fem,+pl}$ and $N_{-fem} > Ne_{-fem,+pl}$). Note that a constrained application domain is not at variance with Clahsen's initial definition of "regular" as involving combinatorial operations on abstract symbolic categories (sect. 1, para. 1). However, in his description of the noun system he tacitly replaces the notion of "regular" with "regular default," by adding the condition that the application domain must be unconstrained (thereby also rendering "irregular" other regular processes of the German noun system, such as the weak case inflection of masculine nouns ending in schwa). Linguistic evidence that *-n* and *-e* plurals, in contrast to *-r* plurals and umlaut, are not based on lexical entries comes from the observation that *-n* and *-e* plurals are applied in default circumstances whenever the usual *-s* plural is blocked for phonological reasons [stem-final (s)]. Examples in case (see sect. 3, para. 5) are eponyms and product names (*Oedipusse,* "copies of *Oedipus*"; *Mercedesse,* "Mercedes cars"), derivations from a different category (*die Etwasse,* "the Somethings"), borrowings from other languages (*Bosse,* "bosses"; *Boxen,* "loudspeakers"), truncations (*Foxe,* "fox terriers, foxtrots,") letters (*"X"e*), and acronyms (*die MAZen, Magnetaufzeichnungen,* "magnetic recordings"). According to Clahsen's own view, inflection in these cases requires processes operating on the category *N* rather than depending on lexical entries.

Discussing the experiments of Köpcke (1988; sect. 4.6, para. 6) and Marcus et al. (1995; sect. 4.2.1, para. 5 and 6), Clahsen characterizes all generalizations of non-*s* plurals to novel nouns as similarity-based (see also sect. 4.7, Table 4). This is oversimplified and does not capture important differences. In Köpcke's elicitation experiment (as well as in our simulation) *-r* plurals were applied to a much smaller extent than predicted by existing patterns. That is, *-n* and *-e* plural allomorphs were applied where phonological similarity would have predicted *-r* plurals. More importantly, subjects rated dissimilar (nonrhyming) novel nouns at least as well as *-s* plurals in the Marcus et al. (1995) experiment. These findings indicate that *-n* and *-e* plurals are generalized independent of phonological similarity. The fact that such generalizations take into account the gender feature of the novel nouns is just what is predicted by the domain specification of the *-n* and *-e* plural rules (see above) and not plausibly captured by the term "similarity."

If *-n* and *-e* plurals are regular and can be applied in default circumstances, why are they rated as bad for surnames (sect. 4.2.1, para. 6)? It is because surnames are not a default category in German. In contrast to the default cases listed above, *-n* and *-e* plurals may not apply to surnames when the *-s* plural is blocked. Instead, they receive a particular affix, *-ens*, or remain invariant (*Heute abend kommen die* *Strauße/Straußens, Strauß' *zu Besuch*, "Tonight the Straußes will come for a visit"). Given that surnames, therefore, have to be learned as a particular domain, their *-s* plural (*die Müllers*) is probably domain-specific, too, and just happens to be identical to the default *-s* plural. German is not unique in its specific treatment of surnames. French, too, deviates from English, in that surnames do not receive the default *-s* plural (surfacing as *liaison facultative* in spoken language, e.g., *les blablablas assommants [blablabla(z)asomã] des politiciens,* "the boring blahblahs of politicians") but invariant plural (*les Chirac,* "the Chiracs"). This suggests that default circumstances are language-specific rather than universal, posing a serious learnability problem for a minority default rule. A child having isolated a plural affix for one default case (e.g., Christian names) cannot possibly know whether it can be generalized to others (e.g., surnames). Clahsen does not explain how in this situation an increase in the child's lexicon leads to the acquisition of a minority default rule.

The place of analogy in Minimalist Morphology and the irregularity of regular forms

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Abstract: Analogy plays an important role in the production of irregular forms but the proposed Minimalist Morphology (MM) representations do not express this. Recent results also show that the regular forms of strong paradigms can have idiosyncratic properties that cannot be accounted for by MM. Methodological problems with an experiment are discussed and a plea for a processing explanation is made.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

The experiments Clahsen reports clearly indicate that the production of German verbs and plural forms can best be accounted for by a dual mechanism, and not by connectionist models. Nonetheless, analogy still plays a distinct role in explaining some of the results. Instead of sharpening the contrast between the two types of models, we should strive to give this analogy a place in the dual-mechanism approach.

In the first experiment (sect. 4.2.1) it was observed that 91% of the correctly produced newly formed irregulars rhymed with existing irregulars, and, from this and other experiments, Clahsen claims that generalization of irregular participle formation can be done only by analogy (sect. 4.7). The formalism he chooses to express irregularity, however, leaves no room for such analogy, and no mechanism for the generalization of irregular participles is given.

Analogy also plays a role in the subregularity structure that the irregular forms of German exhibit: Similarly to the case in English, there is a limited number of ablaut patterns that describe the vowel changes between present, past, and participle. Although there is no strict regularity in these patterns, there is certainly more than coincidental resemblance between the classes (see also Hare & Elman 1995). The Minimalist Morphology trees (sect. 3) cannot account for such family resemblances, because each vowel alternation pattern is expressed as an independent subnode. These subnodes can be shared between verbs, but there is no way to express or exploit resemblance between subnodes. Wunderlich (1996) states that, within a given language, a limited number of *generalized* templates characterizes all irregularity trees, but his suggestion comprises a generalization about the form of the tree for German irregular verbs, not about the vowels that appear in it.

A similar problem arises with the so-called double marking verbs, like *denken – dachte* (to think). These undergo both a vowel change and regular affixation. This particular verb can be captured by a subnode containing $[\ldots \text{A} \ldots \text{TE}]_{+\text{pret}}$, but there is no rule or process relating the final *TE* part of this representation to the regular *-te* suffix. Clahsen stresses the dichotomy between rule application and retrieval of stored forms, but these forms are analyzed most satisfactorily as the result of a rule applying to a retrieved irregular stem, *dach*.

The top node of the MM tree represents the regular form. Irregularity is introduced by adding subnodes, not by modifying the top node itself (Wunderlich 1996, p. 95), which implies that the present tense of strong verbs must be fully regular. This appears to be the case for English, Dutch, and German. In a recent experiment, however, I have found evidence that the present tense form of strong verbs has idiosyncratic properties (Janssen 1999). Several production experiments gave evidence for an inflectional frame that aids the construction of a fully inflected form. The frame contains one slot for each type of inflectional suffix that occurs with a stem, plus a slot for the stem itself. Regular Dutch verbs were shown to require a three-slot frame, for stem, tense, and number.[1]

Strong past tense forms (*zwom,* "swam") never bear the regular tense affixes, and the results indicate that they require irregular two-slot frames (stem and number). In Clahsen's representation, this inflectional frame can be specified at the subnode for *zwom.* Crucially, evidence was found for a two-slot frame accompanying the *present* tense forms of strong verbs (*zwem,* "swim"). This present tense is formed regularly, but the language production system optimizes for the fact that no regular tense affix occurs with this form, owing to zero-marking in the present tense and irregular formation of the past tense. The systematic absence of a tense suffix has made its slot redundant. A specification of the two-slot frame is needed at the top node, but this is not allowed by Minimalist Morphology.

Although the range of experiments presented in the target article is impressive, not all experiments are fully convincing when considered alone. With respect to the methodology, not all possible counterarguments have been properly addressed. The second experiment (sect. 4.2.2), for example, uses a nonword-learning task, but the subjects were apparently not very successful in learning newly formed irregular verbs. In the original report of this experiment (Clahsen et al. 1997), it was mentioned that only 22 of 40 subjects succeeded in mastering the 20 new verbs. The remaining subjects were not included in the experiment proper, but no explanation for this high mortality rate is given. It is not reported whether these rejected subjects regularized the verbs, wrongly applied other paradigms, or made up completely new irregular patterns.

A general methodological problem is whether the remaining subjects did indeed acquire a strong past representation or memorized paired associates. The strong participle ending *-n* induces a marked delay for novel weak verbs, and not so for novel strong ones (see Fig. 2 of the target article). This confirms that the latter verbs were indeed strong. However, the strong verbs were easier to recognize when suffixed with regular *-t* than with the correct *-n.* Clahsen claims that this is evidence for the rule-like nature of the regular suffix, but, if anything, this indicates that the novel strong verbs did not exhibit the expected irregular behavior of not allowing regular suffixation.

Finally, there clearly is a need for a processing perspective on the production of German inflections. How are the proposed tree representations put to use? In what order are the trees traversed? There are several possible experiments that can be used to obtain direct evidence for trees. One would expect forms that are specified farther down the tree to be harder to construct, or more prone to errors. If several verbs share the same underspecified subnodes, as is suggested, this implies that a language change or individual impairment would affect the group of verbs in precisely the same way. The answers to these and similar questions can help us formulate a more specific theory of the production and comprehension of inflected forms.

ACKNOWLEDGMENT

I thank Kerstin Mauth for valuable discussion and comments on an earlier version of this commentary.

NOTE

1. Actually, this last slot contains cumulative morphs for person and number.

The dual-mechanism model of inflectional morphology: A connectionist critique

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Abstract: Clahsen has added to the body of evidence that, on average, regular and irregular inflected words behave differently. However, the dual-mechanism account he supports predicts a crisp distinction; the empirical data instead suggest a fuzzy one, more in line with single-mechanism connectionist models.

Clahsen's work on German is an important contribution to the field, but we believe that his conclusions regarding the superiority of the dual-mechanism model are premature. Several lines of research pursued by Clahsen are subject to alternative interpretations.

Frequency by regularity interactions. Proponents of dual-mechanism approaches have made the claim, repeated in the target article (sect. 4.3), that processing of irregular but not regular inflected forms is affected by their frequency, supporting the dual-mechanism model. There are two flaws in this argument. First, there are several studies reporting frequency effects for at least some regulars (Alegre & Gordon 1999; Baayen et al. 1997b; Stemberger & MacWhinney 1986; also unpublished data from our laboratory). Second, it is questionable whether this kind of data can

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

distinguish between the theories. Single-mechanism connectionist models can produce frequency-by-regularity interactions, including cases in which there is no effect of frequency for regulars (e.g., Seidenberg & McClelland 1989). A more interesting case would be the so-called low-frequency default (e.g., the *-s* plural in German), but Clahsen does not present relevant data from this domain.

Intermediate cases. Regulars and irregulars frequently fail to show the sharp distinction predicted by the dual-mechanism account. For example, several languages have inflected items that are "mixed" in nature; one such case is items that take the regular suffix but also involve a stem change. This occurs in English verbs (*feel – felt*) and English nouns (*wolf –wolves*). It also occurs in the German simple past and past participle, though Clahsen relegates this to the appendices (e.g., infinitive *kennen,* simple past *kannte,* past participle *gekannt*; the regularized versions would be *kennen, kennte, gekennt*).

These cases suggest that regularity is in fact a continuum. There is some evidence to support this claim. Marslen-Wilson et al. (1993) found in a cross-modal priming experiment that English mixed verbs produced a degree of priming intermediate to that of regulars and other classes of irregulars. Clahsen mentions the finding (sect. 4.4) but is unable to explain it within his framework. We have collected evidence for similar cases in the acceptability of plurals inside compounds.

Plurals inside compounds. In the target article (sect. 5.2), Clahsen suggests that regular plurals cannot occur inside compounds in English (*rats-eater*), whereas singulars and irregulars can (e.g., *rat-, mouse-, mice-eater*). Clahsen's discussion of this issue is somewhat misleading. Regular plurals do appear inside some compounds in English (e.g., *weapons inspector, awards ceremony*; see Alegre & Gordon 1996a; 1996b, for discussion). In addition, in our laboratory we have found that irregular plurals (*mice-eater*) are actually less acceptable inside compounds than singular forms (*mouse-eater, rat-eater*).

Clahsen also claims that the regular plural is not acceptable inside compounds in German. He presents no evidence for this claim in the adult case. In the case of children, he discusses two elicited production studies in which children produced regular forms inside compounds approximately 10% of the time. This is much higher than the rate found by Gordon (1985) for English, in which some regular plurals clearly are acceptable inside compounds. Thus there is little support in either English or German for a sharp regular/irregular distinction in this case.

Event-related potentials (ERP) data. In section 4.5, Clahsen discusses two ERP studies of German morphology (Penke et al. 1997; Weyerts et al. 1997) that reported different neural responses when subjects were presented with anomalous irregulars (analogous to *dog – doggen*) compared to anomalous regulars (analogous to *foot – foots*). It is suggested that different localizations of negativity in the two conditions mean that different areas of the brain are specialized for regular and irregular morphology.

Unfortunately the two studies are not consistent with each other. In Weyerts et al. (1997), anomalous irregulars elicited negativity in posterior frontal regions (Cz) at 400 msec; the Penke et al. (1997) study, of the same condition, showed negativity in the anterior temporal region (F7) at 200 msec. In addition, the Weyerts et al. anomalous regular stimuli elicited ERP effects, whereas the same condition in Penke et al. did not. Furthermore, while the F7 area might correspond to Broca's area, where morphological rules are claimed to reside (Ullman et al. 1997b), area Cz is not located near any neural areas claimed to be associated with storing irregular forms (e.g., Wernicke's area; see Ullman et al. 1997b).

Finally, while the ERP methodology has been used extensively to study the detection of syntactic and semantic anomalies (see, e.g., Kutas & Kluender 1994; Neville et al. 1991), it is unclear how reading incorrectly inflected German words relates to either of these tasks. Clahsen notes that the pattern observed for the anomalous irregulars by Weyerts et al. is similar to the N400 effect previously observed for pronounceable nonwords, but this is of little import, insofar as Penke et al. noted a negativity with a different location and time course.

One or two mechanisms? Clahsen mentions two recent studies of English speakers that are interpreted as supporting separate neural mechanisms for regulars and irregulars (sect. 4.5). Jaeger et al. (1996) used positron emission tomography (PET) with normal English-speaking adults while they produced regular, irregular, and nonsense past tenses. They found that some brain regions were more activated for regular and nonwords than for irregular past tenses, whereas others showed the opposite effect. Similarly, Ullman et al. (1997a) report a functional magnetic resonance imaging (fMRI) study finding different patterns of regional cerebral blood flow when subjects processed regular and irregular past tenses.

These studies have serious problems related to methodology and interpretation of results (Seidenberg & Hoeffner 1998). That aside, findings that speakers process regular and irregular patterns differently are not incompatible with single-mechanism connectionist accounts, in spite of claims to the contrary (Marslen-Wilson & Tyler 1997; Pinker 1997). Several connectionist models have exhibited selective impairments to one type or the other, by means of different types of artificial "lesions" (Harm & Seidenberg, in press; Joanisse & Seidenberg 1999; Plaut et al. 1996). This occurs because regular and irregular patterns rely on different types of knowledge to different degrees. Irregular inflections are only poorly predicted by phonology but are perfectly predicted by meaning; thus irregulars depend more on semantics. In contrast, regular inflections are dependent on generalizations drawn across large groups of items with unrelated meanings; thus they rely more on phonological processes. Therefore, it is not surprising that damage to phonological and semantic knowledge had its strongest effects on regulars and irregulars, respectively, both in aphasics (Ullman et al. 1997b) and in connectionist models (Joanisse & Seidenberg 1999).

Conclusions. It is admirable that Clahsen and others have extended the English-centered literature on inflectional morphology to other languages. However, neither the English nor the German data makes a compelling case for the dual-mechanism account.

ACKNOWLEDGMENT

We thank Mark Seidenberg for significant contributions to the preparation of this commentary.

Syntax, or, the embryogenesis of meaning

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Abstract: Syntax is better viewed as the dynamics of a morphogenetic field on a semantic universe of "content" words. This may take widely different forms, making the acquisition of any language by an aspiring speaker an entirely new experience. The existence of an underlying "universal syntax" might be illusory.

As is often noted by historians of science, it is the one remaining anomaly that signals the fault in the dominant interpretation system (Kuhn's "paradigm") and will ultimately lead to its downfall. In the current instance, the anomaly is the one mentioned by Clahsen (sect. 5.1.1, para. 1): "There is an early stage prior to the occurrence of *-t* errors [i.e., *overregularization*] at which all participle forms used by the child are correct."

What does this mean? It means that before German-speaking children derive past participles through an inflection rule acting on a root – leading to a non-negligible number of errors – they generate them as individually stored instances, and do so correctly

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

with little or no error. The plausible developmental stages are therefore:

1. Individual participles are stored separately as single lexemes. Their retrieval is unproblematic. The cost of storage, however, is high: There is a single memory trace per lexeme. In software terms one would say that at this stage each separate lexeme is generated "at compilation time."

2. The root has now been abstracted and the various forms of the verb are inflected from the root. Each past participle is from now on generated "at run time" through a two-step process: (a) evocation of the root form, (b) inflexion of the root (most often in Indo-European languages through the addition of a suffix).

Because in this latter developmental stage general principles of inflexion are used, errors branded as *overregularization* are likely to occur. "Overregularization" is the applying of a dominant principle to every type of occurrence, including the minority cases where the application is incorrect. Overregularization betrays the inherent weakness of what has become a two-step process: the generation of individual lexemes through inflexion of root forms "at run time." Overregularization is the price to pay for the radical economy in storage that such a two-step process allows. By now, as far as storage is concerned, there is only one instance to memorize per root form, plus one instance of each of the possible types of inflexion from this root.

The process at work in passing from the early stage (with correct performance) to the later one (susceptible to overregularization) is that of an increased complexity in the syntactic principles. Clearly, the eruption of an additional principle signifies at the same time a dramatic economy in terms of memory storage, which, if storage room is at all an issue in the brain, allows for many more instances to be memorized.

An article by Yosef Grodzinsky (2000) offers numerous examples of such enhanced complexity at work. Briefly, Grodzinsky's paper establishes that speech impairments resulting from lesions in Broca's area do not affect any syntactic cross-linguistic ability but only the linguistic complexity that a typical speaker can achieve, this being reflected – according to tongue – in different domains of what would constitute a hypothetical "universal syntax." Thus, typically in English, Broca's aphasia corresponds to a lost capacity for introducing a second semantic focus in the clause – most often introduced by a transition with "whom" or "whose" – whereas in Dutch it is the capacity to inflect the verb – typically located at the very end of the sentence – that is impaired.

The conclusion is inescapable: Syntax operates on a universe of *categoremes* (the so-called content words) like a morphogenetic field, in a process reminiscent of embryogenesis, where initially undifferentiated cells evolve in stages toward highly specialized organs. Similarly, syntactic principles organize *categoremes* into layers of unfolding complexity, the *syncategoremes* (the so-called framework words) acting as the equivalent of a conjunctive tissue. Thus emerge different end structures of syntax for each family of natural languages. In *Principes des systèmes intelligents* (Jorion 1990), I spoke of linguistic performance as amounting to a *coating* process in which language acquisition equates with acquiring familiarity with an increasingly large number of such "coatings": the coating of *highlighters* ("a movie that's *real* good"), the coating of *continuity markers* (". . . *meanwhile,* back in the forest"), the coating of *adhesion* ("*It is a fact that* the Earth is flat"), and so on.

In his recent *The minimalist program,* Chomsky (1995) reformulates what has been for him a recurrent theme: that, as the universality of language clearly resides elsewhere than in the lexicon, it must, of necessity, reside in the syntax. However, the whole argument may conjure up a chimera: Starting from an indisputable observation that any speaker is able to learn additional languages, it is assumed that there is a common ground to both the known and the newly acquired ones, this common ground constituting the so-called universals of language. But what if the unity of language was largely fictitious? What if it had no more-assured unity than, say, "sport"? There is nothing much to be concluded from the fact that one can learn to play basketball while already being an expert rollerskater: The newly acquired skill is for its major part unrelated to the one previously known. The "universals" of sport amount to little more than that one uses one's muscles in every sport. What if the "universals" of language were of such an elusive nature?

Any speaker raised in a bilingual environment knows introspectively how little the two known tongues feel like having anything in common: to the bilingual child it is an unproblematic task to switch in a moment from one known language to the other; translating from one into the other, however, remains a demanding and often unsuccessful exercise. The developmental truth, of course, is that a human being is perfectly able to learn one particular tongue while not knowing *any* one beforehand. The acquisition of a new language probably forces us to go through a similar process in which increased familiarity with the syntax is nothing more than an acquired ease with higher levels of complexity, each creating original forms upon the foundations of the earlier ones, the whole construct being idiosyncratic to each individual tongue.

Regular versus irregular inflection: A question of levels

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Abstract: When referring to the organization of the mental lexicon, the distinction between combinatorial rules and lexical listing for regularly versus irregularly inflected words should be further developed to account for subregular morphological processes. Moreover, the distinction may be more or less appropriate depending on the lexical component under consideration, and it is subject to interplay with other factors that are relevant in determining the representational structure of the lexical system.

The main point made throughout Clahsen's target article is the distinction between a representation of inflection based on combinatorial rules (for regularly inflected words) and a representation of lexically based inflection (for irregularly inflected words). I would argue that, in the proposed version, such a distinction, when referring to the organization of the mental lexicon, has the following characteristics: (1) it represents only one particular version of a two-route approach; (2) it might be appropriate for some levels or components of the lexical system, but, in the proposed form, it might be too dichotomously stated for other levels; (3) it is still not detailed enough to capture the range of subregular inflectional phenomena that in some languages is very pervasive; and (4) it must be enriched with the analysis of the parameters that determine whether a word is decomposed into its constituents or is represented as a whole form in all those cases corresponding neither to a completely regular inflected form nor to a clearly irregular and idiosyncratic form.

(1) In Clahsen's paper, the nondistributed, compositional account for the regular inflection in mental lexicon seems to be identified with a "rule-governed" approach. However, the possible appeal to rules is just an option of the compositional approach. In other words, it is likely that many proponents of the compositional approach to the mental lexicon do not acknowledge themselves as particularly committed to a rule-based framework. In many cases, for a given type of inflected words, they simply postulate types of representations (and processes that manipulate those representations) whose format is different from the representational format assumed for the other class of inflected words that undergoes the concurrent, noncompositional treatment.

(2) Which levels of lexical representation and processing are concerned in the distinction between the two categories of inflections? As far as input and output lexicons are concerned, we may still keep a rigid distinction between the (decomposed) represen-

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

tation of regularly inflected words and the (undecomposed) representation of irregularly inflected words. However, if we consider the units that allow for access to the lexicon, we could have good reasons for assuming that, according to factors such as frequency, the decomposed lexical representations for regularly inflected words can be accessed by both the decomposed and the whole-word access units (Caramazza et al. 1988).

(3) How is the proposed distinction able to account for processing and representation of minor lexical patterns, which in some languages derive from the presence of clusters of words sharing the same morphophonological features? I will take one example from Italian. Italian verbs are subdivided into three different conjugations, such that each stem–suffix combination can be licensed only if both morphemes are marked for the same conjugation type. Italian is also characterized by the presence of classes of partially irregular verbs, mainly in the second conjugation. In most cases these verbs display a major regular stem and a minor irregular stem. These latter stems diverge from major stems in a way that is, both phonologically and orthographically, predictable. Even when unpredictable, however, these stems may combine only with a closed class of predictable suffixes. More specifically, the occurrence of a given suffix is completely predictable for each inflected form, given the selection of the minor stem. In Experiment 3 of Caramazza et al. (1988), we found that, in a visual lexical decision task, participants' performance on morphological pseudowords containing minor stems shows effects that are compatible with the view that those stems are represented in a morphologically decomposed format at the lexical level. More precisely, we assumed that, in contrast to unpredictable irregular inflectional forms, which are fully listed in the lexicon, predictable irregular forms are represented – like regular forms – in a morphologically decomposed format. Both regular and irregular stems are separately represented, each associated with separate sets of combinable suffixes. Beyond the details of this specific hypothesis, however, it is not clear how a rigid distinction between combinatorial rules for inflectional regularity and lexical listing for inflectional irregularity would be able to capture such specific subregular morphological processes of inflectional affixation.

(4) The last point turns us to the problem of which parameters, from a processing perspective, determine whether an inflected form is "regular" or "irregular" and, hence, whether it is represented as a whole word or decomposed into its morphemic constituents. One of the main parameters is productivity. This parameter was implicit in the brief discussion of the previous point, at least in the following weak sense: that each legal morpheme combination of a language should be recoverable from the information stored in the lexicon. A further parameter is frequency: The role of frequency factors in determining the probability for a word to be accessed through its morphemic constituents has to be articulated at many levels. Frequency of the included morphemes, as well as the balance between morpheme frequencies and whole-word frequency (i.e., the frequency of that specific root–affix combination) should be relevant for processing. Low-frequency morphologically complex words that include high-frequency constituent morphemes should be the best candidates to be accessed through morphological decomposition. Generally speaking, it is very likely that a complex interaction among many parameters determines the organization of the mental lexicon in different classes or types of representations (Bybee 1995a; Laudanna & Burani 1995).

Atomic lexical entries

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Abstract: Not only do grammars have the dual structure that Clahsen discusses but the lexicon contains atomic, unanalyzed items, which would be still more mysterious for single-mechanism models. Forms of *be* in modern English are listed atomically and this is not a simple function of their morphological richness or of the fact that they move.

Clahsen argues for the dual nature of the language faculty, comparing it to "connectionist" attempts to develop an "associative single-mechanism model of language." It is important to recognize that there is nothing inherent in connectionism that requires invoking "a single type of mental mechanism" (Lightfoot 1998), and, in fact, when one examines "connectionist" models, one finds that they invoke a range of highly specific mechanisms (Marcus 1998; in press). Moreover, the language faculty has a richer structure than the dual nature that Clahsen discusses. The lexicon itself is bifurcated and contains items that do not have the derivational structure that Clahsen postulates, and the problems for a single-mechanism model are more severe. Normal verbs are as Clahsen proposes, but the forms of *be* in modern English are listed atomically in the lexicon, with no internal structure to be accessed by grammatical operations.

Consider verb phrase (VP) ellipsis, which is often insensitive to morphology. One finds ellipses where the understood form of the missing verb differs from the form of the antecedent (1).

1. a. Kim went home on Wednesday, and Jim will [sc. go home] on Friday.
   b. Kim went home on Wednesday, as she often has [sc. gone home] in the past.
   c. Although Kim went to the store, Jim didn't [sc. go to the store].

There is a kind of sloppy identity at work here. One way of thinking of this is that, in 1a, *went* is analyzed as [*past* + $_{V}$go] and the understood verb of the second conjunct accesses the verb *go,* ignoring the tense element. This is exactly the kind of internal structure that Clahsen postulates, and most verbs work this way in ellipses, even irregular verbs. However, Anthony Warner (1995) noticed that *be* works differently. *Be* may occur in elliptical constructions, but only under conditions of strict identity with the antecedent (2). In 2a and b, the understood form is identical to the antecedent, but not in the nonoccurring 2c, d, and e.

2. a. Kim will be here, and Jim will [sc. be here] too.
   b. Kim has been here, and Jim has [sc. been here] too.
   c. *Kim was here on Wednesday, as she often has [sc. been here] in the past.
   d. *Although Kim was well-behaved today, Jim probably won't [sc. be well-behaved] tomorrow.
   e. *Kim was here yesterday, and Jim has [sc. been here] today.

This suggests that *was* is not analyzed as [*past* + $_{V}$be] analogously to *went,* and forms of *be* may be ellipsed only where they are strictly identical to the antecedent.

In addition, particular forms of *be* have idiosyncratic subcategorization restrictions, unlike other verbs. Only finite forms may be followed by *to* + infinitive (3); only *been* may occur with a directional preposition phrase (4); and *being* (but not *been, was,* etc.) is subcategorized as not permitting an *-ing* complement (5).

3. a. Kim was to go to Paris.
   b. *Kim will be to go to Paris.
4. a. Kim has been to Paris.
   b. *Kim was to Paris.
5. a. I regretted Kim reading that chapter.
   b. I regretted that Kim was reading that chapter.
   c. *I regretted Kim being reading that chapter.

So *was, been,* and so on are listed individually in the lexicon, have no internal structure, and have their own subcategorization restrictions.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

This, in turn, raises interesting issues for minimalist analyses. Chomsky (1995) adopted a strict lexicalist view: Verbs, all verbs, are taken from the lexicon fully inflected. Inflected forms have an internal structure resulting from lexical operations; they are drawn from the lexicon and then have to be *checked* against the relevant features of abstract functional heads. For example, *loves* has a third person singular feature, which is checked in an inflection (I) position; so *loves* must move to the I position. For Chomsky, the checking may take place in the overt syntax (in French) or covertly at logical form, or LF (in English).

However, there are problems with this approach, and Lasnik (1998) used Warner's observations about *be* to motivate his "hybrid minimalism": The inflection position may contain an affix or features. Features must be checked in the syntax, whereas an affix must "merge" with a verb at phonological form (PF). Under this view, a verb with features raises overtly to an I position with features, and the verb's features are checked there. A bare verb with no features, on the other hand, has an affix lowered on to it from an adjacent position at PF.

For Lasnik, *be* and *have* are fully formed in the lexicon, but verbs in English are bare, acquiring affixes at PF. *Is* is stored in the mental lexicon in just that form, but *went* is not stored as such; it is created in the course of a derivation. If all verbs were treated the same way, as in Chomsky (1995), there would be no obvious way to make the distinction between those that may be antecedents for ellipsis under conditions of sloppy identity (*go,* etc.) and those that may not (*is, are,* and other forms of *be*).

Lasnik keyed the distinction between affixal and featural verbs to whether the verb moves, but this cannot be right. Modal elements are featural and are generated in I, not moving there. Finite *be* clearly moves to I, because *be* may also occur in other, nonfinite positions if I is filled with a modal (6).

6. Kim might still be reading that chapter.

So forms of *be* and *have* move to I; they are and always have been featural. They have always moved to I at all stages of their history, but it was only in the late eighteenth century that they came to be stored atomically and developed the odd properties discussed here. Jane Austen and writers before her used forms equivalent to the starred sentences of 2–5 (Lightfoot 1999; Ch. 7).[1]

We conclude that, if a verb is featural, it moves to I. However, a featural item may be base generated in I (modern modals) and may or may not be stored atomically: *Was* is stored atomically in modern grammars but was not stored atomically in grammars of the early modern period. Whether an item is stored atomically has syntactic consequences and is an independent property, not a function of rich inflection (contra Roberts 1993; Rohrbacher 1994) or of movement to an inflection position (contra Lasnik 1998). Distinctions of this type illuminate the shape of the language faculty, except for those who insist in advance of inquiry that there must be only one type of operation.

NOTE

1. In Lightfoot (1999) I explain this change in terms of the prior loss of V-to-I movement and the resulting ambiguity about the category membership of *be.*

Hungarian cross-modal priming and treatment of nonsense words supports the dual-process hypothesis

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Abstract: Hungarian data provide support for differences in processing regular and irregular morphologies. Stronger priming was observed with "regular" stem types compared to "irregular" ones. Use of nonwords showed a reliance on the grammatical structure of the nonword: Analogical extension of "irregulars" can be observed only in "root" contexts; in other contexts all types were largely overregularized.

The basic purpose of our commentary is to show that data on languages that are radically different from English and German typologically are interesting and relevant to the rule debates. Without going into the intricacies of the theoretical debates, we present some new data on morphological processing in Hungarian. Hungarian has been a language of interest to studies on the psychological reality of morphological rules since the rule-centered classical age of psycholinguistics. MacWhinney (1978), using a Berko-type task (Berko 1958), showed a clear differentiation between productive rules such as vowel insertion and lengthening, contrasted with nonproductive stem types such as shortening or epenthesis. Lengthening was the earliest rule to emerge, around 2.5 years of age, evidenced by high performance both on real words such as *óra* and on rhyming nonce words such as *póra* (79% in both). Shortening on the other hand [*kenyér-kenyeret, "bread-bread(acc)"*] showed a 79% correct performance only in 7-year-olds, with 42% analogy in nonce words (*kepér-keperet*). New data were obtained by Pléh et al. (1994) in children between 3 and 8 years of age, using different stem types with plural and accusative nominal markers. Whereas in regular, productive types correct performance was already over 90% in 4-year-olds, shortening stems achieved 90% only in 8-year-olds, and performance on v-insertion (a closed stem class with only seven nominal items) was as low as 30% in 7-year-olds.

Although these data are relevant to the rules versus associations debate, the studies were carried out well before the advent of the dispute. Some of our new studies were specifically designed, however, to address this issue. Ágnes Lukács (1999) in her MA thesis tried to apply methods used with English and German materials by Clahsen to study Hungarian morphology. Our starting point is the fact that, whereas suffixes in Hungarian are basically identical over the entire grammatical class they apply to – for example, the accusative is always a final *-t* – the way the suffix is attached to the stem varies, forming stem types differing in the complexity of the required modification, in their frequency, and in their productivity as well (for a classical psycholinguistic description see MacWhinney 1978). In our first experiment we applied a cross-modal morphological priming paradigm (sect. 4.4) to test differences between the priming effects of agglutinated forms belonging to six agglutinative stem classes. Of the six stem classes, three are fully productive (regular), and three are not productive (irregular). Subjects had to listen to the agglutinated form of a noun presented acoustically, and then they had to read its visually presented stem counterpart. Phonological similarity and strategy development were controlled for. Results are shown in Table 1. (The classification of stems into stem types can be found in, e.g., Kálmán 1985.) In each pair of examples the suffixed form is first, followed by the stem. The suffix itself and the morphophonological change are indicated in boldface. Numbers below the first three, nonproductive stem types show the number of noun tokens belonging to each type (courtesy of Péter Rebrus).

Regular plural–stem pairs showed significant priming effects; priming could also be observed in irregular classes, though these displayed much less facilitation. Pairwise comparisons did not

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Table 1 (Lukács & Pléh). *Stem types and their associated priming values in Hungarian nouns. Facilitation is given in milliseconds (* = p < 0, 05, ** = p < 0, 01; reaction times were in the 400–600 milliseconds range)*

Stem class	Example	Facilitation
1. Epenthetic n = 104	*árkok-árok*[a]	24*
2. Lowering n = 71	*lyukak-lyuk*	26
3. Shortening n = 222	*tenyerek-tenyér*	24*
4. 'Low-V'-final	*mesék-mese*	55**
5. C-final	*bútorok-bútor*	36**
6. 'Nonlow V'-final	*gyűrűk-gyűrű*	48**
Exceptional (1–3)		24*
Regular (4–6)		46**
7. Phonologically similar	*partizán-parti*	9

[a]Glosses: *árkok-árok: "ditches-ditch"; lyukak-lyuk: "holes-hole"; tenyrek-tenyér: "palms-palm"; mesék-mese: "tales-tale"; bútorok-bútor: "pieces of furniture-furniture"; gyűrűk-gyűrű: "rings-ring"; partizán-parti: "partisan-party."*

show differences between stem classes within the irregular group (epenthetic, lowering, and shortening stems), whereas the regular group proved to be less homogeneous: Results of the C-final and the low V-final stems differed significantly ($P < 0.05$). When data were divided into two large groups of "regular" and "irregular" stems, a two-way ANOVA with the factors Priming and Regularity showed a significant main effect [$F(1,13) = 46, 1; p < 0.001$] for Priming, and data were clearly divided along the Regularity dimension as well [$F(1,13) = 5, 19; P < 0.05$]; interaction was observed between the two factors [Priming × Regularity: $F(1,13) = 7, 9; P < 0.05$]. Results led us to conclude that in Hungarian distinct mechanisms are responsible for the processing of agglutinated forms of regular and irregular stems. This provides further evidence supporting the dual-route model (Pinker & Prince 1994). Reduced, yet significant, priming effects for irregular stems are not unprecedented in the literature (Stanners et al. 1979). We explained these results through characteristics of the Hungarian language. Plural forms, even irregulars, are phonologically more transparent in Hungarian, than, say, in English: Lowering stems fully contain their stems, and the plural suffix *-k* is invariably present and recognizable in all plurals.

Speakers of agglutinative languages pay special attention to word endings, and these forms can easily be decomposed into stem + suffix components. A possible explanation is that irregulars are not generated by a rule, yet in processing they are decomposed: The division between the rule system and the associative network of the lexicon is observable but is not so clear-cut.

In another study we tried to explore the distinction between regular and irregular morphology on the production side, applying a modified version of the paper-and-pencil test developed by Marcus et al. (1995), adapted to Hungarian. We first presented the nonword rhyming with words in one stem class in one of the contexts "root," "name," or "borrowing"; then, the subject was given another sentence, from which the accusative form of the nonword was missing. Unlike the German version, the Hungarian test asked the subjects to provide the missing agglutinated (accusative) form itself. Table 2 shows the percentages of rule-based answers for each stem type and context.

A two-way ANOVA showed significant main effects for both Context [$F(2,60) = 14, 47; p < 0.001$] and Regularity [$F(1,34) = 33, 8; p < 0.001$] and significant interaction (Regularity × Context: $F = 13, 3; p < 0.001$). Within Context, we observed significant differences between Root and Name, and also between Root and Borrowing contexts ($p < 0.001$ in both cases), but not between Name and Borrowing contexts. The Tukey test showed that the shortening, lowering, and epenthetic stems, just as with the three regular stem classes, form a homogeneous group within the Root context. Within the other two contexts, no division was found between regular and irregular stem classes.

Table 2 (Lukács & Pléh). *The use of the general rule for accusative formation with non-existing Hungarian words similar to different stem types as a function of stem class and production context.*

		Context			
Stem class	Example	root	name	borrowing	mean
1. Shortening	*denyér*	70%	87%	82%	80%
2. Lowering	*rönyv*	51%	66%	62%	60%
3. Epenthetic	*derem*	63%	85%	81%	76%
4. 'Low V'-final	*seve*	93%	93%	89%	92%
5. C-final	*hirány*	93%	96%	99%	96%
6. 'Nonlow V'-final	*rúzli*	97.5%	96%	98%	97%
Grand mean		78%	87%	85%	83%

The test, besides confirming the distinction between regular and irregular morphology, showed that speakers' grammars are sensitive to the grammatical structure of words assigned by different contexts. They apply irregular agglutination based on analogical extension most often when the new "word" appears as a root. We replicated Marcus et al.'s results with Hungarian stimuli. In light of these new data, it is again confirmed that an associative network model of language that represents morphology but ignores abstract formal features and grammatical rules cannot be an adequate model of the mind.

ACKNOWLEDGMENTS

This commentary relies heavily on the MA thesis of A. L. The research was supported by an OTKA (Hungarian Science Foundation) Grant No. T 029514 to C. P. Comments by Péter Rebrus are appreciated.

One, two, or many mechanisms? The brain's processing of complex words

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Abstract: The heated debate over whether there is only a single mechanism or two mechanisms for morphology has diverted valuable research energy away from the more critical questions about the neural computations involved in the comprehension and production of morphologically complex forms. Cognitive neuroscience data implicate many brain areas. All extant models, whether they rely on a connectionist network or espouse two mechanisms, are too underspecified to explain why more than a few brain areas differ in their activity during the processing of regular and irregular forms. No one doubts that the brain treats regular and irregular words differently, but brain data indicate that a simplistic account will not do. It is time for us to search for the critical factors free from theoretical blinders.

To enliven stretches of sound or letter strings with meaning is clearly one of the most formidable tasks the human brain is able

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

to perform. Clahsen focusses on one particular aspect of language processing, the production and comprehension of morphologically complex words. His starting point is the linguistic analysis of two apparently distinct classes of words: words having a regular morphology that seem to be computed on-line by a rule that specifies the concatenation of a stem and an appropriate affix, and those with an irregular morphology that, lacking a rule, seem to require explicit storage and retrieval from a structured lexicon. This "dual-mechanism" account is contrasted with "single-mechanism" accounts, wherein the output (inflected regular and irregular forms) is computed from the stems within a connectionist network with a general-purpose learning mechanism. Proponents of both classes of models view morphological processing as a test case with far-reaching implications for the general architecture of the language faculty (e.g., Pinker 1997).

Clahsen reviews data from developmental studies, reaction time experiments, analysis of patients with brain damage, and event-related brain potential studies pointing to a distinction between regular and irregular words in the direction predicted by his linguistic analysis. He offers these differences as evidence that the brain honors the linguistic distinction between regular and irregular words, and supporting a dual-mechanism account. However, to a cognitive neuroscientist, the neuroimaging and neuropsychological data suggest a more complex pattern than either a one or a two-mechanism class of models can explain fully.

Consider, for example, the fact that in a recent neuroimaging study by Indefrey et al. (1997), comparing the production of regular and irregular German words, no fewer than 12 cortical areas were significantly more active in the irregular than in the regular condition, as well as two more active for regular than for irregular contrasts. Different but equally complex patterns of brain activity were observed in positron emission tomography (PET; Jaeger et al. 1996, who nonetheless argued for a dual-process model) and functional magnetic resonance imaging (fMRI) (Ullman et al. 1997a) investigations of English past tense formation. Moreover, there is good (statistical) reason to believe that such studies underestimate the number of regions involved. Underestimates notwithstanding, what are the principled arguments by which these areas are to be assigned to one or the other mechanism in Clahsen's account or mapped onto the (single) hidden layer of a connectionist neural net? Neither model specifies the computations that are being carried out in the regions of differential activity, their functions, nor their specific contributions to morphological processing.

Patient data, likewise, implicate widespread cortical and subcortical areas, with anterior aphasia and basal ganglia diseases more likely to lead to problems with regular than irregular morphology, and posterior aphasia, Alzheimer's disease, and cerebellar atrophy interfering disproportionately with irregular morphology (Marslen-Wilson & Tyler 1997; 1998; Ullman et al. 1997b; 1998). A more precise decomposition of event-related potentials (ERP) sensitive to morphological processing is also likely to yield an equally complex pattern of effects, not just two mapping neatly onto regular and irregular words.

The complexity of the neural machinery involved in the processing of complex words thus appears to be similar to that for other perceptual and cognitive domains. The visual system, for example, comprises several dozen anatomically and functionally distinct cortical areas as well as subcortical structures, for which specialized functions have been delineated mostly through research on primates (see, e.g., Van Essen et al. 1990; 1992). Visual analysis is specialized and organized in parallel processing streams with multiple feedforward and feedback connections in an architecture that may be a prerequisite for achieving the degree of computational flexibility necessary for complex visual analyses. There is no reason to suppose that the same general neural organizational principles would not apply equally for aspects of language such as morphological processing.

In their current formulations, neither single- nor dual-mechanism models go very far in explaining the cognitive neuroscience data on morphological processing. Connectionist modellers have shown that a general-purpose *learning* mechanism can eventually process regular and irregular forms differentially and that what starts out as an unstructured hidden layer of activations comes to be partitioned into different regions with specialized processing consequences. Is this one or more mechanisms? If so, what computations does each perform? Is there any a priori specification of the nature and number of distinct subregions that are likely to develop with experience and how these are related to the nature and pattern of inputs, initial weights, learning rate parameter, and the learning trajectory? What is the appropriate mapping from regions in the hidden layer to brain areas? We doubt that anyone would wish to equate mechanism with either brain region or a difference in some behavioral or ERP measurement. Dual-process models are equally underspecified when it comes to the notion of process in computational and neural terms, linkages between frontal regions that apply rules to regular words and temporoparietal areas that supply the memory for irregular words aside (see, e.g., Ullman et al. 1997a). Neither class of models can account for the multiplicity of ERP components that any given word might elicit simultaneously.

A more accurate portrayal of morphological processing will have to address a broader range of cross-linguistic phenomena, including languages that do not have classes easily assigned to regular and irregular classes, as well as incorporate answers to some of the following questions, among others:

How and where in the brain is the application of a "rule" blocked?

What processes and which brain regions do the comprehension and production of complex words share in common, and where do they differ?

What are the relative contributions of language-specific and domain general brain areas to morphological analysis?

To what extent are regular words processed by memory mechanisms?

What are the developmental dynamics of morphological processing in neural terms?

How do regular and productive morphological classes (as observed, e.g., in romance languages) differ linguistically and in terms of brain processes?

A revised model, constrained by neuroscience as well as psychological phenomena, will of necessity include a more precise specification of the various computations necessary for comprehending or producing morphologically complex words. We believe that a brain-inspired model of morphological processing will include more than one or two computations, however many mechanisms these might entail. Such a model will be complex, like the brain and the human mind, and might therefore trigger less heated and less polarizing discussions about the nature of the human language faculty than we have heard heretofore.

ACKNOWLEDGMENTS

The authors' work is supported by grants from the DFG (MU1311/7-1) and the Hermann and Lilly Schilling Foundation (TS 013/177/96) to T. F. M., the Spanish Department of Education to A. R.-F., and NICHD grant HD22614, NIA grant AG08313, and NIMH grant MH52893 to M. K.

Are rules and entries enough? Historical reflections on a longstanding controversy

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Abstract: For language to function we clearly need two formal ordering principles: lexical entries and rules. Clahsen's target article provides multiple empirical evidence for this distinction, but this may be simply to overconfirm the undeniable and to overlook the hidden motor of language use

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

and language development, namely, function. Since at least 1859, linguists have argued for the primacy of function, and these arguments are worth rediscovering today.

Rules, entries, and defaults. There is no doubt that for a language to function there must be two formal ordering principles: lexical entries and grammars. Both these components of a language and their proportional work load vary from language to language and change over time through a combination of random changes and intentional action (Keller 1994). Whereas in German the inflectional paradigms for the processing of plural and past tense are highly irregular but have default settings (plural *-s* and past tense *-t*), one of which is of very low frequency (plural *-s*), similar default settings have been adopted in English as general paradigms (*-s* and *-ed*).

To account for this variation we have to distinguish not only between lexical and syntactic forms but between form and function, as August Schleicher (who introduced the term *morphology* into linguistics) pointed out in 1860. Following him, cognitive linguists *avant la lettre,* such as Michel Bréal (1866) and Philipp Wegener (1885), argued that function (meaning) drives the use and evolution of form and, moreover, the distribution of responsibility between lexical entries and combinatorial rules. The division of labour is determined by two factors: where the language "comes from" diachronically, that is, by historical contingency, and what speakers do with it synchronically. The balance between rules and constituents is therefore always one of variable degree.

This variation is mediated by a third factor: the default values adopted by a language, such as, in German, the *-t* and *-s* inflections. The question is, why should *-s* have been adopted as a default value in German despite its low frequency? There are two possible answers: (1) It is the only default setting open to a speaker who does not want to get entangled in the messy world of German morphology, where the choice between various paradigms of noun plural would be quite overwhelming. (2) In most cases, especially when speakers have to find plurals to words borrowed into German, *-s* is a morpheme that is affixable with the least cognitive and articulatory effort. When using *-s* as a default value, speakers are following what Jakob Grimm called in 1819 "the natural law of wise economy" (Grimm 1819, p. 2). Other languages may have other reasons to "choose" their default settings, but default settings always have an important role as mediators between rules and entries.

Rules, defaults, and analogies. Clahsen also argues that children use *-t* and *-s* as default settings in past tense and plural constructions. This seems to be well supported by his experimental evidence but is quite difficult to accept at face value. Even default values have to be in agreement with the sound patterns of the language. One can see that children would use the *-s* plural on low-frequency words such as *Fassung* or *Feder,* but this gets more difficult with words such as *Akt, Auswuchs, Bewilligung, Flanke, Deichsel,* or *Latte.* We would expect many of them to receive an *-(e)n* plural, which has a higher frequency in German than the *-s* plural and can therefore serve as an analogical model or pattern attractor (without taking over the role as default setting in general). In her classical study of children learning English morphology, Jean Berko discovered that the

> children did not treat new words according to idiosyncratic patterns. They did not model new words on patterns that appear infrequently. Where they provided inflexional endings, their best performance was with those forms that are the most regular and have the fewest variants. With morphemes that have several allomorphs, they could handle forms calling for the most common of those allomorphs long before they could deal with allomorphs that appear in a limited distribution range. (Berko 1958, p.117)

This should also apply to children learning German morphology.

Forms, functions, and situations. Early functionalists also argued that there is a third group of factors, apart from form and function, that is fundamental to language production and understanding: situational clues and the organised expectations on the part of the listener. They hold the constituents of verbal representations together, not only the grammatical signs, forms, or morphemes (Knobloch 1991; Nerlich 1990). Again, the ratio between linguistic and other clues varies from language to language and has to be modelled differently depending on each case. In language evolution, "language" exploits functionally what is thrown at it formally, with semantics and analogical reasoning as the driving forces behind this process of adaptation. This should also apply to language development, where focusing on items and rules could be an obstacle to the real understanding of the learning mechanism (Skousen 1989). "It is quite tempting to hypothesize that whenever the complexity of the linguistic data reaches a certain level, the cognitive system adopts a strategy of analogical learning, ultimately based on a trial-and-error principle, as a natural way to overcome the difficulty" (Bertinetto 1994, p. 105).

Rules, entries, and beyond. The shifting relationship between constituents, combinatorial processes, and (semantic) clues deserves to be studied if we want to understand how language works, whereas confirming the distinction between constituents and combinatorial rules is overconfirming the undeniable. Some cognitive/functional linguists and natural morphologists have started to work again in this older tradition (Dressler 1990; Dressler & Tonelli 1994). The challenge for connectionists and rule/entry dichotomists (even those advocating a softened model, such as Wunderlich & Clahsen) is to model the interaction of grammatical rules and lexicon with default values as mediating factors. Default values can be seen as the outcome of the two tendencies that are striving in opposite directions: constraints and rules on the one hand, which facilitate interpretation, and flexibility on the other, which promotes expressiveness (Warren, in preparation). The goal would not be to replace a dual-mechanism model of language by a single-mechanism one or to reject the rule/list dichotomy outright, as some cognitivists and connectionists do, but to investigate whether a dual-mechanism model with built-in flexibility provided by default values would be an even more robust model of human linguistic competence.

On the cross-linguistic validity of a dual-mechanism model

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Abstract: Recent studies of Italian past definite and past participle forms show that human performance with regular and irregular inflections is not dissociated as Clahsen's model would predict. Some performance profiles, accounted for by dual-mechanism models in terms of an underlying symbol-manipulating combinatorial procedure, are generated in Italian by the higher learnability and generalizability of phonologically regular morphological processes.

This commentary will address the question of the cross-linguistic validity of dual-mechanism models. Before setting out the details of my discussion there are two general points concerning the role of cross-linguistic evidence in Clahsen's target article that deserve brief mention. First, there is a problem of structural emphasis. Clahsen refers to cross-linguistic validity only in passing (sect. 4.7; Preliminary summary). In an important study such as this, with wide-ranging implications for the processing of inflection, the fact that cross-linguistic studies do not appear to merit any special treatment (i.e., more than a few lines) is surprising. Second, it is unclear exactly how far Clahsen believes his claims to be affected by studies of Italian inflection that appear to call the universal applicability of the dual-mechanism model into question. These cross-linguistic results are described by Clahsen merely as a "caveat"; he adds that "further experimentation is required before any strong cross-linguistic claims on the processing of inflection can be made" (sect. 4.7, para. 6). Strangely, however, the subse-

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quent sentence appears to make just such a strong cross-linguistic claim.

Setting these two points aside, I now turn to the substance of the argument. Clahsen found that the German verb forms using a default (regular) or nondefault (irregular) morphological process are dissociated in terms of priming profiles (sect. 4.4), use in children's overextension errors (sect. 5.1.1), and generalizability to novel verbs (sect. 4.2.1). I address the issue of whether these dissociation trends are confirmed for Italian, a language in which nondefault inflected forms are distinguished into phonologically regular (i.e., processes using a phonologically intact root form) or phonologically irregular processes.

As is shown in Table 1, there are three types of Italian inflections: no-root-change default forms, which are deployed by the largest class of verbs (conjugation 1); no-root-change phonologically regular forms, which are used by two smaller classes (conjugations 2 and 3); and root-change phonologically irregular forms, which are deployed by a subgroup of conjugation 2 verbs.

Orsolini and Marslen-Wilson (1997) investigated past definite forms using a cross-modal repetition-priming lexical-decision task. They found that root-change conjugation 2 forms and no-root-change conjugation 1 and 3 forms all show morphological priming: Reaction times in the prime condition (past definite forms prime an infinitive target) were significantly faster than a control condition. This finding has been replicated in two other experiments (Fanari 1999) investigating Italian past participles with a visual–visual and an auditory–auditory repetition priming lexical decision task. Although in these Italian experiments there was no counterpart of the identity condition used in Clahsen's experiment (see Fig. 4 of the target article), the German and Italian findings can be compared in terms of the statistical significance of the difference in reaction time between morphological primes and controls. Clahsen found that, when morphological primes consist of irregular forms, the reaction times of primes and controls are not significantly different; Orsolini et al. (1997) and Fanari (1999) found that both regular and irregular primes have reaction times significantly different from controls.

Focussing on the generalizability profiles emerging from Italian children's use of past definite inflections, Orsolini et al. (1998) found that overextension errors with conjugation 2 root-change forms deploy the conjugation 2 no-root-change pattern (*prendere*/**prende'*) and the conjugation 1 default procedure (*prendere*/**prendo'*) with a similar frequency. Conversely, root-change patterns were very rarely overextended (*vedere*/**vise*) and only under phonological similarity constraints. This finding has been replicated in a recent study in which Tuscan children were tested on a sentence completion task using conjugation 1, 2, and 3 verbs (Noccioli 1998). In this study the default phonologically regular process was as likely to be deployed by the 5-year-olds as the nondefault one, whereas the nondefault phonologically regular process was used more often than the default procedure by the 6- and 8-year-olds. These findings suggest that phonological transparency of the verb root in the inflectional process, along with familiarity with verb group organization, underlies inflection generalizability in Italian children's overextension errors.

Investigating generalizability profiles with novel verbs. Orsolini and Marslen-Wilson (1997) found that conjugation 2 and 3 morphological processes show some sensitivity (though in a different way) to phonological similarity to existing verbs. In a more recent study Fanari and Orsolini (in preparation) used the same task and procedure as Orsolini and Marslen-Wilson (1997) but contrasted conjugation 1 and 2 inflections. In this study – in line with the findings mentioned by Clahsen (sect. 4.7) – conjugation 1 forms were found to be used by subjects irrespective of the pseudoverbs' phonological similarity to existing verbs. Strangely, however, in some responses a default past participle suffix was added to an infinitive suffix rather than concatenated to the pseudoverb root (e.g., the target pseudoverb *maffeciare* was inflected as *maffeciarato* instead of *maffeciato*). Thus some subjects occasionally applied an explicit and rather dull strategy of adding a suffix to the end of the target form.

In sum, the default Italian inflectional process, conjugation 1, does not show the same correlation of properties exhibited by regular German inflection. It is applied without phonological restriction in adults' performance with novel verbs, but it does not behave differently from nondefault phonologically regular processes in children's overextension errors, and it is not distinguished, in terms of priming effects, from phonologically irregular root-change inflections.

The hypothesis that the architecture of the language faculty has separate components consisting of lexically listed versus computed inflections deserves further cross-linguistic scrutiny and careful consideration of the representations and processes tapped by different tasks. Morphological priming in a lexical decision task, for instance, does not seem to be a reliable indicator of computed versus listed inflections. Italian findings (but see also the findings

Table 1 (Orsolini). *Main findings of studies investigating Italian inflections*

	Priming in lexical decision tasks	Generalizability shown by children's overextension errors	Generalizability shown by adults' performance with novel verbs
Default conjugation 1 inflections (e.g., *amò–amato*; he loved–loved)	Reaction times with morphologically related prime–target pairs are significantly faster than with control target pairs	High	No sensitivity to phonological similarity
No-root-change conjugation 2 (e.g., *credé–creduto*; he believed–believed) and conjugation 3 forms (e.g., *dormì–dormito*; he slept–slept)	Reaction times with morphologically related prime–target pairs are significantly faster than with control–target pairs	High	Sensitivity to phonological similarity
Root-change conjugation 2 forms (e.g., *prese–preso*; he took–taken)	Reaction times with morphologically related prime–target pairs are significantly faster than with control–target pairs	Extremely low	Sensitivity to phonological similarity

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

on English past tense reported by Marslen-Wilson & Tyler 1998) suggest that listed inflections can generate morphological priming. Moreover, the generalizability profiles shown by children's overextension errors seem to reflect not a distinction between computed versus listed inflections but rather the high learnability of phonologically regular processes. Italian children tend to make errors by using the morphological processes in which the verb root is phonologically transparent, no matter whether these processes are exhibited by the default and largest verb class or a nondefault and small group of verbs. Finally, the use of written tests eliciting sentence completion responses with pseudoverbs should be more carefully considered. Performance in these tests may reflect not the application of on-line morphological computations but off-line use of metalinguistic strategies.

NOTE

1. The verb forms shown in parentheses in this paragraph are the infinitive form and, preceded by an asterisk, a past form with an overextension error.

Please mind the brain, and brain the mind!

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Abstract: True, there may be two language-processing systems, lexicon and syntax. However, could we not say more than that they are computationally and linguistically distinct? Where are they in the brain, why are they where they are, and how can their distinctness and functional properties be explained by biological principles? A brain model of language is necessary to answer these questions. One view is that two different types of corticocortical connections are most important for storing rules and their exceptions: short-range connections within the perisylvian language cortex and long-range connections between this region and other areas. Probabilities of neuroanatomical connections plus associative learning principles explain why different connection bundles specialize in rule storage versus exception learning. Linguistic issues related to language change and plural formation in German are addressed in closing.

Whereas connectionist psychologists consider *unstructured associative* learning devices to be capable of storing grammar rules and their exceptions, generative linguists hold that *two distinct systems* plus *inborn knowledge* are necessary for language acquisition. Clahsen favors the latter view. He presents evidence for two systems and, thus, rejects an unstructured learning device. However, he does not present strong arguments against the relevance of associative learning for storing morphological rules and their exceptions. A brain model of language suggests that associative learning in a structured device is sufficient for the acquisition of both.

The major function of the human cortex is the storage of correlations, that is, associative memory. This view is well-established in neuroscience (see, e.g., Fuster 1995; Braitenberg & Schüz 1998). Associative learning is particularly helpful for understanding the brain mechanisms of word processing. If all word representations include neurons in the so-called language areas in the left perisylvian region, association theory implies that the cortical processing devices of words referring to concrete objects and actions are different. Because an action word and the action it refers to frequently occur in close temporal vicinity, this correlation is stored by a network of neurons including those in language areas and, in addition, cells in the frontal lobes related to the programming of actions. The same point can be made for words referring to concrete objects usually perceived through sensory modalities. Again, the perisylvian word-form representation would incorporate additional *extraperisylvian* neurons. Such widely distributed neuronal representations with extraperisylvian parts are postulated for content words, including verb and noun stems. However, there are also highly abstract words and morphemes, in particular the so-called closed-class or function words (*this, but, it*) and the inflectional affixes (plural *-s,* past *-ed*). They lack high correlations with nonlinguistic actions or stimuli, so their cortical representations are likely restricted to the perisylvian areas (Fig. 1). Evidence for this view comes from numerous neuropsychological and neuroimaging studies (Pulvermüller 1999).

Based on this model, it is easy to make ideas about the cortical mechanisms of morphological rules much more concrete. Because, in the clear cases, morphological rules involve suffixation (addition of a functional morpheme at the end of a word stem, e.g., walk + -ed; rat + -s), they are modelled as connections between widely distributed cell assemblies (representing stems of content words) and a more local perisylvian net (representing the functional affix). Neuroanatomical studies revealed that connection probabilities are much higher within one area and between adjacent areas than between distant areas (Pandya & Yeterian 1985; Young et al. 1995). Therefore, most of the stem–affix connections should be localized in the areas where both types of representations have some of their neurons side by side, that is, in perisylvian space (Fig. 2, right).

Irregular forms should be stored differently. Both stem and derived form have concrete referential meaning. Therefore, they would both be modeled as widely distributed assemblies. Although, in the clear cases, they differ in their phonology (*go – went; mouse – mice*), they share most of their semantic features. Therefore, they can be modeled by overlapping cell assemblies with almost identical extraperisylvian parts but different perisylvian neuron populations (Fig. 2, left). Stem and derived form should thus be held together by extraperisylvian neurons. If the two are phonologically similar, additional perisylvian connections may also be relevant.

Based on these considerations, the idea of the dual nature of morphological processing receives some brain support. A brain model of language together with neuroanatomical facts suggests that there are two types of connections primarily involved in rule and exception storage, respectively. Local high-probability connections in perisylvian areas are more important for rule storage, whereas sparse long-distance connections between perisylvian and other areas are most relevant for memorizing exceptions.

The present view has been spelled out in more detail elsewhere (Pulvermüller 1998). Three points must be mentioned in the context of Clahsen's work.

Neuropsychology. Data from neurological patients indicate

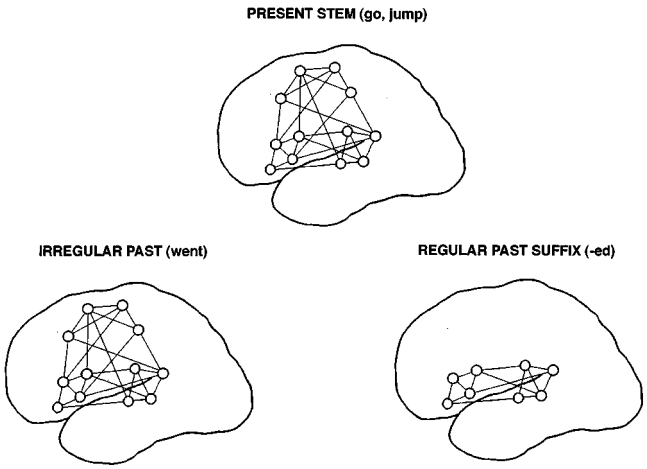


Figure 1 (Pulvermüller). Neural representations with different cortical topographies are proposed for stem, irregularly inflected form, and regular suffix. Whereas the processing device of the rule suffix (*-ed*) is restricted to perisylvian areas, a stem (*go*) and its irregularly derived form (*went*) are represented by widely distributed nets including information about semantic features (from Pulvermüller 1998; reprinted with permission, Institute of Physics Publishing Co., London).

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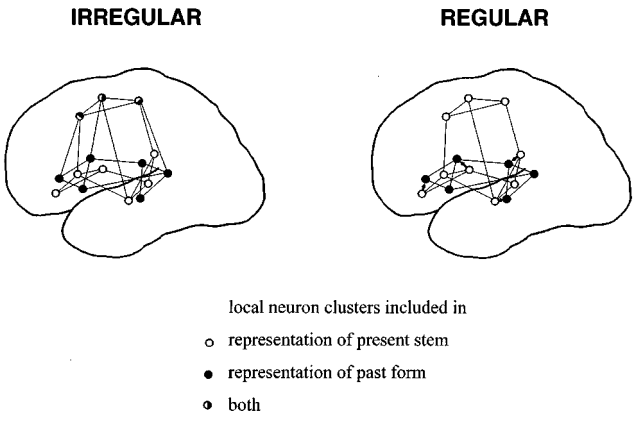


Figure 2 (Pulvermüller). Putative neuronal mechanisms of morphological rules and their exceptions. Knowledge of irregular inflection is stored by widely distributed assemblies sharing neurons outside perisylvian areas (*go – went*). Here, long-distance connections are particularly important. In contrast, knowledge of regular inflection (walk + -ed) is primarily laid down in the perisylvian cortex, by short-distance connections between stem and suffix representation (from Pulvermüller 1998; reprinted with permission, Institute of Physics Publishing Co., London).

that certain brain lesions selectively impair the knowledge of rules and that there are other lesions primarily affecting Clahsen's structured lexical entries (Marslen-Wilson & Tyler 1997; Ullman et al. 1997b). The brain-based model can explain at least a subset of these data (see Pulvermüller 1998, for illustration and a simulation). How would Clahsen's model explain the systematic relation between lesion sites and affection of different knowledge types?

Psychophysiology/neuroimaging. Clahsen's consistent finding of a left anterior negativity in the event-related potential (ERP) occurring with false placement of regular suffixes (sect. 4.5) nicely fits the brain-based model: When activated, left-lateralized perisylvian cell assemblies representing functional affixes are most likely to elicit activity signs over these same cortical areas. Similar left perisylvian ERPs maximal at anterior sites have been found for incorrectly placed function words causing phrase structure violations (Neville et al. 1991) and for function words presented out of context (Pulvermüller et al. 1995). Left anterior negativity (or, more precisely, one type of left anterior negativity) appears to be characteristic of the processing of an unexpected function item (word or affix). Again, the brain-based model is consistent with this.

Language change. The brain-based model may help to explain an etymological tendency seen in many languages. Highly productive rules usually involve affixation, whereas stem changes tend to die out. One factor contributing to this outcome may be the rich local connections in the perisylvian areas that, according to the model, mediate suffixation. This powerful local system may outperform the system mediating stem changes, which, at least partially, depends on sparse long-range connections. This, together with the more extensive phonological variation in the regularly affixed class (Hare & Elman 1995), may help to explain, for example, the decline of systematic stem changes according to the so-called ablaut rules in Germanic languages.

The brain-based account offers the following perspective on different types of morphological mechanisms. Although two different brain systems may well primarily contribute to two distinct linguistic processes, it does not appear likely that these different systems are exclusively devoted to the task at which they are best. The specific involvement of perisylvian high-probability connections in rule knowledge and that of sparse long-range connections in storing exceptions may be a gradual rather than a binary phenomenon. There is no system exclusively devoted to a particular process, but more neuronal connections of one system than connections from the other contribute to the process. I believe that this is biologically more realistic than placing rules and lexical entries in two separate boxes. Likewise, the linguistic phenomena of regular and irregular inflection may also be gradual. There are *very* irregular isolated verbs whose present and past forms are entirely different (*go – went*), moderately irregular verbs belonging to an ablaut class and exhibiting vowel change only (*sing – sang*), German nouns with both vowel change and suffixation, which may be considered cross-breeds (*Maus – Mäuse*), and finally the pure regular classes with suffixation only, which may be further subcategorized according to their type and token frequencies and their distribution over phonological space. These types may gradually rely more and more on perisylvian connections while the contribution of extraperisylvian long-distance connections may decline.

One more linguistic point: According to Clahsen (see also Marcus et al. 1995), the only regular German plural form is *-s*. However, this is far from uncontroversial (Bybee 1995b). There are at least two other productive affixation patterns (*-e* and *-n*). I missed strong arguments *against* their representing rules. Such arguments are probably difficult to find, because, for example, in Marcus et al.'s study (1995), *-e* and *-s* plurals on pseudowords were accepted with equal frequencies by adult Germans, at least in one condition (see Marcus et al. 1995, pp. 249 ff.). When contexts indicated that the pseudowords were actual words from foreign languages, there was an advantage for *-s*, however. But this points to a possible confound: Most Germans know a good deal of English and are likely to apply their second language processor(s) to such forms. Could it be that experiments on pseudoword plurals with German-competent speakers are systematically confounded by their knowledge of English? This would render results on the *-s* plural in German problematic. In addition, compound noun experiments in children produced evidence that the *-n* plural was actually used as a default plural form (sect. 5.2, para. 5). Clahsen proposes that "children may temporarily misinterpret *-n* as a default plural" (sect. 5.2, para. 5), but could not one argue that they rely more on *-n* than on *-s*, because they lack any affixation knowledge from English? Taken together, *-s* pluralization is certainly rule-like in German (but see Bybee 1995b), but this does not prove *-n* and *-e* exceptions. Several rule-like patterns coexist.

Let me finish with a question: Wouldn't it be a good thing to think about the neuronal reality of morphological and syntactic rules? I believe this is a necessary condition for making real progress.

ACKNOWLEDGMENTS

The author's work is supported by grants Pu 97/5-2, Pu 97/10-1, and Pu 97/11-1 from the Deutsche Forschungsgemeinschaft (DFG).

The power of cross-linguistic analysis: A key tool for developing explanatory models of human language

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Abstract: Clahsen's compelling evidence for the dual-mechanism model of the lexicon derives in part from the use of cross-linguistic data in psycholinguistic research. This approach reflects a growing (and positive) trend toward incorporating data from several languages when analyzing and modeling human language behavior. This perspective should be expanded to include data from typologically distinct languages to develop more explanatory models of language.

The data Clahsen presents from research on German inflection provide compelling evidence in favor of the dual-mechanism approach to inflection and lexical processing. Part of the strength of

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Clahsen's arguments for a modular structure to the lexicon comes from the fact that his analysis combines data from a language other than English and data from several different areas of psycholinguistics with theories from both psychology and linguistics. By combining cross-linguistic and interdisciplinary perspectives on language, Clahsen makes a bold effort to address one of the major debates in psycholinguistic research on the lexicon. This kind of approach will lead to a more careful conceptualization of the nature of inflectional morphemes and lexical processing.

This commentary will focus on the value of incorporating cross-linguistic data into psycholinguistic research demonstrated by Clahsen's analysis. The benefits that derive from incorporating cross-linguistic data into psycholinguistic research are quite compelling in the target article. The classical models of the lexicon (Forster 1976; Marslen-Wilson 1987; Marslen-Wilson & Welsh 1978; McClelland & Rumelhart 1981; Morton 1969) were based on data from English, and many features of these models have not yet been tested against data from a range of other languages. Without such data from other languages, it is not possible to determine which aspects of these models reflect general human abilities for language processing and which reflect the specific idiosyncracies of the language (English) upon which the models were originally based.

A cross-linguistic perspective, such as that taken by Clahsen, can make it possible to distinguish more universal characteristics of human language processing in ways that would not be possible using data from English (or indeed any one language) alone. In this instance, Clahsen's focus on German leads to a reexamination of assumptions about the nature of inflection, assumptions that originated from analyses of English. This reexamination makes it possible to dissociate the factors of *default* morphological form (the form that is used in the absence of other rules, as is the case with nonsense or novel nouns) from *frequent* morphological forms (those that occur most often in the language). This cross-linguistic approach enables Clahsen to show that these two factors, which are conflated in English, must nonetheless be considered and accounted for separately in models of the lexicon. This insight makes it possible for Clahsen to develop stronger arguments for a dual-mechanism model than could be developed using data from English.

Clahsen's research parallels a growing and profitable trend toward using cross-linguistic data in the field of psycholinguistics. For example, recent research has begun to incorporate data from many languages in the areas of child language acquisition (Lust et al. 1994; Slobin 1985), specific language impairment (SLI; Leonard 1996; 1998), and aphasia (Wulfeck et al. 1991). The result has been a challenge to many assumptions about the nature of language, its acquisition, and its processing that were originally derived from models based on a single language (often English). For example, recent cross-linguistic work has challenged the assumption that developmental or pathological errors in morphosyntax nearly always include omissions of subject–verb agreement, such as often occur with speakers of English. Evidence from Hebrew-speaking children with SLI, for example, suggests that for a number of verb classes these children do not have significantly more difficulty inflecting verbs than do typically developing children (Leonard & Dromi 1994). Data such as these are now compelling researchers to engage in more precise debates and to develop more refined models of the mechanisms underlying morphosyntactic processing in both language acquisition and language impairment. Clahsen's article here has confirmed the value of cross-linguistic data for challenging and refining models of lexical access as well.

Even though Clahsen presents strong evidence in favor of a dual-mechanism approach, the data presented here do not necessarily preclude the possibility that a single-mechanism model could also be built to account for these data. However, Clahsen's data do challenge the proponents of single-mechanism approaches to account for the same range of data across languages. Thus, whether the lexicon is most accurately represented by dual modules, as argued by Clahsen, or by a single mechanism, such as is suggested by connectionist models, is still open to debate. In either event, however, these data from German will help to challenge and refine models of the lexicon and morphological processing and will ultimately make the resulting models more explanatory.

Indeed, the challenge for the field, regardless of an individual researcher's stance on the modularity of the lexicon, is to work toward developing models that can accommodate and incorporate data and insights from many different languages. Clahsen was able to uncover insights about the nature of the lexicon using data from German, in part because of the structural differences between German and English. At the same time, German and English are closely related Indo-European languages, so a comparison of the two may provide only limited understanding of a range of language phenomena. Typologically distinct languages also need to be explored more rigorously from a psycholinguistic point of view. Models of psycholinguistic processes must be applicable not only for languages such as English and German but for a range of typologically different languages, for example, polysynthetic languages, which make extensive use of morphology, or fusional languages, which encode many relations within single morphemes.

When truly cross-linguistic perspectives are incorporated into psycholinguistic accounts of language and language behavior, the resulting models – whether they be modular, as suggested by Clahsen, or single-mechanism, as suggested by many other approaches – will all be better informed and more refined. A body of cross-linguistic data within many different subfields of psycholinguistics will help to redefine models of language and the brain. Without such data, a comprehensive understanding of how humans process and comprehend language will never be achieved.

Rules or neural networks?

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Abstract: Clahsen's claim to contribute arguments for dual mechanisms based on rule analysis and against connectionist proposals is refuted. Both types of modeling are inadequate for principled reasons.

Clahsen's target article addresses two issues, the principled one of rule versus neural networks and the experimental one of the specific role of affixation and the lexicon in word analyses. The first one, with which I am exclusively concerned, is so obscured by the controversy between rules and connectionist models that no solution is in sight.

Against those defending the analysis by rules only, I would claim that all behaviorally relevant features of brain processing are ultimately expressed by the connectivity and interactivity of neurons in the brain (modulated by humoral supplies) and that there are no other biological or physical mechanisms available! Against the typical proposals from connectionists I would insist that the network of neuronal connectivities in the brain is highly organized and structured in neuronal groups, subareas of neuronal systems, and cortical and subcortical systems. Thus, in addition to the connectivities and interactivities we must be concerned with the topographic arrangements and with the temporal capacities of the neuronal groups and areas involved.

I thus do not accept the analyses by symbolic manipulation rules, nor do I advocate one of the typical connectionist networks. Because there is no storage or manupulation of symbols in the brain, the first approach is inappropriate. Equally, connectionism is inappropriate owing to its topographically and dynamically totally unstructured models. Both fail to provide any empirically

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

plausible proposals to be tested by topographic brain imaging. Instead, the specific faculties that organize behavior depend on the specificity of the architecture of a system of interactive subunits, subunits of subunits, and so on, down to single neurons. We must study these architectures and not completely homogenous rule systems or connectionist systems.

Consequently, Clahsen's alternative is also problematic. The models he assumes require or presuppose storage and manipulation space for engrams of a symbol pattern and thus imply computer architecture. This is, however, inadequate. For the computer, a central processor unit and a random access memory do the job. In the brain, there is neither a CPU, nor RAM, nor anything similar to them. The standard assumption of symbol processing that there is a corresponding underlying hardware is totally misleading for brain models.

Consequently, the typical linguistic descriptions in terms of symbolic entries and combinatorial rules can be understood to generate mere abstract representations of structure. These do not provide any hint as to possible empirical mechanisms. A fortiori, the dual mechanism consisting of a lexical entry system and a combinatorial rule system, which Clahsen claims exists, is without theoretical or empirical foundation. I do not criticize the assumption that there are different subsystems of connectivities taking care of the organization of word forms. Surely there are; empirical observations show different distributions over different brain areas. However, these areas cannot be conceived as processors of entries of symbolic patterns on the one hand and universal symbol pattern combinators on the other.

My book (1991) and various other of my recent articles and, in a technically more detailed way, the book by Wilkens (1997), have shown how linguistic patterns and rule systems could be *translated* into networks of connected interactive units of neuronal type. These translations provide plausible mechanisms, whereas the assumptions of storage mechanisms for symbolic patterns or of universal combinator units do not.

Rules and rote: Beyond the linguistic either-or fallacy

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Abstract: We report an experiment that unambiguously shows an effect of full-form frequency for fully regular Dutch inflected verbs falling into Clahsen's "default" category, negating Clahsen's claim that regular complex words in the default category are not stored.

The traditional linguistic view is that the lexicon is the repository of the irregular and the irregular only. For linguistic theories, this is quite defensible, especially when the aim is to chart the systematicities in language. Clahsen's target article is an eloquent attempt to defend the claim that the economy of linguistic description can be mapped directly onto psycholinguistic theories of lexical processing. He argues for the strong position that all and only irregular inflected words are stored in the mental lexicon, whereas all and only regular inflected words are processed by rule. The two mechanisms, rule and rote, are thus assigned fully disjunct applicational domains.

Clahsen presents an impressive array of experimental data that support his position, but there is an equally impressive array of experimental data that argue for a more nuanced position, especially in the domain of language comprehension. Taft (1979) has reported full-form effects for regular inflected verbs and nouns in English, as did Sereno and Jongman (1997). Baayen et al. (1997b) likewise report full-form effects for noun plurals in Dutch and Baayen et al. (1997a) for Italian noun plurals.

Clahsen's response to the data on Dutch noun plurals is to question whether these noun plurals "involve regular default processes" (see sect. 4.3). Instead of going into a detailed discussion concerning the fully regular complementary distribution of the Dutch plural suffixes, we will present data concerning the Dutch verbal inflectional suffix *-t*, which is fully regular and which has no rival suffix with the same function. Hence, it is by definition a "default" suffix in the sense of Clahsen.

We ran a standard visual lexical decision experiment with 23 participants. We selected 74 inflected verbs in the third person singular (e.g., *klimt*, "climbs") from the CELEX lexical database. Thirty-seven of these verbs had a high surface frequency with an average of 15.42, and 37 had a low surface frequency with an average of 0.19 (all frequency counts standardized per million). The two sets were matched for base frequency (high 74.54, low 75.27), family size (high 19.5, low 19.2), and mean length in letters (high 5.7, low 5.5). The inflected verbs with a high surface frequency (mean reaction time [RT] by participants 571, mean error rate 5%) elicited reliably faster RTs and lower error scores than the inflected verbs with a low surface frequency (mean RT by participants 630, mean error rate 14%). For the response latencies, $t1(22) = -10.70$, $P = 0.00$; $t2(72) = -4.24$, $P = 0.00$; for the error rates, $t1(22) = -7.48$, $P = 0.00$; $t2(72) = -2.57$, $P = 0.01$. This experiment clearly demonstrates a solid 59 msec effect of full-form frequency for a completely regular inflectional suffix and, again, negates the linguistic projection of defaulthood onto lexical processing. Note that we do not interpret this result to indicate that rule-based processing is absent. Instead, we assume that lexical access is attempted in parallel both by rule and by rote (Baayen et al. 1997b), that on average the parsing route will be the winning route for lower frequency words, and that on average the direct route will be the winning route for higher frequency words.

Interesting positive evidence for Clahsen's position is furnished by his neuroimaging studies, which suggest an effect of syntactic incongruity when a "regular" suffix replaces an "irregular" suffix, whereas an effect of semantic incongruity is observed for one "irregular" suffix that replaces a "regular" suffix. Although these data are compatible with Clahsen's position, alternative explanations are possible. The semantic incongruity effect observed for words such as *Karusellen* may be a problem of interpreting a novel deverbal noun: The structure of *Karusellen* is the same as the structure of the noun *Pfeffern* in *das Pfeffern* (Duden Grammatik 1984, p. 401). The absence of a syntactic incongruity effect for *getanzen* may be due to *tanz* combining very frequently with *-en* – this combination of stem and suffix is licensed by the grammar. The presence of such an effect for *geladet* may be due to *lad* combining only rarely with *-et*. For participles with an irregular stem such as *gegangen*, replacing *-en* by *-et* results in a local ungrammaticality: *Ganget* is not a grammatical form; the correct form is *geht*. More detailed research is required before data such as these can be accepted as evidence for the cascaded dual-route model advocated by Clahsen.

Finally, we find Clahsen's analysis of noun plurals in German unconvincing from a comprehension point of view. Irregular inflections are problematic primarily in language production, where it has to be ensured that the correct unpredictable form gets precedence over the incorrect regular form. In comprehension, by contrast, the plural form always appears in the correct form. Once affix and base have been recognized, the compositional meaning of the plural can be accessed. From this point of view, the claim that nondefault German plurals, that is, 93% of all plural types, are always processed by rote and that rules do not play a role for otherwise formally and semantically regular forms such as *Frauen* and *Hunde* is rather counterintuitive. We suspect that in word recognition rules play a far more important role for these German plurals than Clahsen would have us believe. Our hypothesis is that, irrespective of whether a regular rule has "default" status or not, parallel access on the basis of both rule and rote leads to more efficient lexical processing than mechanisms based on the linguistic either-or fallacy, which in the case of German nouns has

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

led to a Pyrrhic victory over connectionism, insofar as only 7% of the noun plural types and only 2% of the noun plural tokens would be processed by rule.

Entries and operations: The great divide and the pitfalls of form frequency

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Abstract: Results from our laboratories show clear frequency effects for regularly inflected forms in both German and English. Moreover, there does not seem to be sufficient evidence to treat the *-s* plural as the default plural in German. Together, these data do not support a dual modular structure of the language faculty.

Clahsen claims that experiments on German inflection support a modular representation of language processing, with two basic components, a lexicon and a computational system of combinatorial operations. In this type of model, there are two distinct processing systems, lexical and syntactic. The lexicon contains a set of entries that are specified for grammatical information (class membership, gender), phonological or orthographic form, and meaning. The computational syntactic system comprises a set of rules that derives well-formed linguistic expressions from the combination of lexical entries.

From our perspective, two issues are critical in the evaluation of Clahsen's claims. The first concerns the empirical evidence. There is no strong evidence to treat the *-s* plural as the default regular plural in German, and, as we will show, frequency effects for regularly inflected forms can be observed. Second, and more generally, it is unclear how the dissociation of regular and irregular morphology maps onto the dual lexical/syntactic contrast of the language faculty. We address these two issues below.

The data. We find a number of problems with Clahsen's classification of regular and irregular inflection in German. In his research, Clahsen assumes that the *-s* plural in German is the default plural marking; if it is not, his entire argument falls apart. This assumption is not uncontroversial. A search of *-s* plurals in the German database (CELEX) shows a preponderance of borrowings from English, French, and Italian. One could argue that this is the primary function of the default plural, that is, pluralizing loan words. Many loan words do not obey German phonology. Polysyllabic borrowings ending in a full vowel (absolutely exceptional for German) can only receive the *-s* plural. Also, non-German stress patterns prevent the application of other plural markers. In an experiment in German by Clahsen et al. (1997), the "regular" *-s* plurals look like a stimulus list for an experiment in English. Because most words end in full vowels, application of the *-s* plural is obligatory on phonological grounds. These "regular" words are then compared to irregulars. One of Clahsen's main motivations for using German is to avoid stem changes in irregular forms. However, in this experiment, all but four irregular items have an umlaut in their plural form. One could have chosen "less irregular" *-n* or *-en* plurals.

Even more problematic is the fact that the frequency count for the *-s* plurals is unreliable. The database provides merely frequency of surface forms. For masculine and neuter words (90% of the materials), the *-s* plural form cannot be distinguished from the genitive *-s* singular form (e.g., *Der Klang des Echos,* "the sound of the echo"). Thus, if the interpretation of the data is incorrect, if pluralization obeys specific phonological constraints and *-s* plural application is largely limited to borrowings, *-s* cannot be considered the regular default plural form in German.

In English, there is no controversy regarding the division of regular and irregular morphology. Clahsen is correct in claiming that a comparison of regular and irregular forms in English is problematic because of the presence of an overt affix and frequency confounds. However, these pitfalls can be avoided by examining frequency effects within regular items. Sereno and Jongman (1997) directly examined the frequency contribution in regularly inflected nouns in English. Frequency of occurrence of singular and plural forms was systematically manipulated, holding total frequency constant, to determine what drives response latency. In the singular, responses to nouns with relatively high-frequency singular forms were faster than those to nouns with low-frequency singular forms; in the plural, these same nouns (with relatively low-frequency plural forms) were slower than those with high-frequency plural forms. Frequency effects are clearly present for regularly inflected items, directly refuting Clahsen's claims.

In a similar vein, preliminary results from one of our laboratories show frequency effects for regular past participles in German. In a production experiment, participants had to produce past participles on the basis of an infinitival prompt (*mischen* – "*gemischt*"; *mix* – *mixed*). With overall (lemma) frequency meticulously matched, high-frequency participles were produced some 25 msec faster than low-frequency participles. Interestingly, lemma frequency had no effect whatsoever on participle production. When participle frequency was held constant, virtually identical participle production times were obtained, even when there were large differences in lemma frequency. The effects of sublemma frequencies on morphological processing observed here are not easily reconciled with rule-based systems such as Clahsen's and can be taken as support for a full listing hypothesis.

The theory. Clahsen contends that his data on processing of German inflectional morphology support the modular view of two distinct processing systems. Our data are problematic for this view. He cites no direct or, for that matter, indirect evidence to support the claim that the lexical versus grammatical distinction can be applied to the regular versus irregular contrast. Clahsen must show that the modular structure that accounts for the construction of a syntactic representation is also responsible for the processing of regular morphology. A dissociation of regular versus irregular morphology in itself does not necessarily constitute support for a lexical/grammatical dichotomy. Moreover, in such a dual-architecture view, frequency effects in regularly inflected forms should not exist. A viable theory of inflectional morphology must posit a more explicit representation of the interface between lexical, morphological, and syntactic processes.

ACKNOWLEDGMENTS

This commentary was prepared while J.S. was a Humbolt Fellow at the University of Münster and while J.S. and A.J. were Visiting Scientists at the Max Planck Institute for Psycholinguistics. Support from both institutions is gratefully acknowledged. We thank the following funding agencies: Alexander von Humboldt Foundation (J.S.), Nederlandse Organisatie voor Wetenschappelijk Onderzoek (J.S.), National Science Foundation (J.S.), Deutsche Forschungsgemeinschaft (P.Z.), and the National Institutes of Health (A.J.). We also thank Oliver Müller for assistance in conducting some of the experiments reported here.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Inflectional classes, defaults, and syncretisms

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Abstract: I argue for an extension of Clahsen's psycholinguistic paradigm to well-known languages with more complex morphological systems. This would help to address conceptual questions such as the nature of defaults and the way in which syncretisms are coded in the brain.

The work of Clahsen and his collaborators illustrates very well the two principal ways in which linguistics can exert a benign influence on psycholinguistic research. First, Clahsen is able to make use of detailed analytic procedures to identify precisely those sets of language facts that can be deployed in experiments. Second, he is able to develop psycholinguistic models based on linguistic theory (in this case Wunderlich's model of inflection and lexical representation). Both modes provide fine role models for the field. In this commentary I will mention a few additional data sources, developing some of Clahsen's own ideas, and briefly touch upon a couple of theoretical questions.

Compared to many other European languages, German morphology is impoverished in an important respect: There is a clear distinction between the default inflectional class (regular verbs vs. all the rest, nouns with *-s* plurals vs. the rest). Clahsen (sect. 4.7) mentions the work of Say on the three Italian conjugations, but it is not clear how regular the two nondefault classes are. In Slavic languages, there is a default conjugation, but other conjugations tend to be rather more regular and well-represented than is generally the case in Romance languages. Thus, in Russian there are two regular conjugations. Class 1 has all the properties of the default, but class 2 verbs are very numerous, and at least one productive word formation process (the formation of causative verbs from adjectives) regularly puts the verb into this class. Class 2 verbs are subject to lexically conditioned stress alternations, final consonant alternations, and one or two other phonological alternations, whereas the default class 1 verbs are free of such variation. However, in the majority of cases the alternations shown by class 2 are predictable. Moreover, while class 1 has about 13,000 members, class 2 has about 7,500, so it is in no way a minor class. Thus, it is not clear that we would want to relegate class 2 verbs to associative memory. The case of Polish is more interesting. It has three regular conjugations, broadly speaking. Class 1 has all the standard diagnostics of the default except for one. Slavic verbs have two aspect forms, perfective and imperfective. Most verbs derived by prefixation are perfective and undergo a regular process that creates a secondary imperfective. Most Slavic verbs are so derived, so this means that there is a very large proportion of secondary imperfectives. Unusually for Slavic, the secondary imperfective in Polish enters not the default class but one of the other two classes, which therefore end up with more members than the default class. Thus, Polish verbs illustrate a phenomenon similar to that of German *-s* plurals.

Another rich source in Indo-European inflection is declension. Nouns in most Slavic languages inflect for a rich set of cases as well as number, including at least a "masculine" declension (usually ending in a consonant in the nominative singular) and a "feminine" declension (usually ending in *-a* in the nominative singular). There are grounds for regarding the "masculine" declension as the overall default (Corbett & Fraser 1993) but it seems very odd to think that this entails the vast number of perfectly regular "feminine" -class nouns being less "symbolic." Again, similar remarks can be made about Greek and a number of other languages.

The first theoretical question I wish to raise concerns the notion of "default." Clahsen (n. 2) suggests that his conception of default corresponds to that of "global" rather than "nested default" (or the equivalent) in realizational theories such as those of Corbett and Fraser (1993) or Stump (1993). However, it is very unclear that the global default would bear any real relation to Clahsen's notion when the language data mentioned above are studied experimentally, one of the reasons being that the linguistic theory Clahsen is working with still relies to some extent on the morpheme theory, whereas in realizational theories that notion plays no role. This matter could be resolved only by looking at well-understood inflectional systems that have a much more complex paradigm structure than German.

Here is one intriguing example of how difficult it might be to pin down the notion. In Hungarian, verbs agree with their subjects (and to some extent their objects) for person/number. Nouns cross-reference their possessors in person/number, so that *ház* means "(a) house" while *házam, házad, háza* mean "my/thy/his house." The verb root *vár,* "wait," conjugates in the past tense (with suffix *-t*) thus: *vártam, vártad, várta* "I/thou/he waited." The person/number endings for verb and noun are identical. This correspondence, however, is not found throughout the whole paradigm, which means that for some person/number combinations there may well prove to be a single default form covering nouns and verbs and for others there will be distinct forms for nouns and verbs. It would be very interesting to know how this overlap is coded psycholinguistically. (This phenomenon is far from rare across the world's languages.)

The second point concerns syncretisms. In many inflectional systems we find that one word form is systematically identical to another form from the paradigm. Thus, in English the past participle of regular verbs (*has played, was played*) is invariably identical to the past tense form (*played;* cf. *has/was written* vs. *wrote*). Unlike Wunderlich's theory, realizational theories make use of the notion of "referral" to handle certain of these syncretisms (though not all). A referral is a special rule in the grammar that says, for instance, "to form the past participle of a regular verb, first construct the past tense and then use that form as the past participle." Rules of this sort are not allowed in Wunderlich's system; he handles the syncretisms by other means. Which approach is correct is currently a matter of controversy in morphological theory and it would be interesting to explore psycholinguistic ways of adjudicating this decision.

Frequency determines defaults in German: Default perfect *-t* versus irregular plural *-s*

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Abstract: The German facts are consistent with the hypothesis that the default is the most frequent allomorph. Plural *-s* is the least frequent allomorph and does not act as a default. There is another way to measure the frequency of perfects in which no single *-n* allomorph is as frequent as *-t*. Lexical versus computational components do not correlate with regularity.

Clahsen argues that regular and irregular morphological affixes reflect two distinct cognitive systems: "a lexicon of (structured) entries, and a computational system of combinatorial operations." There are many sources of information, and "the evidence from all . . . sources converges" (Abstract). Unfortunately, the evidence does not converge for German plurals, and the evidence for German perfects converges with frequency.

Clahsen argues that, among other characteristics, regular affixes generalize to nonce forms and overgeneralize to irregulars. German perfect *-t* does act like a default. German plural *-s* is *very* different. Marcus et al. (1995, p. 235) found the following experimentally:

Adults do not often generalize *-s* to nonce forms, even when they do not rhyme with real German words.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

With foreign words, *-s* is at best tied with other plural suffixes. Only in proper names do adults prefer *-s* as the best plural suffix.

All three facts are counter to Clahsen's predictions, but especially the behavior of proper names. Clahsen treats proper names as an arbitrary class, but they are in fact a special meaning-based class in many languages (including English and German, in which they are the only singular count nouns that do not obligatorily take an article: proper noun **the John* vs. common noun *the john*). Defaults in Clahsen's system *cannot* generalize *just* to a meaning-based subclass of words. The intermediate status of foreign words is easily explainable, insofar as all subjects were familiar with English, French, or Spanish, all of which mark plural with *-s;* the speakers may have generalized this foreign plural, much as the plural of nonce *gorbus* might be *gorbi.* Clahsen et al. (1992, p. 244) also show that normal and SLI children rarely generalize or overgeneralize *-s* in natural speech. In section 5.1.2, Clahsen shows that normal children in experimental situations, however, *do* generalize *-s,* but he does not explain the discrepency with previous studies.

Clahsen claims that perfect *-t* and plural *-s* are not the most frequent allomorphs in adult German. However, it it is not clear how to measure frequency. Clahsen counts all forms that contain *-n,* but differentiates between two classes of verbs that take *-t:* those in which the suffix is added to the base and those with an idiosyncratic stem change. However, *-n* is not a single pattern; there are more than ten subpatterns, in all but one of which there is an idiosyncratic stem change. Clahsen does not give the statistics, but it is likely that no single subpattern matches the frequency of *-t.* The default pattern is the most frequent, as predicted by associative learning theories. Only by summing the frequencies of different subpatterns of *-n* (without justifying doing so) can Clahsen argue that frequency does not predict the results.

With *-s,* the main issue is why it generalizes to common nouns as much as it does, given its low frequency. Stemberger (1996) notes that *-s* is unique among nonzero plurals in that it never increases the number of syllables. Zipf (1935) showed that German has a strong statistical tendency towards short words, with one syllable more common than two, two more common than three, and so on. *-s* Leads to words of more frequent lengths than any other plural suffix (as does perfect *-t*). There may be a statistical favoring of *-s* owing to the high frequency of its phonological characteristics. We know that such factors influence morphological development in young children (Bernhardt & Stemberger 1998, pp. 475ff, 654ff) and also play a role in adult language morphology (see, e.g., Kager 1996). Associative theories may also take phonological frequencies into account in learning morphology, explaining the slight advantage that *-s* has.

Plural *-s* and perfect *-t* behave differently in other ways. In Figure 6, for the F7 site, event-related potentials (ERP) for incorrect noun plurals are comparable for masculine/neuter and regular (counter to Clahsen's prediction) but are different for *correct* forms. However, in Figure 7, ERPs for perfects are different for *incorrect* forms but comparable for correct forms. If *-t* and *-s* are both defaults, these differences cannot be explained.

Clahsen argues for a distinction between lexicon and computational combination, but that distinction cannot correspond to regular versus irregular. Clahsen assumes that an irregular form such as *drank* has a complex lexical entry: /drɪŋk/+/æ/. The actual pronunciation, [dræŋk], is not part of the lexical representation but must be constructed computationally by combining the parts in the lexical representation. The difference between irregular *drank* and regular *walked* is solely whether the lexical representation contains a link between the verb and the "affix" (see Stemberger 1985, pp. 178ff) Furthermore, in producing the word *drank,* the base *drink* is accessed in Clahsen's model. Should that not mean that the frequency of the base is inherited, so that irregulars should not show frequency effects different from the frequency of their bases? The model is not presented in enough detail for us to know whether Clahsen's predictions follow from his model.

In phonological processing, there is also a great difference between defaults (such as [Coronal] in /t/) vs. nondefaults (such as [Labial] in /p/). Phonological defaults interact with lexical information in a way that is quite different from nondefaults; see Bernhardt and Stemberger (1998, pp. 122ff, 171ff, 421ff, and passim) for exploration in first-language acquisition. One would hope that /t/ and /p/ do not represent two distinct cognitive systems, but Clahsen's approach leads to that conclusion.

There is clearly a difference between regular and irregular forms. However, that difference is not a binary one. German perfect *-t* acts like a default and is also undeniably the most frequent subpattern. German plural *-s* does not act like a default, so its low frequency is not a problem, but it does not act like other irregular patterns either. It has not been demonstrated that there are different mechanisms underlying regular versus irregular forms in German, but there is clearly a distinction between information that is restricted to one or a few lexical items and information that is general to the system. All evidence suggests that the two types of information are thoroughly intermixed, in speech processing and within grammars.

The functional neuroanatomy of inflectional morphology

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Abstract: Clahsen has presented an impressive range of psycholinguistic data from German regular and irregular inflection to support the view that lexical memory and the combinatorial operations of grammar are subserved by distinct mental mechanisms. Most of the data are convincing and important. I particularly applaud Clahsen's effort to extend this lexical/grammatical dichotomy from mind to brain. Here I discuss some problems with the evidence presented by Clahsen in support of a neural lexical/grammatical dichotomy, and offer some additional evidence to reinforce this neural distinction.

Clahsen discusses data from two event-related potential (ERP) studies of German inflection and from one of Italian inflection. In all three studies, regular and irregular items yielded distinct difference waves for incorrectly versus correctly inflected forms. He takes these results to suggest that affixation-based and lexically based inflection are subserved by distinct brain structures. However, this conclusion must be treated with caution.

In two of the studies, of German and Italian past participle inflection, only the irregulars yielded large difference waves. The absence of substantial difference waves for regulars is consistent not only with dual-mechanism models but also with single-mechanism models that posit that regulars and irregulars are computed by the same neural processes and that incorrect irregulars are particularly difficult to process. Much stronger support for a dual-mechanism view would come from double dissociations that link regulars and irregulars to distinct difference waves.

It is also puzzling why different ERP patterns were found in each of the three studies. Whereas the German plural and past participle incorrect irregulars yielded left anterior negativities (compared to correct irregulars), Italian incorrect irregulars yielded widespread but somewhat right lateralized negativities. Also, whereas the incorrect regulars yielded a central negativity for German plurals, this was not found for the other two studies.

The most convincing results were found in the German plural study. Incorrect irregulars yielded a left anterior negativity (LAN), a pattern that has previously been associated with syntactic and morphosyntactic violations. In contrast, incorrect regulars produced an N400, which has previously been linked to lexical-semantic violations (Hagoort & Kutas 1995). As in the other two

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

ERP studies, the incorrect regulars were irregularized (*-n*-suffixed) and the incorrect irregulars were regularized (*-s*-suffixed). Clahsen suggests that the LAN reflects grammatical processes of affixation, whereas the N400 may be tied to lexical processing. However, the violations of regulars and irregulars confound lexical and grammatical processes. The presentation of an overregularization such as *mouses* involves a violation of the lexical expectancy of *mice* as well as an application of the suffixation rule, making it impossible to link the LAN to either lexical or grammatical processing. Similarly, irregularizations of regulars involve both a grammatical violation – a failure of the rule to apply – and the formation of an irregular-like novel form, again making an unambiguous interpretation of the observed N400 impossible. Thus, this ERP study is important in that it suggests a neurophysiological dissociation between the processing of regulars and irregulars, but it stops short of linking either regular or irregular transformations to electrophysiological patterns that are independently associated with grammatical or lexical-semantic processing.

In contrast, in a recent ERP study of regular and irregular English past tense morphology, incorrect regulars and irregulars were presented as stem forms (e.g., Yesterday I *walk* after lunch). In comparisons to ERP waves of correctly inflected forms, incorrect regulars (i.e., an illicit absence of past tense affixation) yielded a LAN, whereas incorrect irregulars (i.e., an illicit absence of a memorized past tense form) yielded a more central distribution (Newman et al. 1998). In a second study designed directly to compare regular/irregular morphology and syntax/lexical-semantics, subjects viewed sentences with and without violations of syntactic phrase structure and lexical-semantics (after Neville et al. 1991) as well as regular and irregular past tense morphology. Violations of regular verb inflection and syntactic phrase structure yielded LANs, whereas incorrect irregulars and lexical-semantic anomalies yielded N400-like waveforms (Newman et al. 1999). These results link regular morphology to syntax and irregular morphology to lexical-semantic processing.

Because the N400 pattern is associated with temporal lobe sites (Nobre et al. 1994), the findings also link irregular morphology to temporal lobe structures. However, the LAN has not been associated with any neuroanatomical loci. Therefore, we must resort to other types of evidence if we are to discover the neural correlates of regular morphology and grammatical rule processing more generally.

Anterior aphasia, which is associated with damage to left frontal regions, and with impairments producing syntactically correct sentences and using morphological affixes, leads to greater difficulty producing, reading, and judging regular than irregular English past tense forms (Badecker & Caramazza 1987; 1991; Marin et al. 1976; Ullman et al. 1995; 1997b; in press). Posterior aphasia, which is associated with damage to left temporal/temporoparietal regions, and impairments in the use of "content" words such as nouns and verbs, leads to the opposite pattern (Ullman et al. 1997b; in press).

A similar double dissociation has been found between two types of neurodegenerative disease. Alzheimer's disease (AD) is associated with temporal-lobe damage and lexical-semantic impairments but relatively spared frontal/basal-ganglia structures and syntactic processing (Nebes 1997). Parkinson's disease (PD) is associated with frontal/basal-ganglia damage and syntactic processing deficits but relatively spared temporal lobe structures and word use (Dubois et al. 1991). Whereas AD patients with lexical-semantic deficits have greater difficulty producing irregular than regular English past tenses and Italian present tenses and past participles, PD patients with right-side motor skill deficits have greater difficulty with English regular than irregular past tenses (Cappa & Ullman 1998; Ullman et al. 1993; 1994; 1997b).

Magnetoencephalography (MEG) provides a method to investigate the real-time spatio-temporal dynamics associated with the production of regular and irregular past tense forms. Rhee et al. (1999) recorded from a whole-head 64-channel magnetometer while subjects produced past tenses of regular and irregular verbs. Satisfactory solutions to the inverse problem of dipole fitting for data averaged over all subjects were found at a number of 10 msec time slices following stimulus presentation. No right hemisphere dipoles were found. Dipoles in both the regular and irregular verb conditions were localized to a single left temporal/parietal region (250–310 msec). Dipoles in left frontal regions were found only for regular verbs and only for time slices immediately following the left temporal/parietal dipoles (310–330 msec). The results are consistent with a dual-system model in which temporal/parietal-based memory is searched for an irregular form, whose successful retrieval blocks the application of a frontal-based suffixation rule (Ullman et al. 1997b).

In sum, although the findings from the ERP studies reported by Clahsen must be treated with caution, his main argument appears to be correct. Converging evidence from multiple investigations indicates that distinct brain structures subserve regular and irregular morphology. Moreover, the data suggest that processing regulars (and grammatical rules more generally) depends largely upon left frontal/basal-ganglia circuits, whereas processing irregulars (and lexical forms more generally) depends largely on left temporal lobe circuits.

Single mechanism but not single route: Learning verb inflections in constructivist neural networks

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Abstract: Clahsen's theory raises problems that make it seem untenable. As an alternative, a constructivist neural network model is reported that develops a modular architecture and in which a single associative mechanism produces all inflections, displaying an emergent dissociation between regular and irregular verbs. Thus, Clahsen's rejection of associative models of inflection concerns only a subgroup of these models.

The qualitative distinction between the mechanisms for regular and irregular inflections lies at the heart of the dual-mechanism theory adopted by Clahsen: Each inflected form is produced either by the default rule or in the associative lexicon. However, the important question of the character of the interaction between these two mechanisms remains unclear. The only specific explanation that has been put forward is the *blocking principle* (Marcus et al. 1995), which states that when an inflection is produced, the lexicon is searched for an entry that, if found, blocks the application of the rule. Although it can intuitively account for several psycholinguistic data, an implementation of this principle (Nakisa et al. 1999) has shown that it bears many problems and yields no advantage over single-route classifiers. The dual-mechanism theory is underspecified in this important aspect, and Clahsen's rejection of fully implemented single-mechanism associative models on the basis of the vague dual-mechanism theory seems premature.

A second problem arising from the assumed qualitative distinction concerns the German mixed verbs. These verbs, which represent 32% of all participle tokens, combine an irregular stem with the regular ending *-t* (e.g., *denken à gedacht*). In a dual-mechanism account these verbs have to be considered as irregular (because they are not formed by the rule), with the consequence that *-t* can be both a regular and an irregular ending.

A third problem concerns the acquisition of the English past tense. Here, children occasionally make mistakes such as *broked* and *tooked*, where the regular ending is attached to an irregular past tense form (see, e.g., Marcus et al. 1992). If the two mechanisms of the inflection system are distinct, such blends between the two mechanisms are hard to explain.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

A final problem concerns impaired processing: Penke et al. (1999) found that, for German agrammatic aphasics who showed specific deficits for irregular inflections, the only errors occuring with regular verbs were for those regulars that were similar to irregulars, and they could therefore be viewed as "less regular" than others. An analysis of the errors made with irregular verbs showed that those that were similar to regular verbs were overregularized more often than those that were dissimilar to regulars. Thus, there seemed to be a grading within regular and irregular verbs that was determined by the similarity to the respective other group. Such phenomena are best explained by associative effects for regulars, which, according to the dual-mechanism theory, should not exist.

Taken together, these points support a view in which there are no qualitatively distinct mechanisms for the production of regular and irregular inflections. Instead, regulars and irregulars can be seen as two ends of a continuum, with mixed verbs and the blends produced by children representing intermediate cases.

An implemented model that is based on this view is a constructivist, single-mechanism neural network that accounts for the phenomena found in past tense acquisition (Westermann 1997; 1998) and in impaired adult language processing (Westermann et al. 1999). This model starts with direct connections between the input and the output units, and during the learning process it constructs a hidden layer of *receptive fields* in response to the input data. The model takes into account recent theoretical arguments (Quartz 1993) and neurobiological and cognitive developmental evidence for constructivist development (Elman et al. 1996; Johnson 1997; Quartz & Sejnowski 1997).

The network model displays a double dissociation between regular and irregular verbs without having to rely on qualitatively distinct mechanisms. Instead, it exploits two representations for each verb: The direct phonological input representation is, through the constructivist learning process, enhanced with similarity-based, localist representations in the hidden layer. The dissociation between regular and irregular verbs emerges because they rely to different degrees on these two representations.

This explanation does not imply, however, that the claim of two qualitatively distinct production mechanisms is merely shifted onto two qualitatively distinct representations with all else being equal: Both representations are activated for all verbs, but they are exploited to different degrees by regular and irregular verbs. Whereas production of most of the regular participles is based on the direct input representation alone, most irregulars rely mainly on the localist hidden layer. In this way the model accounts easily for the problematic data outlined above: The degree of activation of each pathway determines the degree of (ir)regularity of a verb, and intermediate cases are produced when both pathways are active. The distinction between the mechanisms producing regular and irregular inflections is thus quantitative and not qualitative.

Hence, instead of a dual-mechanism theory I propose a dual-representation model emerging from a constructivist learning process. In this way, a single associative mechanism can account for the dissociation between regular and irregular inflections and avoid the problems of the dual-mechanism theory outlined above.

According to this interpretation, theories and models can be distinguished along three essential dimensions: *fixed structure* versus *structure emerging from constructivist development; homogeneous architecture* versus *modular architecture;* and *single mechanism* versus *multiple mechanisms.* The dual-mechanism theory propagated by Clahsen is a fixed, modular-architecture, multiple-mechanism account, and his rejection of associative models is aimed at fixed, homogeneous-architecture, single-mechanism models. The model reported here is a constructivist, modular-architecture, yet single-mechanism account that avoids problems both of the dual-mechanism theory and of homogeneous neural networks. The strength of this model lies in its constructivist nature, which leads to modularization in response to environmental input and which allows it to account for the observed human data based on a single associative mechanism. The constructivist model thus makes the postulation of two qualitatively distinct mechanisms in the language system unnecessary.

ACKNOWLEDGMENTS

I thank Martina Penke, Richard Shillcock, and David Willshaw for helpful comments on a draft of this commentary.

On default rules and other rules

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Abstract: This commentary concentrates on the nature of irregularity in morphology. What is called "irregular" in the target article by Clahsen is not a homogeneous class. Rather, there are areas of strong subregularities in the domains both of German participle formation and of German plural information that need to be distinguished from the irregular domain.

Introductory remarks. The work under discussion here constitutes one of the few examples where very specific (and therefore testable) hypotheses of linguistic theory are under close scrutiny from experimental studies. I should state at the outset that I have been involved in some of this work, and that I am convinced that most of the claims made by Clahsen in his target article are correct, as far as our current knowledge goes. It cannot be stressed enough how many-sided and versatile the various experiments on the status of the "regular" vs. "irregular" parts of German inflectional morphology are. Furthermore, new evidence for the position taken here is found almost constantly. For example, one of the fundamental empirical claims, namely, that the plural system of German nouns is basically divided into a default system (suffix *-s*) and the rest, has been confirmed by our own research in an additional event-related potential (ERP) study (Niedeggen-Bartke et al. 1998).

It must be stressed that in German linguistics there is widespread disbelief in some of the claims defended in this paper. In particular, the claim that the plural suffix *-s* constitutes the default affix in German is debated vigorously (e.g., Neef 1998b; Wurzel 1990). In this sense, this work does not reiterate self-evident truths. In the following, I wish to elaborate from the linguist's perspective on a few points where further elaboration of the basic model seems possible or even, according to my own research, necessary.

A general comment. The model advocated in the target article distinguishes between two components, a rule-based system and a memory system. In current linguistic theory, the first of these can be captured by a variety of mechanisms, of which the "rule" is only one, especially if by "rule" we mean a rewrite rule of the type "A replaces B (in some context C)." Clahsen is quite aware of the conceptual alternatives, so we find alternative formulations such as "computational system" (which is probably too general) or "symbol-manipulating system of combinatorial operations," (which comes closer to a particular type of rule system in which information-preserving combination of units is the basic mechanism instead of [information-changing] rewriting). Another type of symbol-manipulating system explored in more recent work is constraint-based grammar, in which well-formed expressions are those that follow some logic of constraint satisfaction. Constraints can be either violable or "soft," as in optimality theory (Prince & Smolensky 1993), or unviolable, "hard," as in various theories developed in computational linguistics (Pollard & Sag 1987). These observations are important; they demonstrate that the rule component of the dual-mechanism model is not necessarily one that adheres to the rewrite-rule formalism of Chomsky (1965) and Chomsky and Halle (1968). In other words, the nature of the linguistic "computational system" itself is in need of further exploration.

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

The nature of irregulars. Morphological theory, focussing on the word grammar, is currently very much divided into adherents of a rule-based description and adherents of a description that relies purely on the (more or less) idiosyncratic relationships between words. There is good reason for the fact that this debate is fought in morphology (and not elsewhere); words tend to acquire all kinds of idiosyncrasies over time. Therefore, the mental lexicon (presumably of each language) is a conglomerate of both regularity as well as irregularity. My main point in this commentary is this: The irregular formations in German are not just irregular, neither for nouns nor for verbs; there is a substantial area of partial regularity alongside the true irregularities. Although the results found by Clahsen and many other researchers demonstrate clearly that there are substantial differences between types of morphology, my claim is that there may be more finely structured sets of morphological classes.

Take the cross-modal priming experiment on German participles (sect. 4.4): The difference between *-t* participles and *-n* participles in terms of priming is ingeniously brought to light by the experimenters, but this proves only that *-n* participles are different, not that they are irregular, and, in fact, linguistically they are both regular as well as irregular: They invariably have the *-n* suffix, but they also show internal vowel alternations that are, by and large, unpredictable. The fact that all so-called irregular participles have a suffix *-n* is a substantial area of regularity within the irregular domain.

There are also substantial generalizations within the system of noun plurals. Such regularities are quite strong and thus have to be distinguished from true irregularities. These regularities in the domain identified as irregular have always been discussed by scholars of German (see references from Clahsen's target article). I will call these regularities "subregularities" in the rest of this commentary, to emphasize that the default role of the *-s* plural is not disputed here.

The most salient of these subregularities are the following three: (1) Feminine nouns predominantly take an *-n* as plural affix, whereas the plural form of nonfeminine nouns cannot be clearly predicted by gender alone. (2) Within the group of nonfeminines, plural forms represented by the *-e* suffix are found as well as plurals marked with the *-er,* but the latter plural is in a clear minority. This view is confirmed by the countings based on the CELEX lexical database. (3) There is a substantial number of nonfeminine nouns taking a *zero* plural. All of these are nouns ending in a so-called reduced syllable, as in *Filter,* "filter," *Segel,* "sail," *Garten,* "garden." Not a single noun consisting of just a single syllable or of two full syllables (see *Hund,* "dog," or *Arbeit,* "work") ever has a *zero* plural.

Thus, we can identify at least these three rather strong subregularities in the German noun system. Relevant evidence arises not just from quantitative patterns as found in, for example, the CELEX database but also from the integration of loan words. The majority of loan words adopt the 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 assimilated, they follow the subregularities sketched above.

To be sure, small sets of counterexamples to the patterns presented exist, and the distinction between assimilated and nonassimilated loan words is not always clear-cut either. Nevertheless, the distinction between subregular and irregular patterns seems to be very robust. In our own research, we are currently investigating these distinctions by means of an ERP study of irregular plurals.

Final remarks. Why a dual system? A linguistic system of rules and memorized items is quite plausible, but it is also conceivable that matters are just slightly more complex. My remarks above suggest a triple hierarchy of regularity. Although it is completely unclear how general this pattern is, it is striking that inflectional systems of languages are quite often described by means of a tripartite hierarchy. For example, McCarthy and Prince (1990), in their carefull analysis of the plural system of Arabic nouns, distinguish a default case (sound plural), a semiregular case (broken plural), and various truly irregular formations. From the perspective of linguistic theory, there are various approaches that could model the threefold distinction within the inflectional morphology; one possibility would be a three-level lexicon (proposed for German by Wiese (1996, sect. 5.3.2); another would be a straightforward reference to the well-established categories of roots, stems, and words, with irregular inflection being equated to root inflection, subregular inflection to stem inflection, and default inflection to word inflection. Finally, it is worth keeping in mind that the controversy between accounts relying on explicit symbols and those relying on distributed patterns is not necessarily to be decided in favor of one or the other. As has been noted before, it is quite conceivable that connectionism and symbolism address different levels of the mind (Johnson-Laird 1998, p. 192): "One resolution of the competing theories is therefore to postulate different levels of representation: high-level explicit symbols and low-level distributed symbolic patterns. . . . The low-level processes implement the high-level rule."

German noun plural reconsidered

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Abstract: German noun plurals not ending in *-s* are not as irregular as Clahsen suggests. Feminine nouns get the *-n* plural, unless they umlaut and are subject to a constraint that requires a reduced final syllable in the plural. Another regular class is masculine nouns ending in schwa, which are weakly inflected. It is suggested that more differentiated psycholinguistic experiments can identify these regularities.

Clahsen concludes from his experimental findings that the dual-mechanism model holds for both German participles and German noun plurals. I fully agree with his conclusions concerning participles but disagree with those about plural.

In the participles, only two suffixes compete, so only two mechanisms can be distinguished: the regular *-t* suffix and the irregular *-n* suffix. The latter cannot be affixed by rule but must be regarded as part of the participle entry. If one assumes a disjunctive rule of participle formation,

(1) a. Strong verbs take the suffix *-n*
b. All other verbs take the suffix *-t,*

the first part (1a) is circular, because a verb is strong regarding participle formation exactly if it takes the *-n* suffix. There are verbs with vowel alternation in the past that nevertheless have a weak participle (*stecken, stak, gesteckt,* "stick"; *können, konnte, gekonnt,* "can") and also verbs that are weak in the past but strong in the participle (*hauen, haute, gehauen,* "hew").

The situation is quite different with the noun plural, which can be marked with *-s, -n, -er,* or *-e* (schwa) or can be unmarked; in addition, umlaut can appear in the plural. Clahsen claims that *-s* is the only regular plural suffix and has to be distinguished from all other plural endings of nouns, which are said to be irregular, and hence lexically fixed, according to the dual-mechanism assumption. My objections are as follows.

First, one can see that the *-s* plural is restricted to *atypical* nouns, including proper names, nonnative and onomatopoeic nouns, nouns that end in a back vowel (o, u, or a), and those that are converted from other categories, as well as acronyms and truncated forms (Marcus et al. 1995). If the syntactic context (e.g., "many X") requires a plural noun, many words, and even phrases, can become a plural noun, so /s/ simultaneously makes X a noun and pluralizes it. Let us assume that a typical noun is characterized by [+N] in the lexical entry, and ends in a consonant or a nonback vowel. Clearly, most nonsense words do not bear the feature

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

[+N]; they are forced to become nouns only by the syntactic context. Therefore, these words undergo *-s* suffixation. Moreover, low-frequency nonfeminine (and nonumlauting) nouns ending in a consonant (such as *Mittwoch,* "Wednesday"), for which the speaker has not stored a plural form, either receive schwa plural or *-s* plural. Thus, there is good reason to assume that the *-s* plural has acquired default status in order to capture all these instances of atypicality.

Second, typical nouns do not behave as irregularly as Clahsen suggests. In many instances, the plural form of the noun can be predicted. This is particularly true for the following three classes of nouns:

1. All (nonumlauting) feminines have an *-n* plural (Wiese 1996, p. 139). For instance, the productive derivational suffixes *-ung* (turning verbs to nouns) and *-heit/keit* (turning adjectives to nouns), as well as many less productive suffixes, create nonumlauting feminines. All derived feminines take the *-n* plural, a fact that must not be fixed in their lexical entries. (The regular *-n* plural of feminines must not be confused with the irregular *-n* plural of nonfeminines, which must be lexically fixed: *Professor-en,* "professors"; *Muskeln,* "muscles"; *Rhythmus – Rhythmen,* "rhythms"; *Bau – Bauten,* "constructions.")

2. All masculines ending in schwa are weakly inflected: They take *-n* both in the plural and in all case-inflected singular forms (*Hase,* "hare"; *Falke,* "falcon"; *Russe,* "Russian"). Again, no plural entry is necessary. (All other nouns with weak inflection must have an additional lexical entry for the inflected *-n* form.)

3. Nouns with an umlauting plural must have an unassociated vocalic feature in their lexical entry (say, CORONAL). From general assumptions, unassociated features in the underlying form must be associated in a derived context such as plural, so the appearance of umlaut in the plural is triggered by the unassociated vocalic feature. The plural form itself must be lexically fixed only for nouns with *-en* plural (*Rad – Räder,* "wheels"; *Dorf – Dörfer,* "villages") but is predictable for all other umlauting nouns (see below).

All typical noun plurals of German are subject to the prosodic constraint REDUCEDFINSYLL: They have a final syllable whose rhyme is reduced to schwa or a syllabic sonorant (*n, l, r;* Golston & Wiese 1996; Neef 1998b). This constraint allows German nouns that already end in a reduced syllable to have an unmarked plural, whether they umlaut or not: *Vogel – Vögel,* "birds"; *Mutter – Mütter,* "mothers"; *Laken,* "sheet"; *Gebirge,* "mountains." There is no need for a lexical entry that duplicates the same form for singular and plural, because from the absence of a more specific plural one can predict that the plural should be unmarked in these cases.

Furthermore, one can predict that all typical German nouns ending in a consonant should be subject to REDUCEDFINSYLL in the plural. Under the assumption that schwa epenthesis is the least expensive operation that satisfies this constraint, nouns ending in a consonant should be suffixed with schwa in the plural (if not specified otherwise), regardless of whether they umlaut or not: *Hut – Hüte,* "hats"; *Kraft – Kräfte,* "forces"; *Arm-e,* "arms"; *Abend-e,* "evenings." Again, there is no need to assume a lexical entry for the plural.

One must notice that umlaut takes precedence over *-n* plural: if a feminine noun umlauts, its plural form ends in schwa or is unmarked, otherwise it gets *-n* plural. Thus, by the interaction of these devices, all German feminine nouns have a regular plural. Only for nonfeminines might the plural be lexically fixed, and only for these nouns can uncertainty about the correct plural form arise. If one assumes that REDUCEDFINSYLL and *-s* plural are equally ranked, the plural of a noun already ending in a reduced syllable (such as *Trecker,* "tractor") can be unmarked or *-s,* and the plural of other consonant-final nouns (such as *Mittwoch*) can be schwa or *-s.* This explains why speakers can produce two different plural forms in free alternation for uncommon nonfeminine nouns: They follow either the prosodic constraint for typical nouns or the default for untypical nouns.

Summarizing, it is unmotivated to assume that the plural form is lexically fixed for regular instances of German plural nouns. One expects that more differentiated experiments will identify these instances as regular. To cite just one piece of evidence, Penke and Krause (1999) found that aphasics make significantly fewer errors in (regular) feminine *-n* plurals than in (irregular) nonfeminine *-n* plurals; moreover, the error rates reveal frequency effects only for the latter. A similar difference was found in a priming study with normal subjects by Sonnenstuhl (1999).

The dual-mechanism model is correct in dissociating regular from irregular affixation. It is incorrect when it identifies regular affixation with default affixation. There can be phonological, prosodic, or categorial (e.g., gender) conditions under which affixation is regular, *without* being default. In other words, the dual mechanism, as it is proposed in Clahsen's target article, is too pure a mechanism to capture the several kinds of conditions under which morphological regularities have to be described.

Dissociation between regular and irregular in connectionist architectures: Two processes, but still no special linguistic rules

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Abstract: Dual-mechanism models of language maintain a distinction between a lexicon and a computational system of linguistic rules. In his target article, Clahsen provides support for such a distinction, presenting evidence from German inflections. He argues for a structured lexicon, going beyond the strict lexicon versus rules dichotomy. We agree with the author in assuming a dual mechanism; however, we argue that a next step must be taken, going beyond the notion of the computational system as specific rules applying to a linguistic domain. By assuming a richer lexicon, the computational system can be conceived as a more general binding process that applies to different linguistic levels: syntax, morphology, reading, and spelling.

Two-process models represent a fairly general solution to the "quasi-regularity" problem in a number of cognitive domains. Quasi-regularity implies that, in a given problem domain, examples occur for which the solution is not fully consistent with the regularities represented in the problem set as a whole. Three paradigmatic quasi-regular domains within the English language are (1) the past tenses of verbs, (2) reading aloud, and (3) spelling.

For all these domains, various two-process models have been proposed. In the area of reading aloud, for instance, the idea that the regularities employed in reading nonwords (i.e., novel forms) may be represented separately from knowledge of individual word pronunciations has a long history (see, e.g., Baron & Strawson 1976; Coltheart 1978). A similar architecture has been postulated for spelling (see, e.g., Ellis 1982). The similarity between these two domains and inflectional morphology is striking. Neuropsychological studies of brain-damaged patients have shown double dissociations between the two forms of knowledge for all these domains.

In reading, surface dyslexic subjects show an impairment in reading irregular words but can read regular words and nonwords. Phonological dyslexics, on the other hand, cannot pronounce words they have not encountered before (e.g., nonwords). A corresponding dissociation has been observed in spelling (see Denes et al., 1999, for a review of acquired dyslexias and dysgraphias).

For the past tense domain, an equivalent dissociation has been recently shown by Ullman and colleagues (1997b). What is most striking, however, is that problems with the irregular inflections are associated with problems in reading and spelling irregular words, whereas problems in the production of regular inflections

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

are associated with problems in reading novel words (Ullman et al. 1997b). Furthermore, in the study by Ullman et al. (1997b) the patients performing poorly on regular past tenses were also those with "syntactic" problems (agrammatism and Parkinson's disease), whereas the patients performing poorly on the irregular past tenses were anomic (posterior aphasia and Alzheimer's disease). Although neuropsychological associations are not considered to be very informative (see Shallice, 1988, for discussion; also book reviews and Précis of Shallice's *From Neuropsychology to Mental Structure BBS* 14 (3) 1991), in the present case they may be.

Some neural network modellers have proposed that the distinction between word-specific representations and a computational system has no psychological validity and that a neural network with a single, homogenous route from input to output can handle both the regular and the irregular cases and still can generalize the regularities to novel cases (see, e.g., Plaut et al. 1996; Plunkett & Marchman 1993; Rumelhart & McClelland 1986; Seidenberg & McClelland 1989). However, the successful simulation of double dissociations has proved elusive for single-route models. Recently, Bullinaria and Chater (1995) have presented a very careful and insightful analysis of the properties of single-route neural network models, looking at how they manage to handle both productive regularities and exceptions in a single knowledge base and how these capacities dissociate under disruption (addition of noise, removal of hidden units, etc.). The authors demonstrate that, especially as the complexity (size) of the problem increases, double dissociations do not occur under disruption. They conclude that their results "set a challenge to modelling researchers to show that rule/exception double dissociations can occur in such networks" and they predict that "such a challenge cannot be met" (Bullinaria & Chater 1995, p. 260).

Neuropsychological double dissociations, however, can be easily handled by connectionist two-process models. Zorzi et al. (1998a) have shown that the distinction between word-specific information and (componential) knowledge about the regularities of the domain can be quite easily realized in standard neural networks if the input and output layers, as well as being linked via some kind of intermediate representation (hidden units), are allowed to make direct contact, that is, that part of the network is a *two-layer* net. A kind of "modular decomposition" (see Jacobs 1999) emerges in the system simply in response to the different computational demands posed by the problem of learning regular and irregular items. The use of two-pathway network architectures results in a decomposition of the problem in terms of regular versus irregular (or componential versus word-specific) for the different domains of reading (Zorzi et al. 1998a; 1998b), spelling (Houghton & Zorzi 1998), and past tenses (Westermann 1998).

If we consider inflectional morphology and reading, there is evidence that in both cases equivalent computational solutions can fit the observed data. Where does this lead us? To an interesting new and parsimonious hypothesis. Assuming a structured lexicon (see Levelt 1989; McDonald et al. 1994), we may not have to postulate that each domain draws from specific abstract linguistic rules (part of the language faculty) but instead might postulate some more general binding mechanisms that allow for the *componential* manipulation of stored codes (phonological codes in particular). These binding mechanisms may be shared between domains, and/or they may share resources. As has been shown by recent connectionist models, the ability of productive generalization in a given domain can be based on simple associative systems (rather than on abstract, algebra-like rules; see also McClelland & Plaut 1999). However, the issue of rules versus connections must not confound that of one versus two mechanisms: Connectionist two-process models (see, e.g., Zorzi et al. 1998a) dispense with explicit symbolic rules but predict double dissociations.

Author's Response

The dual nature of the language faculty

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Abstract: The following discussion aims to illuminate further the way in which morphologically complex words are represented in the mental lexicon. It is argued that the dual-mechanism model can accommodate the linguistic and psycholinguistic evidence currently available, not only on German inflection (as pointed out in the target article) but also on other languages (as presented in several commentaries). Associative single-mechanism models of inflection, on the other hand, provide only partial accounts.

The core idea that I argued for in the target article was that the language faculty has a dual structure consisting of two components, a lexicon of (structured) entries and a system of combinatorial operations to form larger linguistic expressions. The commentaries received can be divided into two broad categories. On the one hand, the dual-mechanism model is claimed to be too simple in that it does not capture relevant linguistic generalizations, such as those among irregular German noun plurals. On the other hand, the dual model comes out as too complicated. Single-mechanism associative models of language are claimed to be sufficient to explain the facts of German inflection, and the extra mechanism of combinatorial rules is allegedly superfluous. These different responses were expected and reflect the fact that the dual-mechanism model is a hybrid that combines elements from linguistics ("symbolic operations") with notions from psychology ("associative structures"). The result is that the model does not fit in with the mainstream views, either in linguistics or in psychology.

Most linguists do not like the idea that predictable forms, such as the participle *-n* and the plural *-n* in German, which used to be described in terms of inflectional rules, should now be assumed to be stored in associative memory. Many psychologists, on the other hand, find it hard to accept an extra computational mechanism that accounts for only a small set of vocabulary items, as in the case of the German *-s* plural. However, putting the traditions of the two disciplines aside, what matters is whether the model and the analyses presented in the target article are empirically correct. To this end, we have investigated two inflectional systems of German from almost every angle imaginable, aiming at producing empirical evidence to determine the role of combinatorial operations and of stored entries in language.

A large number of commentaries were contributed, and I am grateful to the authors of all of them. As will become clear from the discussion below, some of them led me to rethink and modify claims made in the target article; others misinterpreted some of the findings and signaled the need for clarification. However, the major claim of the target article will be maintained: The dual-mechanism model can account for the full set of empirical facts presented, whereas single-mechanism models provide only partial explanations. The subsequent discussion will be structured along four fundamental questions, adopted from Chomsky (1986): (1) What is the nature of the cognitive system that

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underlies the knowledge of language? (2) How do children acquire this system? (3) How is this system used in production and comprehension? (4) How is this system represented in the brain?

It should be clear that an answer to question (1) is *logically* prior to answers to the other questions; that is, we must have some view of the nature of the relevant cognitive system before we can even address the other questions. In this sense, the approach I take is nonreductionist. Models of the knowledge of language might be highly abstract and still contribute to our understanding of the mind. **Schnelle**'s rigid reductionism that rejects "for principled reasons" all kinds of cognitive models that have not (yet) been elaborated "down to single neurons" does not in my view offer a sensible research perspective for cognitive science in general, and certainly not for linguistics.

R1. Words and rules in the mental grammar

The research presented in the target article was undertaken from a specifically linguistic perspective. With respect to the fundamental question (1), we have assumed that knowing a language means having a mentally represented grammar and that the key to understanding the knowledge of language is to study the nature of such a grammar. Proposals about the mentally represented grammar can be formulated and evaluated using evidence from different sources and disciplines: adult languages, child language, psycholinguistic experimentation, language change, and so on. It was argued in the target article that the mental grammar has a dual structure and that the distinction between the two representational mechanisms ("storage" and "computation") is supported by empirical evidence. In this context, it was helpful that **Clifton et al.** pointed out that the dual-mechanism model is primarily concerned with (modality-independent) *central representations* (which are in our terms part of the mental grammar) and not with access representations in word recognition, which might be specific to either the visual or the auditory modality. The results of the experiment they report do indeed support the dual model in that regulars (but not irregulars) show a "lack of separate central representations."

R1.1. Words, rules, and more? Several commentators accepted the basic distinction between words and rules but argued for additional layers of complexity. **Dressler** proposes a triple system of major rules, minor rules, and lexical storage. **Wunderlich, Wiese,** and **Indefrey** believe that so-called subregularities, such as feminine nouns that take *-n* plurals in German, are rule-based rather than stored in associative memory. **Corbett** points out that many languages involve more complex morphological distinctions for the category of number than the simple binary opposition we find in German and English. **Spencer** and **Carstairs-McCarthy** highlight the importance of inflectional classes where an inflectional form may act as a default for a particular class of nouns or verbs. Inflectional classes are particularly important for understanding Romance and Slavic languages, for example; see **Orsolini** and **Laudanna** on Italian and Spencer on Russian and Polish.

I will make three responses to these comments. First, it is important to note that nothing in the dual-mechanism account prevents us from assuming more than one rule per inflectional category. Consequently, there may very well be "minor" rules for the *-n* plural in German or class defaults in Italian, Russian, or Polish. What matters to the model is the central opposition between items that are stored in the permanent lexicon and elements that are defined from items in the lexicon by symbolic operations.

Second, it is not necessarily the case that the descriptively most highly valued analysis of a given phenomenon is true. Morphologists have demonstrated over and over again that almost any inflectional phenomenon can be described in terms of rules or equivalent operations, and they strive to make their accounts more economical and elegant by reducing the number of rules needed for any given phenomenon. **Wunderlich**'s latest treatment of the German plural system (Wunderlich 1999), for example, posits just two rules (for *-s* and for-*n* plurals) and nine classes of nouns, a major improvement compared for example with Mugdan's (1977) treatment, which had 10 rules and 15 lists of exceptions. But the descriptively more highly valued analysis may be empirically incorrect. I believe that this is the case for Wunderlich's account of *-n* plurals, a point to be picked up below when we further discuss the intricacies of German plurals.

Third, I concede that our research on German inflection is only a short move away from the traditional focus of psychomorphology on English and that more cross-linguistic comparisons are needed in this field (**Santelmann**). In this regard, I was happy to see that some commentators have presented new results on languages other than English or German that are relevant to the debate. The most interesting of these are perhaps those reported by **Lukács & Pléh** on Hungarian. In priming and elicited production experiments, they found clear regular/irregular differences for noun plurals that are parallel to those we found for German, despite the fact that Hungarian is a non-Indo-European language and has an inflectional system typologically different from that of either German or English. It is also important to point out that German noun plurals are not the only morphological system that has a low-frequency default. For instance, the so-called sound plurals in Arabic exhibit default behavior, even though they are less frequent than the (irregular) broken plurals. **Spencer** has identified another potential case of a low-frequency default, Polish verb inflection, and experimental study of this system should be put onto the agenda.

Orsolini claims to have found evidence against the applicability of dual-mechanism models to Italian. However, in the studies by Orsolini and her collaborators, an important linguistic property of Italian word formation is not taken into account, namely, the distinction between stem formation and affixation. For their priming experiment, the group of verbs classified as "regular" included both first and third conjugation verbs, classes that have independently been shown to exhibit divergent generalization properties (Say 1998). Say found that only the first conjugation stem forms generalize freely to all types of novel verbs, regardless of phonological content, thus exhibiting the characteristics of a default; the third conjugation stem forms, on the other hand, showed nondefault behavior, namely, frequency and similarity effects in their generalization properties. Thus, in contrast to what Orsolini and her coworkers did, one would have to tease apart first and third conjugation stem forms in order to see potential regular/irregular distinctions in priming more clearly. We have also reanalyzed Orsolini and collaborators' data from Italian child lan-

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

guage (Say & Clahsen 1999) and found three types of error: (1) default regularizations, that is, incorrect assignment of the first-conjugation regular suffix to a second- or third-conjugation verb; (2) regular conjugation-specific stems plus the regular affix instead of the correct irregular forms of a second- or third-conjugation verb, such as **venì* instead of *venne* (from *venire*, "to come"); (3) irregularizations, such as **vise* for *vide* (from *vedere*, "to see"). Errors occur on irregular verbs, not on regulars. More important, whereas all irregularizations can be interpreted as analogy-based, error types (1) and (2) are not constrained by phonological similarity. Thus, in contrast to what Orsolini suggests, her data do indeed provide support for the dual-mechanism model. Italian children overgeneralize regular stems and regular affixation to irregular verb forms, just as German- and English-speaking children do, irrespective of phonological similarity. Irregular forms, however, do not generalize beyond similarity.

Moving even further away from the languages we have been discussing so far, **Behrens & Tomasello** raise the question, What about Chinese?, wondering what the dual-mechanism model would have to say about a language that has no inflection at all. The answer is: a lot. What matters to the dual-mechanism model is not regular versus irregular inflection per se but, rather, the postulation of different mental representations for combinatorial operations and lexical entries, and this dual structure can be found in any language. Even the distinction between a regular default and a set of stored irregulars can be found in a language such as Chinese. An example from Mandarin is its classifier system, in which the classifier *GE* acts as a default in that it can be assigned to any noun that is not associated with its classifier in memory.

R1.2. Minimalist Morphology is a linguistic implementation, not a conceptualization. In the target article, I have used Wunderlich's framework of Minimalist Morphology (MM). Some commentators took issue with this framework. The morpheme concept assumed in MM or, equivalently, the notion that affixes have lexical entries (**Spencer, Blevins**) is said to be problematic, and MM is claimed to be unable to represent analogies (**Janssen, Hahn**). **Behrens & Tomasello** wonder what the model would have to say about portmanteau morphemes.

It is important to note that the dual-mechanism model does not hinge on the adoption of a particular morphological framework for analyzing the phenomena under study. MM was used as one way of linguistically implementing the distinction between lexical entries and productive morphological operations, but the core idea is compatible with various other theories of morphology. This was mentioned in note 2 of the target article and was also pointed out by **Blevins.** To take one example, the morphological phenomena under study (German participles and noun plurals) are affixal, but it is conceivable that in other languages productive morphological processes involve nonaffixal operations, such as the cases of truncational operations mentioned by Blevins. Furthermore, the crucial distinction between words and rules should apply to derivation as well as to inflection. Finally, the model does not hinge on the morpheme concept. Realization models of morphology may turn out to be superior to the item-and-arrangement approach used in MM, for example, in dealing with portmanteau morphemes. What matters to the dual-mechanism model is not the surface form, "exponence" in morphological terms; what matters is whether the phenomena are to be accounted for by symbolic operations or by (access to) lexically stored information. On the other hand, it is not exactly clear how a syntactic theory such as the one advocated by **Lightfoot** would account for the regular/irregular differences reported in the target article, even though I take Lightfoot's point that, in addition to the evidence presented in the target article, the existence of "atomic" lexical entries such as the verb *to be* in English should be mysterious for single-mechanism associative models of language.

Returning to MM, **Janssen** claims that this model of morphology does not properly express the family resemblance structure of irregulars, and **Hahn** says that the model does not capture "product-oriented analogies." Notice, however, that the lexical templates posited in MM are not merely generalizations about the hierarchical structure of lexical entries; their subnodes also contain phonological and morphological information, and these can be used to capture product-oriented generalizations and analogies.

Sereno et al. require me to show that the "structure that accounts for the construction of a syntactic representation is also responsible for the processing of regular morphology." This is based on the view that there is just one type of symbolic operation in grammar, which is used in syntax and (regular) morphology. I do not subscribe to that view. To mention just two differences, syntactic operations may involve long-distance dependencies, whereas morphological rules may refer to lexical classes (Aronoff 1994). Clearly, the claim that regular morphology is rule-based does not entail that morphology is syntax.

Finally, **Hahn** argues that schema theories as discussed in section 4.6 of the target article can handle the facts better than any kind of dual-mechanism model. To explain the properties of regulars, she posits so-called open schemas, for example, *V-/ed/* for the regular English past tense and "a particularly open schema" for German *-s* plurals. The notion of an open schema, however, is in essence just a different label for what we would call a symbolic rule, that is, a representation that imposes no conditions other than nounhood or verbhood itself. I am happy to accept that something equivalent is needed to account for the facts of German inflection.

R1.3. Quibbling over German noun plurals. What I had to say about participles in German appears to be relatively uncontroversial, and most commentators seem to accept that *-t* acts as a default, though there is the issue of how to count the frequency of *-t* (**Bybee, Stemberger**), to which I will return. With respect to plurals, commentators reacted rather differently. Many accept that *-s* is the default, while they disagree with the view that the other plural forms are stored in the mental lexicon. **Wunderlich** and **Wiese** believe that at least some *-n* plurals are rule-based; **Dressler, Indefrey,** and **Pulvermüller** think that *-e* plurals are also rule-based. On the other hand, **Stemberger** claims that the plural *-s* "does not act as a default." **Sereno et al., Nerlich & Clarke,** and **Schreuder et al.** have similar doubts. They find it hard to believe that low-frequency defaults even exist. As Schreuder et al. put it, the case of German noun plurals "has led to a Pyrrhic victory over connectionism," in that the default rule is used in only a small number of cases.

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The most interesting challenge to the account of German noun plurals given in the target article is that, in addition to *-s, -n* plurals might also be rule-based. It is true that many feminine nouns take *-n* plurals, as was pointed out by several commentators, but this does not necessarily mean that *-n* plurals are rule-based. Consider the results of our ERP plural study (Weyerts et al. 1997) in a little more detail. In addition to the conditions reported in section 4.5 of the target article, we also investigated *-n* plurals in feminine nouns ending in schwa, which according to **Wunderlich, Wiese, Indefrey,** and **Dressler** are rule-based. What we found, however, was that *-n* plurals of feminine nouns behaved like irregulars and differently from *-s* plurals. Overapplications of *-s* plurals produced a LAN (left anterior negativity) effect, an ERP response that is typical of morphosyntactic rule violations. Overapplications of *-n* plurals, however, elicited an N400 effect, which typically occurs as a response to anomalous lexical entries. These findings do not support the view that *-n* plurals of feminines involve rule-based processes. Furthermore, the priming experiment referred to by Wunderlich as Sonnenstuhl (1999) did *not* yield significant priming differences between feminine and nonfeminine *-n* plurals. Instead, both kinds of *-n* plurals produced partial priming, in contrast to regular *-s* plurals, which (as reported in sect. 4.4) led to full priming effects. Finally, the observation from Penke and Krause (1999), mentioned by Wunderlich, that aphasics produce fewer errors in feminine *-n* plurals than in nonfeminine ones, could simply reflect the fact that the former are much more frequent than the latter. Although I agree with Wunderlich that more psycholinguistic experimentation is needed in this area, the evidence currently available seems to indicate that *-n* plurals are not rule-based.

The formation of *-e* plurals has also been claimed to be rule-based, the rule being restricted to nonfeminine nouns (**Indefrey**). However, the alleged rule errs in both directions: (1) there are numerous feminine nouns that take *-e* plurals (*die Hand – Hände,* "hand – hands"), and (2) there are also many nonfeminine nouns that do not take *-e* plurals, such as *der Bär – Bären,* "bear – bears" (see Neef 1998a for relevant frequency information). Thus, to get the right results, additional phonological constraints (**Dressler**) and lists of exceptions have to be posited. An alternative has been suggested by Wunderlich (1999), following Wiese (1996). It is argued there that *-e* (which is actually pronounced as schwa) is not a plural suffix but that its presence follows from prosodic contraints such as the constraint that inflected words must not end in a stressed syllable (Golston & Wiese 1996), which are independently needed to describe the word structure of German. Wunderlich (1999) points out that these prosodic constraints also apply to base forms that end in *-s.* This accounts for all the cases mentioned by Indefrey. Similarly, the cases mentioned by **Hahn** of deverbal nouns that have a schwa plural form can also be derived from prosodic constraints, as shown by Wunderlich (1999). According to these suggestions, a special *-e* plural affixation rule is not required in German, because the presence of schwa-final syllables follows from more general constraints.

Some commentators question the default status of the plural *-s* in German. **Stemberger** makes the strongest claim, declaring that the "German plural *-s* does not act like a default." However, he does not provide an alternative account of the heterogeneous conditions under which *-s* can be used in German. It is true that *-s* does not increase the number of syllables, as Stemberger points out, but this is also true for irregular plurals, for example, those that take umlaut in the plural *Vater – Väter,* "father – fathers," *-n* plurals such as *Fee – Feen,* "fairy – fairies," and so on. Furthermore, what **Stemberger** and **Hahn** say about our plural judgement study (Marcus et al. 1995) is not accurate. We found that the *-s* plural is rated significantly better for nonrhymes than for rhymes, whereas all other plurals produced the reverse pattern. This yielded a Rhyme/Nonrhyme by Regularity/Irregularity interaction that was significant at $P < 0.001$ for subjects and $P < 0.05$ for items. The same was found for plurals of foreign words (see Marcus et al. 1995, pp. 237ff). This shows that adults do indeed generalize *-s* plurals to nonrhyming real words and to foreign words in German. Hahn's claim that *Vergissmeinicht,* "forget-me-not," does not receive *-s* is also incorrect. I tried this item informally on 15 native speakers of German (not including myself, of course), providing them with an appropriate context for a plural form, and all of those who were willing to pluralize it gave me *Vergissmeinichts.*

Sereno et al. believe that the plural *-s* "is largely limited to borrowings," many of which do not obey the phonology of German, and that *-s* should therefore not be considered a default. This observation is also wrong. The plural *-s* applies in a wide range of circumstances, including proper names, abbreviations, lexicalized phrases, and 18 other conditions summarized by Marcus et al. (1995, p. 240), most of which are phonologically fine in German.

Finally, given the low frequency of *-s* plurals in German, **Nerlich & Clarke** and **Schreuder et al.** find it difficult to accept that *-s* is the default. From a dual-mechanism perspective, however, a default is a fallback option, an elsewhere form, that is used in cases in which the entries stored in the lexicon are not of any use. This is not necessarily expected to happen frequently, especially not in a system such as the German plural for which there is a rich set of stored lexical entries and classes available.

Clearly, the structure of German noun plurals is controversial, and we may continue to quibble over the nature of *-n* and *-e* plural forms, for example. But what seems to me to be undeniable is that the *-s* plural acts as an "emergency suffix," that is, as a default, despite its low frequency.

R1.4. Frequency counts and properties of particular languages. Once we accept that the plural *-s* is a regular default in German, it is clear that frequency of occurrence cannot determine default behavior. However, with respect to participles, **Bybee** and **Stemberger** argue that the default nature of the *-t* ending directly follows from its relatively high frequency and that therefore our results on participles can be dismissed. However, this argument holds only if we count German verb forms as if they were coming from English. As was pointed out in the target article, Bybee restricts her frequency counts to root forms, that is, to a small subset of the verb forms available in the language. This might be appropriate for English, but German has many families of particle and prefix verbs, such as *ankommen,* "arrive," *bekommen,* "receive," *aufkommen,* "support, pay," which have noncompositional meanings, which orthographically and phonologically behave like single verbs, and which in their participle form (i.e., the form we tested) always appear as a single verb. In all these respects, Ger-

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

man participle forms behave differently from English past tense forms. By collapsing all verbs that share a root, these differences are ignored. We find this procedure questionable, and consequently counted verbs such as those mentioned above separately (Clahsen & Rothweiler 1993); this yielded similar frequencies for regulars and irregulars, as was pointed out in the target article.

The second point made by **Stemberger** and **Bybee,** that irregulars should not be grouped together for frequency counts because of (different kinds of) stem changes, is again more appropriate for English than for German. Note that there is just one unique property shared by all irregular participle forms in German: the *-(e)n* ending. English does not have an equivalent property that could be used to define the class of irregulars. This property of German is reflected in our frequency counts, for which we compared *-n* and *-t* participle forms, a perfectly sensible procedure, we think, for the language under study. Moreover, if one starts identifying subpatterns of verbal stems, as suggested by Stemberger and Bybee, this should not be restricted to irregular verbs. Regular verb forms also fall into families of similar-sounding items, and it is likely (given the heterogeneity of regulars) that these "product-oriented" patterns are lower in frequency than many of the irregular verb families. Determining the "right" way of counting frequencies is, of course, a difficult matter. The way in which we counted German participles seems more appropriate, at least for this particular language, than Bybee's and Stemberger's suggestions. In any case, their claim that frequency determines default behavior completely falls apart when it comes to the German *-s* plural.

R1.5. Connectionist simulations of German inflection. It was argued in the target article that connectionist single-mechanism models of language cannot handle German inflection. **Joanisse & Haskell,** however, favor single-mechanism connectionist models, but they do not tell us how such a model would account for the facts of German inflection. Indeed, none of the commentators proposed an alternative single-mechanism model for German inflection, and **Dressler** was even honest enough to say that he and his coworkers have failed to develop connectionist networks that acquire German noun plurals and participles. **Zorzi & Vigliocco** also find certain facts "elusive for single route models," such as double dissociations between regular and irregular inflection. What is offered instead are *dual-process* networks with binding mechanisms for componential analysis (**Zorzi & Vigliocco**) and a *dual-representation* network (**Westermann**). These are interesting ideas of how the structure of language could be implemented in a dual architecture, even though it remains to be seen how they would handle low-frequency defaults. The point I made in the target article was *not* that connectionist models of inflection are inappropriate in general; my point was that single-mechanism associative models are inappropriate, at least for German inflection, and that we cannot dispense with symbolic operations and abstract categories or features such as [+N(oun)] or [+V(erb)]. Once we accept a dual architecture, the further question of whether these operations and categories are directly represented or perhaps indirectly, such as by the kinds of binding mechanisms alluded to by Zorzi and Vigliocco, seems to me mainly of technological interest.

R2. Developmental issues

The second fundamental question of our research programme concerns child language acquisition. In the target article, I argued that the dual structure of the language faculty does not change over time ("continuity") and that developmental changes can be explained through the gradual increase of entries in the child's lexicon ("lexical learning").

R2.1. Emerging orthodoxies. Several commentators were not happy with these claims. For **Bybee,** our account is "totally driven by innate structures." **Behrens & Tomasello** maintain that it is "simply one more way to try to save Chomskian innate Universal Grammar," and **Deutsch & Müller** label it as "Chomsky's new clothes." **Jorion,** finally, declares that Chomsky's "'universal syntax' might be illusory." These comments reflect a deep skepticism against anything Chomskian, but otherwise have nothing much to do with the contents of the target article. Clearly, the distinction between words and rules is in no way specific to Chomskian theory but goes back to Wilhelm von Humboldt (if not further) and is shared by many linguists from different theoretical backgrounds. Indeed, current Chomskian theory is concerned more with other phenomena than with the distinction between regulars and irregulars. The same is true for the continuity assumption and the lexical learning hypothesis, none of which forms part of Chomsky's theory. The former comes from formal learning theory (see, e.g., Pinker 1984), the latter from developmental psycholinguistics (Clahsen 1992), and both are invoked to explain certain acquisition facts rather than to save a particular linguistic theory. Our account of acquisition involves a strong learning component and is *not* totally driven by innate structures. Hence the criticism we are receiving from Ken Wexler, Martin Atkinson, and other more orthodox acquisition theorists for relying too much on learning (see, e.g., Wexler 1999, p. 61 and Atkinson 1996 p. 473). Promoting orthodoxies is certainly not very helpful for the scientific study of language acquisition, but this should apply to all kinds of orthodoxies, including the orthodoxy of *anti*-Chomskianism.

R2.2. Acquiring defaults. Perhaps, the most interesting question for acquisition research in the area under study is how children acquire a regular default, particularly a minority default such as the plural *-s* in German (**Indefrey, Bybee**). One possibility can be ruled out immediately, namely, **Pulvermüller's** conjecture that knowledge of a second language (English) may determine the default behavior of the plural *-s*. We found that overregularizations of the plural *-s* may occur from the age of 2 years, 7 months onwards (Clahsen et al. 1992); at this age an average German child has not yet learned English. We see at least two possible explanations for how children might learn regular defaults. First, the default, by its very nature, can apply to words with any phonological characteristics. In the German plural system, for example, irregular patterns are typically limited to words of a particular stress pattern or gender. The regular default, in contrast, can apply to monosyllables, polysyllables of any stress pattern, and words of any gender. Children might be able to exploit this fact as a way of determining the default; they might search for an affix that may apply to words exhibiting a variety of phonological patterns. Second, the default is applied in unusual circum-

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stances such as names, truncations, abbreviations, borrowings, onomatopoeia, and derived words, some of which are rather frequent in early child language. Children may attend to these circumstances to determine the default.

In contrast to what **Bybee** states, the dual-mechanism model does not require any massive reorganizations of the child's grammar. Instead, it was argued (towards the end of sect. 5.1) that the observed developmental changes can all be explained by lexical learning, by the child's identification of suitable affixes and lexical entries. Thus, the child does not have to learn grammatical operations such as affixation or the "blocking device." These operations and the basic dual structure of language, we argued, are (latently) available from the earliest stages of acquisition. What the child has to learn are the language-particular vocabulary items that undergo these operations, for example, the *-t* participle and the *-s* plural affixes. Hence, the child might initially store items such as *autos* "cars," and later decompose them into stem and affix, once *-s* has been identified as the default. This may cause some reanalysis of this particular vocabulary item but not a reorganization of the grammar. In any case, our findings on German child language indicate that children's inflectional systems do not simply mirror the frequencies of input but that they depend in important ways on the linguistic circumstances of default inflection.

R2.3. Alternative models of acquisition. Commentator **Bybee** believes that acquisition can be better explained in terms of associative models of language. Similarly, **Westermann** and **Dressler** promote a constructivist approach to acquisition according to which the dissociation between regular and irregular inflection emerges in development. **Behrens & Tomasello** argue that children's overgeneralization errors are associatively based rather than being caused by a default rule.

The trouble with associative approaches to language acquisition is that they can account for only a subset of the facts. A frequency-based acquisition device à la **Bybee** cannot learn a low-frequency default, such as the plural *-s.* **Behrens & Tomasello** mention similarity-based generalizations in German child language, for example, overapplications of *-n* to feminine nouns, in analogy to a frequent pattern in the language. **Dressler** points out that *-n* and *-e* plural forms are overapplied *earlier* in development than *-s* plurals. These observations are not disputed and can easily be explained in associative terms. What is crucial, however, is what children (and adults) do under no-similarity conditions, that is, when they cannot form an analogy to items stored in memory. As is shown in section 5.1 of the target article, children clearly prefer the default forms, the plural *-s* and the participle *-t,* under these circumstances, irrespective of frequency, and it is this finding that challenges single-mechanism associative models of language acquisition.

Finally, a note on **Westermann's** models of the English past tense. It is not clear how Westermann could argue that the dissociation between regulars and irregulars is an emergent property; in these models the distinction between regulars and irregulars seems to be built into the network's architecture, in the form of two qualitatively different representational devices, a set of direct input–output connections (essentially made for handling regular inflection) and a set of hidden layer units (which acts as a memory for irregulars). In this sense, Westermann's models are not exactly "constructivist."

R2.4. Plurals inside compounds. Commentators **Joanisse & Haskell** believe that there is little support for a sharp regular/irregular distinction in the development of plurals inside compounds (see also **Dressler** for adult German). However, as was pointed out in section 5.2 of the target article, children (and adults) treat regular and irregular plural affixes differently with respect to compounding. In one of our child experiments, 92% of the plural forms that children used in overregularization errors were omitted inside compounds, in contrast to only 31% for nonoverregularized plural forms, a statistically highly significant difference ($P < .0001$). In adult German, the plural *-s never* occurs inside compounds. Joanisse & Haskell say that I do not present evidence for this claim. The evidence, however, comes from the whole of the German language, and it would have been enough for them to present one single case of an *-s* plural inside a lexical compound to falsify my claim. Such cases, however, do not seem to exist.

Dressler points out that the genitive *-s* may appear inside compounds, but it is more likely that the cases he mentions are instances of the linking morpheme *-s,* a form that is also available in English in compounds such as *bond-s-men* and *hunt-s-men.* In German, the linking morpheme *-s* can appear inside compounds, even in cases in which it is clearly neither a plural nor a genitive, such as in *Liebe-s-kummer,* "love sickness," and *Schmerzen-s-geld* "compensation," literally "pain money." Thus, by saying that German (and English) have a linking morpheme *-s,* we can capture all the relevant cases, including the ones mentioned by Dressler.

With respect to English, **Joanisse & Haskell** mention counterexamples to the constraint against regulars inside compounds, *weapons-inspector,* and so on. These are cases in which the first element of the compound has a generic (rather than a truly plural) meaning, and their structure is parallel to so-called phrasal compounds, such as *over-the-fence gossip, a connect-the-dots puzzle, brown flowers eater,* in which any kind of phrase can be used as the first element of a compound. Thus, English (like many other languages) has two ways of forming compounds, phrasal and lexical compounding. Once this distinction (which is needed for independent reasons; Wiese 1996) is made, it becomes clear that the constraint against regular plurals applies to lexical compounds and that it does indeed produce sharp regular/irregular distinctions, both in adult and in child language. These results challenge associative models of language acquisition that try to make do without such a distinction.

Before turning to issues of language processing, it is important to mention that the developmental perspective is not restricted to child language acquisition, but also involves language change, adult language learning, language loss, and so on, none of which were discussed in the target article. **Fertig's** contribution is important in this regard. He argues that processes of historical change can be accounted for by dual-mechanism models of inflection but not by associative models of language change. His most important finding is that in language change regularization processes affect low-frequency forms, whereas irregularizations affect high-frequency forms. This is parallel to what has been found in language acquisition, indicating that two different

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generalization processes are at work, associative generalizations (what Fertig calls "analogical change") and default regularization.

R3. Storage and computation of inflected words

The third point on our research agenda concerns the question of how the mental grammar is employed in language processing. In the target article, I argued for a direct "correspondence hypothesis" according to which the language processor makes use of essentially the same structures and operations as the mental grammar. Together with dual-mechanism morphology this led us to expect that the structural and the processing properties of inflected words would converge into one of two clusters: Regularly inflected words are processed by rule, whereas irregularly inflected words are stored in memory. Experimental results using different kinds of on-line processing measures were presented in support of this dissociation. The responses to this part of the target article can be divided into two groups. The first group of commentators argues that regularly inflected words may (also) have full-form representations (**Booij, Bybee, Laudanna, Sereno et al., Schreuder et al., Joanisse & Haskell**). The second set of commentators raises methodological points directly addressed to our experiments (**Orsolini, Hahn, Drews, Indefrey, Janssen**). I will discuss these comments separately.

R3.1. Regulars may have stored access representations.

Studies are referred to by **Joanisse & Haskell, Schreuder et al., Sereno et al.,** and **Laudanna** that demonstrate frequency effects for regularly inflected words, suggesting that at least high-frequency regulars are stored in memory. The studies these commentators mention do indeed represent an impressive array of experimental data, but most of the results are based on just one experimental technique, the lexical decision task (LDT). As **Deutsch & Müller** point out, lexical decision is a rather odd task, and it is hard to tell what response times to this task actually mean (see also Balota 1994 for discussion). One thing, however, seems to be clear. Because of the task demands, the LDT encourages subjects to rely on memory rather than on rules. Recall that the task is to discriminate between existing words (that have been encountered before) and nonce words (that have never been encountered before). This means that the LDT is directly sensitive to any trace of a word left in memory. Hence, the observed frequency effects do indeed suggest that regulars may leave memory traces, but the further claim, made by Joanisse & Haskell and Sereno et al., that regulars are not processed by rule is not borne out; the LDT is simply less likely to tap rule-based processes.

In addition to results from the LDT, **Sereno et al.** allude to a production experiment on German participles to support their claim that regulars are not rule-based. However, this experiment has not been published and is therefore hard to evaluate. Moreover, the production experiments available on the English past tense (see, e.g., Beck 1997; Prasada et al. 1990; Ullman 1993; and Pinker 1999, for review) have all found that subjects took longer to produce a low-frequency irregular form than a corresponding high-frequency one, whereas for regulars there was no such effect. It remains to be seen how these findings can be reconciled with those reported by Sereno et al.

Bybee mentions Stemberger and MacWhinney's (1986) study indicating a frequency effect for regulars in speech errors, a result she takes to support her view that (at least high-frequency) regulars are listed. But data from speech errors also provide evidence for morphological decomposition. So-called stranding errors (e.g., "he is schooling to go" instead of "he is going to school," in which the suffix *-ing* has been stranded in its original position, with the stem *go* being moved somewhere else) would be hard to explain if a (high-frequency) word form such as *going* had no internal morphological structure. Clearly, speech errors are rare events, reflect unusual circumstances, and are sometimes hard to interpret. Recently, more natural measures of on-line language production have been developed, such as the measurement of pronunciation latencies (see Roelofs 1997 for an overview of the role of morphological structure in language production). According to Roelofs (1997, p. 152), the results of these studies support decompositional rather than full-listing models of morphological processing (see also Levelt et al. 1999).

Sereno et al. and **Joanisse & Haskell** believe that the regularity-by-frequency interactions that are typically found in the LDT cannot be reconciled with a dual-mechanism model of morphological processing. **Booij** believes that our "reasoning suffers from the "rule/list fallacy," and **Hahn** says that the regular/irregular differences reported in our LDT (in sect. 4.3) are left unexplained. These claims are unwarranted. Dual models posit two mental mechanisms for dealing with inflected words, stored entries and combinatorial rules, and these two mechanisms may work in parallel (Baayen et al. 1997b; Caramazza et al. 1988; Pinker 1999). It is therefore conceivable that the words we hear or read leave some traces in memory, perhaps in the form of modality-specific access representations. This is more likely to happen for high-frequency items, and indeed Alegre and Gordon (1999) have shown that whole-word frequency effects occur only for regular items above a certain frequency threshold. Regulars with surface frequencies below this threshold, however, do not produce whole-word frequency effects. This also accounts for the results presented by **Schreuder et al.** Note that the items in their high-frequency condition were on average 80 times more frequent than their low-frequency ones. It does not come as a surprise that the response times for the former are shorter, and this effect is probably caused by memory traces of high-frequency regulars picked up by the LDT. What we have shown in our LDT (see sect. 4.3) is that less dramatic frequency contrasts produce a surface frequency effect for irregulars, but not for regulars. This, we argued, is due to the fact that the lexical entries of irregulars (but not of regulars) have subnodes that might form the basis for surface frequency effects. Schreuder et al.'s findings are therefore orthogonal to ours and reflect differences in the materials used, massive frequency differences in their materials, smaller differences in ours.

The important point to note is that, even though high-frequency regulars may produce memory traces, the processing of regulars does not *depend* on stored representations. It is clear, for example, from the generalization properties of regular inflections, that subjects do not have to rely on stored versions of regularly inflected words in making use of the rule. Hence, the fact that some regulars produce memory effects in the LDT does not show that full-listing accounts of morphological processing are superior to the dual-mechanism model.

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R3.2. Methodological worries. Several commentators raised methodological points about and criticisms of our experiments. **Drews** claims to have identified several confounding factors in our lexical decision experiments. As will become clear, however, all her points can be refuted. With respect to her first observation, alleged stem/word-form frequency confounds, stem frequency was controlled in experiment 3 of Clahsen et al. (1997), the study to which Drews refers. As is clear from Figure 3 (p. 228) and Figure 4 (p. 230), we found a surface frequency effect for irregulars, but not for regulars, despite the fact that all experimental conditions had the same stem frequency. Thus, it is *not* the case that our lexical decision results on participles are confounded by stem frequency differences. Next, Drews notes that our LDT on plurals is confounded by "idiosyncratic differences in the structure of the stimuli." This is also incorrect. Items such as *Gespenster,* "ghosts," *Gemächer,* "chambers," and *Gewänder,* "vestments," are certainly not "derivationally affixed." Word length, another point picked up by Drews, was in fact controlled in our experiment, with a mean of 2.7 syllables for the low-frequency condition and 2.1 for the high-frequency one. This did not yield any statistically reliable differences. Finally, Drews points out that the *-s* affix is not unambiguous in German. What this remark is supposed to imply, however, is not clear; in fact *none* of the plural endings in German (including the irregular *-er* we tested in our experiment) is unambiguous; *-er* nominalizations, for example, are very productive in German. Moreover, as Drews admits, the genitive reading of a word form affixed with *-s* is "unlikely to be the first that comes into mind."

Indefrey reports results from a production task on participles in which he could not replicate the frequency-by-regularity interaction we found in our LDTs for plurals and participles. It is always hard to decide why an experiment did *not* produce a particular kind of effect, and one would have to look in detail at the materials and designs to determine possible reasons. We cannot do this in the present case. Suffice it to mention here that production studies on the English past tense have consistently found a regularity-by-frequency interaction, similar to the results of our LDTs (see Pinker 1999 for review).

Our priming task reported in section 4.4 was criticized by **Orsolini, Drews,** and **Hahn.** Orsolini says that for irregulars we did not find any priming differences between the test and the control conditions. This is simply false. We did indeed find differences between these two conditions, as is clear from Figures 4 and 5 in the target article. The important point, however, is that irregulars produced *partial* and regulars *full* priming effects. In Orsolini's own priming experiments, one cannot make this distinction; she did not include an identity condition.

Drews tries to identify potentially confounding factors in our priming studies. Her first point concerns differences in the identity conditions in the participle experiment. It is true that the mean reaction times for the identity condition were shorter for irregular verbs than for regular verbs, but this difference is likely to be due to properties of the lexical items involved and cannot account for the regular/irregular differences in morphological priming we found. This is because we determined priming effects not by directly comparing regulars and irregulars but rather by comparing the *same* lexical item in the experimental and in the identity conditions. Drews's second observation is that the control condition for the irregulars in the plural priming study produced relatively short RTs in comparison to the regulars, whereas there was no such difference in the identity condition. This is correct and, as was pointed out by Drews, is likely to reflect frequency differences between *-er* and *-s* plurals. Note that the former were 10 times more frequent than the latter, and this may have caused the shorter lexical decision times. This is particularly clear from the unprimed control condition, but the effect is also present in the identity condition, albeit to a smaller extent (531 vs. 558 msec). That the frequency difference has a smaller effect in the identity condition could be due to the immediate repetition of the same item in this condition, which yielded extremely short response times for both types of items ("floor effect"). But, once again, the frequency differences between *-s* and *-er* plurals do not affect our findings on morphological priming, insofar as we have not directly compared *-s* and *-er* plurals.

Hahn notes that "for participles and for plurals, the 'irregular' primes have an *additional syllable* relative to their targets." This is correct for plurals but not for participles. In fact, primes and targets of all the *-n* participles we used for the experiment had the same syllable structure, aside from the *ge-* prefix of course, for example; *gegraben* → *grabe,* "dug – dig." Although this was also true for some of the regulars, in most of the regular verbs the syllable structures of prime and target forms were different, for example, *gezeigt* → *zeige,* "shown – show" (see Sonnenstuhl et al. 1999 for the complete stimulus set). Thus, if the lack of full priming in irregular plurals were due to differences in syllable structure (as suggested by Hahn), we would expect to find a parallel effect in participles. This was not the case. Regular participles produced full priming (despite prime/target differences in syllable structure), and irregular participles did not produce full priming (even though they had the same syllable structure as the corresponding targets; see also Marslen-Wilson et al. 1994 for related results on English). We conclude that Hahn's explanation of our priming results is not valid.

Janssen says that the matching experiment reported in section 4.2.2 shows that "novel strong verbs did not exhibit the expected irregular behavior of not allowing regular suffixation." This is accurate and does not contradict our interpretation. We argued that, if *-n* suffixation existed as a rule (i.e., the "expected irregular behavior" in Janssen's terms), this should have had an effect on the novel strong verbs in our experiment. It did not. By contrast, *-t* affixation had an effect on the response times for weak verbs. We therefore concluded that *-t* suffixation exists, whereas *-n* participles are not rule-based. For the nonword learning task that preceded the actual experiment, we had to be rather strict to make sure that subjects were able to reproduce past-tense forms correctly for all items. This produced a large dropout rate in the pretest, at least among the Düsseldorf student population, as Janssen noticed. A variety of errors was found, but no predictions were made about the dropouts in the pretest, so they were not further analyzed.

R4. Brain potentials and the dual structure of the language faculty

The fourth question raised at the beginning was how linguistic knowledge is represented in the brain. One might

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regard this as the most fundamental question, in that ultimately all cognitive capacities (including language) are the product of structures in the brain. However, the direct study of the human brain is fraught with difficulties, and language-related research using modern techniques is still in its infancy. With this in mind, I have made relatively modest claims about brain representations, arguing that the results of our ERP studies present us with an electrophysiological correlate for the distinction between rules of language and lexical entries as suggested in the dual-mechanism model. Two kinds of responses were received to this part of the target article. **Joannise & Haskell, Schreuder et al., Stemberger,** and **Ullman** provide methodological criticisms and alternative interpretations. **Pulvermüller** and **Münte et al.** argue that our work in this area is not going far enough in that relevant brain regions and their contributions to morphological processing are left unspecified. I will consider these points separately.

R4.1. ERP effects of morphological processing. Commentators **Joannise & Haskell** believe that in our experiments anomalous irregular plurals elicited an N400 and anomalous irregular participles a LAN. This is *not* correct. Rather, the LAN was seen in both studies for incorrect irregulars. Thus, an illicit regular suffix elicited a LAN, that is, a brain response typical for violations of rules of grammar. Illicit irregular endings, on the other hand, did not elicit a LAN, in either the plural or the participle study. We took these findings as supporting the view that regular suffixes are supplied by rule, whereas irregular endings are stored on words.

In the plural study, we also found that illicit irregular endings produced an N400, a response characteristic for anomalous words. **Joannise & Haskell, Schreuder et al.,** and **Ullman** observed that the N400 effect did not occur in our participle experiment. This is correct, even though participles of nonce verbs elicited an N400 component (see Fig. 4 of Penke et al. 1997). The lack of an N400 for incorrect participles of existing regular verbs (**ge-tanzen,* "danced") is probably due to the fact that these items – even though ungrammatical – are rather similar to the infinitive form of the corresponding verb (=*tanzen,* "to dance"), and hence do not elicit a nonword effect. This was not the case for irregularized plurals.

Schreuder et al. pointed out that illegal plurals such as **Karussellen* could be interpreted as deverbal nouns and that this could have affected our results. This might have been the case had the items been presented in isolation, but in our plural ERP study all items were presented in sentential contexts that ruled out a deverbal interpretation. For the participle study, Schreuder and collaborators suggest an alternative interpretation in terms of different degrees of "local ungrammaticality." However, all our irregular items were of the A–B–A class, for example, *rufen–rief–gerufen,* "to shout," for which the combination of the participle stem and either *-t* or *-n* yields a locally well-formed string; ruf+*en* is the infinitive, ruf+*t* the third singular, as well as the second plural form. These forms are neither ungrammatical nor rare in German. The same is, of course, also true for regular verbs. The items we used do not differ with respect to "local ungrammaticality"; hence the observed ERP effects cannot be explained in this way.

Stemberger observed that in our plural study the ERPs to the *correct* forms of regulars and irregulars were different, whereas in the participle study they were different for the *incorrect* forms. Unfortunately, it is not legitimate to compare regulars and irregulars directly in this way; different vocabulary items are involved in this comparison, which (owing to their different semantics and phonologies) are likely to produce uncontrolled effects. This is why in our ERP studies regular and irregular forms of the same lexical item were compared to each other.

R4.2. Which brain areas control morphology? My impression is that the evidence currently available from neuroimaging studies does not warrant any strong claims about which cortical areas are responsible for morphological processing. If this is correct, **Pulvermüller's** brain model and his remarks on the cortical areas involved in the processing of inflection should be treated with caution, even though they may turn out to be correct. The problem is that not only are there many different cortical areas activated for regulars and irregulars but, even worse, that each study has given a different set of active regions for regular and irregular tasks (see Pinker 1997 for review). **Münte et al.'s** observation that "neither single- nor dual-mechanism models go very far in explaining the cognitive neuroscience data" is of course correct, and the questions they raise are important. But, given inconsistencies in localization patterns and the likelihood of methodological artifacts, it seems too early to answer them. Take, for example, PET studies of inflection. Of the many cortical activations one sees in such studies, it is not clear which are due to real linguistic differences and which are caused by properties of the PET methodology, such as the block design, the substraction method, or the poor temporal resolution (see Seidenberg & Hoeffner 1998 and Jaeger et al. 1998 for discussion). It is hard to tease apart these factors, and it is certainly impossible to read the brain areas responsible for morphological processing directly from the activation patterns of a PET study. In this sense, Münte and collaborators' remark that "brain data indicate that a simplistic account will not do" might even turn out to be wrong. It is perfectly conceivable that cognitive models of language can be kept maximally simple, even though PET studies (or indeed any other of the current neuroimaging techniques) using linguistic stimuli show a multitude of active regions, many of which may have nothing much to do with language. We will have to leave this open.

As a concluding note, I would like to mention one aspect of our research programme on German inflection that I found extremely useful throughout, and this is the multidisciplinary approach we have adopted by using different experimental methods, different groups of subjects, and different linguistic phenomena. In this way, uncertainties arising from weaknesses of particular techniques, gaps in particular data sets, and potentially confounding factors could be avoided or, at least, reduced. Perhaps, a research strategy such as this might also be beneficial for studying the brain areas that deal with morphology, by making use of different imaging techniques, ERPs, and different subject groups. **Ullman's** research on the functional neuroanatomy of the English past tense goes in that direction, even though not all of his experiments are entirely convincing. For instance, the ERP study Ullman refers to is actually testing not a violation of a morphological rule but rather a syntactic violation, namely, a present-tense form appearing in a past-tense context. Another potentially valuable perspective for future research on brain representations of mor-

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

phology is cross-linguistic studies. Ullman and his team are studying Italian inflection, and, in collaboration with Thomas Münte and Antoni Rodriguez-Fornells, we have recently started to investigate different Romance languages (Italian, Catalan, Spanish) using ERPs. Ullman points out that the brain potentials elicited in Italian are not exactly the same as those for German. This is correct, and it is possible that these ERP differences reflect structural properties of the particular languages involved, such as the fact that Italian (like other Romance languages) has conjugational classes. In any case, cross-linguistic studies will help to tease apart properties of particular languages from the more general structure of the language faculty and how it is represented in the brain.

ACKNOWLEDGMENTS

I am grateful to Martin Atkinson, Sonja Eisenbeiss, Tessa Say, Andrew Spencer, Ingrid Sonnenstuhl, and Helga Weyerts for providing helpful comments on an earlier version of this response.

References

Letters "a" and "r" appearing before authors' initials refer to target article and response, respectively.

Alegre, M. & Gordon, P. (1996a) Red rats eater exposes recursion in children's word formation. *Cognition* 60:65–82. [MFJ]
(1996b) Why parks commissioners aren't rats eaters: Semantic constraints on regular plurals inside compounds. Unpublished manuscript, University of Pittsburgh. [MFJ]
(1999) Frequency effects and the representational status of regular inflections. *Journal of Memory and Language* 40:41–61. [rHC, MFJ]
Anderson, S. R. (1992) *A-morphous morphology.* Cambridge University Press. [JPB]
Aronoff, M. (1994) *Morphology by itself. Stems and inflectional classes.* MIT Press. [rHC]
Atkinson, M. (1996) Now hang on a minute: Some reflections on emerging orthodoxies. In: *Generative perspectives on language acquisition,* ed. H. Clahsen. John Benjamins. [rHC]
Baayen, H., Burani, C. & Schreuder, R. (1997a) Effects of semantic markedness in the processing of regular nominal singulars and plurals in Italian. *Yearbook of Morphology 1996*:13–33, ed. G. E. Booij & J. v. Marle. Kluwer. [aHC, RS]
Baayen, H., Dijkstra, T. & Schreuder, R. (1997b) Singulars and plurals in Dutch: Evidence for a dual parallel route model. *Journal of Memory and Language* 37:94–119. [arHC, MFJ, RS]
Baayen, H., McQueen, J. M., Dijkstra, T. & Schreuder, R. (in preparation) Dutch inflectional morphology in spoken-word recognition. [CEC]
Baayen, H., Piepenbrock, R. & van Rijn, H. (1993) *The CELEX lexical database (CD-ROM).* Linguistic Data Consortium, University of Pennsylvania. [aHC, ED]
Badecker, W. & Caramazza, A. (1987) The analysis and morphological errors in a case of acquired dyslexia. *Brain and Language* 32:278–305. [MTU]
(1991) Morphological composition in the lexical output system. *Cognitive Neuroscience* 8(5):335–67. [MTU]
Balota, D. (1994) Visual word recognition. The journey from features to meaning. In: *Handbook of psycholinguistics,* ed. M. Gernsbacher. Academic Press. [arHC]
Baron, J. & Strawson, C. (1976) Use of orthographic and word-specific knowledge in reading words aloud. *Journal of Experimental Psychology: Human Perception and Performance* 2:386–92. [MZ]
Bartke, S. (1998) *Experimentelle Studien zur Flexion und Wortbildung. Pluralbildung und lexikalische Komposition im unauffälligen Spracherwerb und im Dysgrammatismus. Dissertation.* Niemeyer. [aHC]
Bartke, S., Marcus, G. & Clahsen, H. (1996) Acquiring German noun plurals. In: *Proceedings of the 19th Annual Boston University Conference on Language Development,* ed. D. MacLaughlin & S. McEwen. Cascadilla Press. [aHC]
Bates, L., Bretherton, I. & Snyder, L. (1988) *From first words to grammar: Individual differences and dissociable mechanisms.* Cambridge University Press. [aHC]
Bates, L. & Elman, J. (1993) Connectionism and the study of change. In: *Brain development and cognition,* ed. M. Johnson. Blackwell. [aHC]
Beck, M. (1997) Regular verbs, past tense and frequency: Tracking down a potential source for NS/NNS competence differences. *Second Language Research* 13(2):93–115. [rHC]
Berko, J. (1958) The child's learning of English morphology. *Word* 14:150–77. [aHC, AL, BN]
Bernhardt, B. H. & Stemberger, J. P. (1998) *Handbook of phonological development: From the perspective of constraint-based nonlinear phonology.* Academic Press. [JPS]
Bertinetto, P. M. (1994) Phonological representation of morphological complexity: Alternative models (neuro- and psycholinguistic evidence). *Cognitive Linguistics* 5(1):77–109. [BN]
Bittner, D. & Köpcke, K.-M. (1999) Acquisition of the German plural markings: A case study in natural and cognitive morphology. *Folia Linguistica* (submitted). [HB]
Bloomfield, L. (1933) *Language.* Holt, Rinehart and Winston. [aHC, DF]
Boland, J. & Cutler, A. (1996) Interaction with autonomy: Multiple output models and the inadequacy of the Great Divide. *Cognition* 58:309–20. [aHC]
Bond, Z. S. (1973) The perception of sub-phonemic phonetic differences. *Language and Speech* 16:351–55. [CEC]
Booij, G. E. (1977) *Dutch morphology: A study of word formation in generative grammar.* Foris. [GB]
(1993) Against split morphology. *Yearbook of Morphology 1993*:27–51. [GB]
(1998) Output constraints in morphology. In: *Phonology and morphology of the Germanic languages,* ed. W. Kehrein & R. Wiese. Niemeyer. [GB]
Borer, H. (1988) On the parallelism between compounds and constructs. *Yearbook of Morphology:* 45–66. [aHC]
Braitenberg, V. & Schüz, A. (1998) *Cortex: Statistics and geometry of neural connectivity.* Springer. [FP]
Bréal, M. (1866) De la forme de la fonction des mots (Leçon faite au Collège de France pour la réouverture du cours de grammaire comparée). *Revue des cours littéraires de la France et de l'étranger.* 4ième année, no. 5 (29 Décembre):65–71. [BN]
Bullinaria, J. & Chater, N. (1995) Connectionist modelling: Implications for cognitive neuropsychology. *Language and Cognitive Processes* 10(3/4):227–64. [MZ]
Burani, C. & Laudanna, A. (1992) Units of representation for derived words in the lexicon. In: *Orthography, phonology, morphology, and meaning,* ed. R. Frost & L. Katz. Elsevier. [ED]
Butterworth, B. (1983) Lexical representation. In: *Language production, vol. 2,* ed. B. Butterworth. Academic Press. [aHC, WD]
Bybee, J. L. (1985) *Morphology: A study of the relation between meaning and form.* John Benjamins. [JB, DF]
(1991) Natural morphology: The organization of paradigms and language acquisition. In: *Crosscurrents in second language acquisition and linguistic theories,* ed. T. Huebner & C. Ferguson. Benjamins. [aHC]
(1995a) Diachronic and typological properties of morphology and their implications for representation. In: *Morphological aspects of language processing,* ed. L. B. Feldman. Erlbaum. [AL]
(1995b) Regular morphology and the lexicon. *Language and Cognitive Processes* 10:425–55. [JB, aHC, UH, FP]
(1999) The phonology of the lexicon: Evidence from lexical diffusion. In: *Usage-based models of language,* ed. M. Barlow & S. Kemmer. CSLI. [JB]
Bybee, J. & Moder, C. (1983) Morphological classes as natural categories. *Language* 59:251–70. [aHC]
Bybee, J., Perkins, R. & Pagliuca, W. (1994) *The evolution of grammar: Tense, aspect and modality in the languages of the world.* University of Chicago Press. [JB]
Bybee, J. & Slobin, D. (1982) Rules and schemas in the development and use of English past tense. *Language* 58:265–89. [aHC]
Cappa, S. & Ullman, M. T. (1998) *A neural dissociation in Italian verbal morphology.* Paper presented at the 5th Annual Meeting of the Cognitive Neuroscience Society, San Francisco, CA. [MTU]
Caramazza, A., Laudanna, A. & Romani, C. (1988) Lexical access and inflectional morphology. *Cognition* 28:297–332. [rHC, AL]
Carstairs, A. (1987) *Allomorphy in inflexion.* Croom Helm. [AC-M]
Carstairs-McCarthy, A. (1994) Inflection classes, gender and the Principle of Contrast. *Language* 70:737–88. [AC-M]
Chambers, S. & Forster, K. (1975) Evidence for lexical access in a simultaneous matching task. *Memory and Cognition* 3:549–59. [aHC]
Chomsky, N. (1965) *Aspects of the theory of syntax.* MIT Press. [RW]
(1970) Remarks on nominalization: In: *Readings in English transformation grammar,* ed. R. Jacobs & P Rosenbaum. Ginn.
(1981) *Lectures on government and binding.* Foris. [aHC]
(1986) *Knowledge of language: Its nature, origin and use.* Praeger. [rHC]
(1995) *The minimalist program.* MIT Press. [aHC, PJMJ, DL]
Chomsky, N. & Halle, M. (1968) *The sound pattern of English.* MIT Press. [RW]
Churchland, P. (1995) *The engine of reason, the seat of the soul: A philosophical journey into the brain.* MIT Press. [aHC]

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Churchward, C. M. (1940) *Rotuman grammar and dictionary.* Methodist Church of Australasia. [JPB]

Clahsen, H. (1990) Constraints on parameter setting: A grammatical analysis of some acquisition stages in German child language. *Language Acquisition* 1:361–91. [aHC]

(1992) Learnability theory and the problem of development in language acquisition. In: *Theoretical issues in language acquisition,* ed. J. Weissenborn, H. Goodluck & T. Roeper. Erlbaum. [arHC]

(1997) The representation of German participles in the German mental lexicon: Evidence for the dual-mechanism model. *Yearbook of Morphology 1996*:73–96. [aHC]

Clahsen, H. & Almazán, M. (1998) Syntax and morphology in children with Williams Syndrome. *Cognition* 68(3):167–98. [aHC]

Clahsen, H., Eisenbeiss, S. & Penke, M. (1996a) Lexical learning in early syntactic development. In: *Generative perspectives on language acquisition,* ed. H. Clahsen. Benjamins. [aHC]

Clahsen, H., Eisenbeiss, S. & Sonnenstuhl-Henning, I. (1997) Morphological structure and the processing of inflected words. *Theoretical Linguistics* 23:201–49. [arHC, WD, ED, DPJ, JS]

Clahsen, H., Eisenbeiss, S. & Vainikka, A. (1994) The seeds of structure. A syntactic analysis of the acquisition of case marking. In: *Language acquisition studies in generative grammar,* ed. T. Hoekstra & B. Schwartz. John Benjamins. [aHC]

Clahsen, H., Hong, U. & Sonnenstuhl, I. (1995) Grammatical constraints in syntactic processing: Sentence-matching experiments on German. *The Linguistic Review* 12:5–33. [aHC]

Clahsen, H., Marcus, G., Bartke, S. & Wiese, R. (1996b) Compounding and inflection in German child language. *Yearbook of Morphology 1995:* 115–42. [aHC]

Clahsen, H., Penke, M. & Parodi, T. (1993) Functional categories in early child German. *Language Acquisition* 3(4):395–429. [aHC]

Clahsen, H. & Rothweiler, M. (1993) Inflectional rules in children's grammars: Evidence from the development of participles in German. *Yearbook of Morphology 1992*:1–34. [arHC]

Clahsen, H., Rothweiler, M., Woest, A. & Marcus, G. (1992) Regular and irregular inflection in the acquisition of German noun plurals. *Cognition* 45:225–55. [arHC, JPS]

Clark, E. (1993) *The lexicon in acquisition.* Cambridge University Press. [aHC]

Coltheart, M. (1978) Lexical access in simple reading tasks. In: *Strategies of information processing,* ed. G. Underwood. Academic Press. [MZ]

Corbett, G. & Fraser, N. (1993) Network morphology: A DATR account of Russian nominal inflection. *Journal of Linguistics* 29:113–42. [aHC, AS]

Corbett, G. G. & Hayward, R. J. (1987) Gender and number in Bayso. *Lingua* 73:1–28. [GGC]

Cutler, A. (1997) The comparative perspective on spoken-language processing. *Speech Communication* 21:3–15. [CEC]

Daugherty, K. & Hare, M. (1993) The past tense by some other name might be called a connectionist net. In: *Proceedings of the 1993 connectionist models summer school,* ed. M. Mozer, P. Smolensky, D. Touretzky & J. Elman. Erlbaum. [aHC]

Denes, F., Cipolotti, L. & Zorzi, M. (1999) Acquired dyslexias and dysgraphias. In: *Handbook of clinical and experimental neuropsychology,* ed. G. Denes & L. Pizzamiglio. Psychology Press. [MZ]

De Saussure, F. (1973) *Course in general linguistics,* trans. W. Baskin; ed. C. Bally & A. Sechehaye (with A. Riedlinger). Payot. [JB]

Di Sciullo, A.-M. & Williams, E. (1987) *On the definition of word.* MIT Press. [aHC]

Dorffner, G., Hentze, M. & Thurner, G. (1966) A connectionist model of categorization and grounded word learning. In: *Proceedings of the Groningen Assembly of Language Acquisition 1995,* ed. C. Koster & F. Wijnen. [WUD]

Dressler, W. U. (1985) *Morphonology.* Karoma. [WUD]

(1990) The cognitive perspective of "naturalist" linguistic models. *Cognitive Linguistics* 1(1):75–98. [BN]

(1997a) On productivity in inflectional morphology. *CLASNET Working Papers (Montreal)* 7. [WUD]

Dressler, W. U., ed. (1997b) *Studies in pre- and protomorphology.* Österreichische Akademie der Wissenschaften. [WUD]

Dressler, W. U. & Dziubalska-Kolaczyk, K. (1998) Polish inflection classes within natural morphology. *Bulletin de la société Polonaise de linguistique* 53:95–119. [WUD]

Dressler, W. U., Dziubalska-Kolaczyk, K. & Katičič, A. (1998) A contrastive analysis of verbal inflection classes in Polish and Croatian. *Suvremena Lingvistika* 22:127–38. [WUD]

Dressler, W. U. & Ladányi, M. (1998) On grammatical productivity of word formation rules. *Wiener Linguistische Gazette* 62–63:29–55. [WUD]

Dressler, W. U. & Merlini Barbaresi, L. (1994) *Morphopragmatics.* Mouton de Gruyter. [WUD]

Dressler, W. U. & Tonelli, L., eds. (1994) *Natural morphology: Perspectives for the nineties.* Unipress. [BN]

Dubois, B., Boller, F., Pillon, B. & Agid, Y. (1991) Cognitive deficits in Parkinson's disease. In: *Handbook of neuropsychology, vol. 5,* ed. F. Boller & J. Grafman. Elsevier. [MTU]

DuBois, J. (1987) The discourse basis of ergativity. *Language* 63:805–55. [JB]

Duden Grammatik (1984) *Grammatik der Deutsche Gegenwartssprache.* Dudenverlag. [RS]

Ellis, A. W. (1982) Spelling and writing (and reading and speaking). In: *Normality and pathology in cognitive function,* ed. A. W. Ellis. Academic Press. [MZ]

Elman, J. (1993) Learning and development in neural networks: The importance of starting small. *Cognition* 48:71–99. [aHC]

Elman, J., Bates, L., Johnson, M., Karmiloff-Smith, A., Parisi, D. & Plunkett, K. (1996) *Rethinking innateness: A connectionist perspective on development.* MIT Press. [aHC, GW]

Ewers, H. (1999) Schemata im mentalen Lexikon: Empirische Untersuchungen zum Erwerb der deutschen Pluralbildung. In: *Das Lexikon im Spracherwerb,* ed. J. Meibauer & M. Rothweiler. Francke. [HB]

Fanari, R. (1999) Representation and process in children's and adults' mental lexicon. Ph. D. dissertation. University of Rome "La Sapienza." [MO]

Fanari, R. & Orsolini, M. (in preparation) Generalizability of morphological processes in children's and adults' use of Italian past forms. Unpublished manuscript. University of Rome "La Sapienza." [MO]

Fertig, D. (1998) Suppletion, natural morphology, and diagrammaticity. *Linguistics* 36:1065–91. [DF]

Fodor, J., Bever, T. & Garrett, M. (1974) *The psychology of language.* McGraw Hill. [aHC]

Fodor, J. & Pylyshyn, Z. (1988) Connectionism and cognitive architecture: A critical analysis. In: *Connections and symbols,* ed. S. Pinker & J. Mehler. MIT Press. [aHC]

Forster, K. (1976) Accessing the mental lexicon. In: *Explorations in the biology of language,* ed. E. Walker. Bradford Books. [LS]

(1987) Binding, plausibility and modularity. In: *Modularity in knowledge representation and natural language processing,* ed. J. Garfield. MIT Press. [aHC]

Forster, K. & Stevenson, B. (1987) Sentence matching and well-formedness. *Cognition* 26:171–86. [aHC]

Forster, K. I., Davis, C., Schoknecht, C. & Carter, R. (1987) Masked priming with graphemically related forms: Repetition or partial activation? *Quarterly Journal of Experimental Psychology* 39:211–51. [aHC]

Fowler, C., Napps, S. & Feldman, L. (1985) Relations among regular and irregular morphologically related words in the lexicon as revealed by repetition priming. *Memory and Cognition* 13:241–55. [aHC]

Fox, B. (1987) The noun phrase accessibility hierarchy revisited: Subject primacy or the absolutive hypothesis. *Language* 63:856–70. [JB]

Fox, B. & Thompson, S. (1990) A discourse explanation of the grammar of relative clauses in English conversation. *Language* 66:51–64. [JB]

Frauenfelder, U. & Schreuder, R. (1992) Constraining psycholinguistic models of morphological processing and representation: The role of productivity. *Yearbook of Morphology 1991:*165–83. [aHC]

Freedman, S. & Forster, K. (1985) The psychological status of overgenerated sentences. *Cognition* 24:171–86. [aHC]

Friederici, A. D., Hahne, A. & Mecklinger, A. (1996) Temporal structure of syntactic parsing: Early and late event-related brain potential effects. *Journal of Experimental Psychology: Memory and Cognition* 22:1219–48. [aHC]

Friederici, A. D. & Mecklinger, A. (1996) Syntactic parsing as revealed by brain responses. First-pass and second-pass parsing processes. *Journal of Psycholinguistic Research* 25:157–76. [aHC]

Fuhrhop, N. (1996) Fugenelemente. In: *Deutsch-typologisch,* ed. E. Lang & G. Zifonun. De Gruyter. [WUD]

Fuster, J. M. (1995) *Memory in the cerebral cortex. An empirical approach to neural networks in the human and nonhuman primate.* MIT Press. [FP]

Gawlitzek-Maiwald, I. (1994) How do children cope with variation in the input? The case of German plurals and compounding. In: *How tolerant is universal grammar? Essays on language learnability and language variation,* ed. R. Tracy & E. Lattey. Niemeyer. [HB, WUD]

Gilley, L. G. (1992) *An autosegmental approach to Shilluk phonology.* (Summer Institute of Linguistics and the University of Texas at Arlington Publications in Linguistics 103). International Academic Bookstore. [GGC]

Gillis, S., ed. (1998) *Studies in the acquisition of number and diminutive marking.* Antwerp Papers in Linguistics 95. [WUD]

Givón, T. (1979) *On understanding grammar.* Academic Press. [JB]

Goebel, R. & Indefrey, P. (1999) The performance of a recurrent network with short term memory capacity learning the German -s plural. In: *Cognitive models of language acquisition,* ed. P. Broeder & J. Murre. MIT Press. [aHC, PI]

Golston, C. & Wiese, R. (1996) Zero morphology and constraint interaction:

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Subtraction and epenthesis in German dialects. *Yearbook of Morphology 1995*:143–60, ed. G. Booij & J. van Marle. Kluwer. [rHC, DW]
Gopnik, M. (1994) Impairments of tense in a familial language disorder. *Journal of Neurolinguistics* 8:109–33. [aHC]
Gordon, P. (1985) Level-ordering in lexical development. *Cognition* 21:73–93. [aHC, MFJ]
Grimm, J. (1819/1968) *Vorreden zur deutschen Grammatik von 1819 und 1822.* Reprint: Wissenschaftliche Buchgemeinschaft, 1968. [BN]
Grodzinsky, Y. (1990) *Theoretical perspectives on language deficits.* MIT Press. [aHC]
(2000) The neurology of syntax: Language use without Broca's area. *Behavioral and Brain Sciences* 23(1).
Gross, M., Say, T., Kleingers, M., Münte, T. F. & Clahsen, H. (1998) Human brain potentials to violations in morphology complex Italian words. *Neuroscience Letters* 241:83–86.
Hagoort, P. & Brown, C. (1994) Brain responses to lexical ambiguity resolution and parsing. In: *Perspectives on sentence processing,* ed. C. Clifton, L. Frazier & K. Rayner. Erlbaum. [aHC]
Hagoort, P. & Kutas, M. (1995) Electrophysiological insights into language deficits. In: *Handbook of neuropsychology, vol. 10,* ed. J. C. Brown. Series editors: F. Boller & J. Grafman. Elsevier. [MTU]
Hahn, U. & Nakisa, R. C. (1999) German inflection: Single- or dual-route? (submitted). [UH]
Hahn, U., Nakisa, R. C., Bailey, T. M., Holmes, M., Kemp, D. & Palmer, L. (1998) Experimental evidence against the dual-route account of inflectional morphology. *Proceedings of the 20th Annual Meeting of the Cognitive Science Society.* Erlbaum. [UH]
Hale, K. (1967) Some productive rules in Lardil Mornington Island syntax. In: *Papers in Australian Linguistics 2,* Pacific Linguistics Series A-11:63–73. Australian National University. [JPB]
Halle, M. & Marantz, A. (1993) Distributed morphology and the pieces of inflection. In: *The view of building 20: Essays in linguistics in honor of Sylvain Bromberger,* ed. K. Hale & J. Keyser. MIT Press. [aHC]
Halle, M. & Mohanan, K. (1985) Segmental phonology of modern English. *Linguistic Inquiry* 16:57–116. [aHC]
Hankamer, J. (1989) Morphological parsing and the lexicon. In: *Lexical representation and process,* ed. W. Marslen-Wilson. MIT Press. [aHC]
Hare, M. & Elman, J. L. (1995) Learning and morphological change. *Cognition* 56:61–98. [DPJ, FP]
Hare, M., Elman, J. L. & Daugherty, K. (1995) Default generalisation in connectionist networks. *Language and Cognitive Processes* 10:601–30. [aHC]
Harm, M. & Seidenberg, M. (in press) Phonology, reading acquisition, and dyslexia: Insights from connectionist models. *Psychological Review.* [MFJ]
Houghton, G. & Zorzi, M. (1998) A model of the sound-spelling mapping in English and its role in word and nonword spelling. In: *Proceedings of the Twentieth Annual Conference of the Cognitive Science Society,* 490–95. Erlbaum. [MZ]
Hyams, N. (1986) *Language acquisition and the theory of parameters.* Reidel. [aHC]
Indefrey, P., Brown, C., Hagoort, P., Herzog, H., Sach, M. & Seitz, R. J. (1997) A PET study of cerebral activation patterns induced by verb inflection. *NeuroImage* 5:S548. [PI, TFM]
Indefrey, P., Hagoort, P., Brown, C., Herzog, H. & Seitz, R. (1996) Cortical activation induced by syntactic processing: A [^{15}O]-butanol PET study. *NeuroImage* 3:442. [aHC]
Jackendoff, R. (1997) *The architecture of the language faculty.* MIT Press. [aHC]
Jacobs, R. A. (1999) Computational studies of the development of functionally specialized neural modules. *Trends in Cognitive Sciences* 3:31–38. [MZ]
Jaeger, J. J., Lockwood, A. H., Kemmerer, D. L., Van Valin, R. D., Murphy, B. W. & Khalak, H. G. (1996) A positron emission tomographic study of regular and irregular verb morphology in English. *Language* 72:451–97. [aHC, MFJ, TFM]
Jaeger, J. J., van Valin, R. & Lockwood, A. (1998) Response to Seidenberg and Hoeffner. *Language* 74:123–28. [rHC]
Janda, R. (1990) Frequency, markedness and morphological change: On predicting the spread of noun-plural -s in Modern High German and West Germanic. *ESCOL '90:*136–53. [aHC]
Janssen, D. P. (1999) Producing past and plural inflections. Unpublished doctoral dissertation, Nijmegen University, Nijmegen, The Netherlands. [DPJ]
Joanisse, M. & Seidenberg, M. (1999) Impairments in verb morphology following brain injury: A connectionist model. *Proceedings of the National Academy of Sciences, USA* 64(13):7592–97. [MFJ]
Johansson, S. & Hofland, K. (1989) *Frequency analysis of English vocabulary and grammar.* Oxford University Press. [CEC]
Johnson, M. H. (1997) *Developmental cognitive neuroscience.* Blackwell. [GW]
Johnson-Laird, P. (1998) *The computer and the mind. An introduction to cognitive science.* Fontana Press. [RW]
Jorion, P. (1990) *Principes des systèmes intelligents,* Collection "Sciences cognitives." Masson. [Summary in English: http://cogprints.soton.ac.uk/abs/comp/199806039]. [PJMJ]
Kager, R. (1996) On affix allomorphy and syllable counting. In: *Interfaces in phonology,* ed. U. Kleinhenz. Akademis Verlag. [JPS]
Kálmán, L. (1985) Inflectional morphology. In: *Approaches to Hungarian, vol. 1,* ed. I. Kenesei. SATE. [AL]
Karmiloff-Smith, A. (1992) *Beyond modularity: A developmental perspective on cognitive science.* MIT Press. [aHC]
Kean, M.-L. (1977) The linguistic interpretation of aphasic syndromes: Agrammatism in Broca's aphasia. *Cognition* 5:9–46. [aHC]
Keller, R. (1994) *On language change. The invisible hand in language.* Routledge. [BN]
Kempley, S. & Morton, J. (1982) The effects of priming with regularly and irregularly related words in auditory word recognition. *British Journal of Psychology* 73:441–54. [aHC]
Kilani-Schoch, M., de Marco, A., Christofidou, A., Vassilakou, M., Vollmann, R. & Dressler, W. U. (1997) On the demarcation of phases in early morphology acquisition in four languages. *Papers and Studies in Contrastive Linguistics* 33:15–32. [WUD]
Kim, J. J., Marcus, G. F., Pinker, S., Hollander, M. & Coppola, M. (1994) Sensitivity of children's inflection to morphological structure. *Journal of Child Language* 21:173–209. [aHC]
King, J. W. & Kutas, M. (1995) A brain potential whose latency indexes the length and frequency of words. *CRL Newsletter* 10:1–9. [aHC]
Kiparsky, P. (1982) From cyclic phonology to lexical phonology. In: *The structure of phonological representations (Part I),* ed. H. van der Hulst & N. Smith. Foris. [aHC]
(1992) Analogy. In: *International encyclopedia of linguistics, vol. 1,* ed. W. Bright. Oxford University Press. [DF]
Knobloch, C. (1991) Introduction. In: P. Wegener, *Untersuchungen über die Grundfragen des Sprachlebens,* ed. E. F. K. Koerner. John Benjamins. [BN]
Kohnen, B. (1933) *Shilluk grammar.* Nigrizia School Press. [GGC]
Köpcke, K.-M. (1988) Schemas in German plural formation. *Lingua* 74:303–35. [JB, aHC, PI]
(1993) *Schemata bei der Pluralbildung des Deutschen.* Narr. [aHC, UH]
(1998) The acquisition of plural marking in English and German revisited: Schemata vs. rules. *Journal of Child Language* 25:293–319. [HB]
Krauss, M. (1992) The world's languages in crisis. *Language* 68:4–10. [GGC]
Kutas, M. & Hillyard, S. (1980) Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science* 207:203–205. [aHC]
(1983) Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition* 11:539–50. [aHC]
Kutas, M. & Kluender, R. (1994) What is who violating: A reconsideration of linguistic violations in light of event-related brain potentials. In: *Cognitive electrophysiology,* ed. H.-J. Heinze, T. Münte & G. Mangun. Birkhaüser. [aHC, MFJ]
Kutas, M. & Van Petten, C. (1994) Psycholinguistics electrified. In: *Handbook of psycholinguistics,* ed. M. Gernsbacher. Academic Press. [aHC]
Langacker, R. (1987) *Foundations of cognitive grammar. Vol 1: Theoretical prerequisites.* Stanford University Press. [GB]
Lapointe, S. (1983) Some issues in the linguistic description of agrammatism. *Cognition* 14:1–39. [aHC]
Lasnik, H. (1998) Verbal morphology: *Syntactic structures* meets the minimalist program. In: *Minimalist analysis,* ed. H. Lasnik. Blackwell. [DL]
Laudanna, A. & Burani, C. (1985) Address mechanisms to decomposed lexical entries. *Linguistics* 23:775–92. [aHC]
(1995) Distributional properties of derivational affixes: Implications for processing. In: *Morphological aspects of language processing,* ed. L. B. Feldman. Erlbaum. [aHC, AL]
Leonard, L. B. (1996) Characterizing specific language impairment: A crosslinguistic perspective. In: *Toward a genetics of language,* ed. M. L. Rice. Erlbaum. [LS]
(1998) *Children with specific language impairment.* MIT Press. [LS]
Leonard, L. B. & Dromi, E. (1994) The use of Hebrew verb morphology by children with specific language impairment and children developing language normally. *First Language* 14(42, part 3):283–304. [LS]
Levelt, W. J. M. (1989) *Speaking: From intention to articulation.* MIT Press. [MZ]
Levelt, W. J. M., Roelofs, A. & Meyer, A. S. (1999) A theory of lexical access in speech production. *Behavioral and Brain Sciences* 22(1):1–75. [GGC]
Lightfoot, D. W. (1998) Promises, promises: General learning algorithms. (review article of Elman et al. 1996). *Mind and Language* 13(4):582–87. [DL]
(1999) *The development of language: Acquisition, change and evolution.* Blackwell. [DL]
Lindner, K. (1998) Overgeneralization revisited: The case of German past participles. In: *Models of inflection,* ed. R. Fabri, A. Ortmann & T. Parodi. Niemeyer. [HB]

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Lively, S., Pisoni, D. & Goldinger, S. (1994) Spoken word recognition. In: *Handbook of psycholinguistics,* ed. M. Gernsbacher. Academic Press. [aHC]
Losiewicz, B. L. (1992) *The effect of frequency on linguistic morphology.* Ph. D. dissertation, University of Texas, Austin.
Lukács, Á. (1999) Rules and exceptions – characteristics of processing regular and irregular forms of Hungarian morphology. Unpublished MA thesis, ELTE, Budapest. [AL]
Lust, B., Barbier, I., Foley, C., Hermon, G., Kapur, S., Kornfilt, J., Nuñez del Prado, Z., Suñer, M. & Whitman, J. (1994) Syntactic theory and first language acquisition: Crosslinguistic perspectives. In: *Syntactic theory and first language acquisition - crosslinguistic perspectives: Vol. 1 - heads, projections and learnability,* ed. B. Lust, M. Suñer & J. Whitman. Erlbaum. [LS]
MacWhinney, B. (1978) The acquisition of morphophonology. *Monograph of the Society for Research in Child Development,* No. 174. [AL]
MacWhinney, B. & Leinbach, J. (1991) Implementations are not conceptualizations: Revising the verb learning model. *Cognition* 40:121–57. [aHC]
Manelis, L. & Tharp, D. (1977) The processing of affixed words. *Memory and Cognition* 5:690–95. [aHC]
Marcus, G. (1995) The acquisition of English past tense in children and multilayered connectionist networks. *Cognition* 56:271–79. [aHC]
(1998) Can connectionism save constructivism? *Cognition* 66:153–82. [DL]
(1999) *The algebraic mind: Reflections on connectionism and cognitive science.* MIT Press (in press). [aHC, DL]
Marcus, G. F., Brinkmann, U., Clahsen, H., Wiese, R. & Pinker, S. (1995) German inflection: The exception that proves the rule. *Cognitive Psychology* 29:189–256. [arHC, UH, PI, AL, FP, JPS, GW, DW]
Marcus, G. F., Pinker, S., Ullman, M., Hollander, M., Rosen, T. & Xu, F. (1992) *Overregularization in language acquisition. Monographs of the Society for Research in Child Development 57* (4, Serial No. 228). [JB, aHC, GW]
Marin, O. S. M., Saffran, E. M. & Schwartz, M. F (1976) Dissociations of language in aphasia: Implications for normal function. *Annals of the New York Academy of Sciences* 868–84. [MTU]
Marslen-Wilson, W. D. (1987) Functional parallelism in spoken word recognition. *Cognition* 25:71–102. [LS]
Marslen-Wilson, W., Hare, M. & Older, L. (1993) Inflectional morphology and phonological regularity in the English mental lexicon. *Proceedings of the Fifteenth Annual Conference of the Cognitive Science Society.* Erlbaum. [aHC, MFJ]
Marslen-Wilson, W. & Tyler, L. (1997) Dissociating types of mental computation. *Nature* 387:592–94. [aHC, MFJ, TFM, FP]
(1998) Rules, representations, and the English past tense. *Trends in Cognitive Sciences* 2:428–35. [TFM, MO]
Marslen-Wilson, W., Tyler, L., Waksler, R. & Older, L. (1994) Morphology and meaning in the English mental lexicon. *Psychological Review* 101:3–33. [arHC]
Marslen-Wilson, W. & Welsh, A. (1978) Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology* 10:29–63. [LS]
McCarthy, J. & Prince, A. (1990) Foot and word in prosodic morphology: The Arabic broken plural. *Natural Language and Linguistic Theory* 8:209–83. [RW]
McClelland, J. L. & Plaut, D. C. (1999) Does generalization in infant learning implicate abstract algebra-like rules? *Trends in Cognitive Sciences* 3:166–68. [MZ]
McClelland, J. L. & Rumelhart, D. (1981) An interactive activation model of context effects in letter perception. *Psychological Review* 88:60–94. [LS]
McDonald, M. C., Pearlmutter, N. J. & Seidenberg, M. S. (1994) The lexical nature of syntactic ambiguity resolution. *Psychological Review* 101:676–703. [MZ]
McKinnon, R. & Osterhout, L. (1996) Constraints on movement phenomena in sentence processing: Evidence from event related brain potentials. *Language and Cognitive Processes* 11:495–523. [aHC]
McQueen, J. M. & Cutler, A. (1998) Morphology in word recognition. In: *The handbook of morphology,* ed. A. Spencer & A. M. Zwicky. Blackwell. [CEC, ED]
McQueen, J. M., Van Ooijen, B. & Cutler, A. (1992) Are regular and irregular inflections represented in the same way in the lexicon? Paper presented to the Experimental Psychology Society, University of Oxford, April 1992. [CEC]
Meier, H. (1964) *Deutsche Sprachstatistik.* Buske. [aHC]
Miller, G. & Chomsky, N. (1963) Finitary models of language users. In: *Handbook of mathematical psychology,* ed. R. Luce, R. Bush & E. Galanter. Wiley. [aHC]
Morton, J. (1969) Interaction of word information in word recognition. *Psychological Review* 76:165–78. [LS]
Mugdan, J. (1977) *Flexionsmorphologie und Psycholinguistik.* Narr. [arHC]
Münte, T. F., Anvari, E., Matzke, M. & Johannes, S. (1995) Brain potential correlates of number errors in Turkish language. *Neuroscience Letters* 199:57–60. [aHC]
Münte, T. F., Heinze, H.-J. & Mangun, G. (1993) Dissociation of brain activity related to syntactic and semantic aspects of language. *Journal of Cognitive Neuroscience* 5:335–44. [aHC]
Münte, T. F., Say, T., Clahsen, H., Gross, M. & Kutas, M. (1998) Decomposition of morphologically complex words in English: Evidence from even-related brain potentials. *Cognitive Brain Research* 7:241–53. [aHC]
Münte, T. F., Matzke, M. & Johannes, S. (1999) Brain activity associated with number errors in words and pseudo-words. *Journal of Cognitive Neuroscience* (in press). [aHC]
Nakisa, R., Plunkett, K. & Hahn, U. (1999) A cross-linguistic comparison of single and dual-route models of inflectional morphology. In: *Cognitive models of language acquisition,* ed. P. Broeder & J. Murre. MIT Press. [aHC, GW]
Napps, S. (1989) Morphemic relationships in the lexicon: Are they distinct from semantic and formal relationships? *Memory and Cognition* 17(6):729–39. [aHC]
Nebes, R. D. (1997) Alzheimer's disease: Cognitive neuropsychological aspects. In: *Behavioral neurology and neuropsychiatry,* ed. T. E. Feinberg & M. J. Farah. McGraw-Hill. [MTU]
Neef, M. (1998a) A declarative path through the jungle of German noun inflection. SFB Working Paper *Theorie des Lexikons,* vol. 102. [rHC]
(1998b) The reduced syllable plural in German. In: *Models of inflection,* ed. R. Fabri, A. Ortmann & T. Parodi. Niemeyer. [RW, DW]
Nerlich, B. (1990) *Change in language. Whitney, Bréal and Wegener.* Routledge. [BN]
Neville, H., Nicol, J., Barss, A., Forster, K. & Garrett, M. (1991) Syntactically based sentence processing classes: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience* 3:151–65. [aHC, MFJ, FP, MTU]
Newman, A., Izvorski, R., Davis, L., Neville, H. & Ullman, M. T. (1999) *Distinct electrophysiological patterns in the processing of regular and irregular verbs.* Paper presented at the 6th Annual Meeting of the Cognitive Neuroscience Society, Washington, DC. [MTU]
Newman, A., Neville, H. & Ullman, M. T. (1998) *Neural processing of inflectional morphology: An event-related potential study of English past tense.* Paper presented at the 5th Annual Meeting of the Cognitive Neuroscience Society, San Francisco. [MTU]
Niedeggen-Bartke, S., Niedeggen, M., Wiese, R. & Rösler, F. (1998) An ERP-investigation of German plurals. Poster presented at the XIIth International Conference on Event-Related Potentials of the Brain, Boston. [RW]
Nobre, A. C., Allison, T. & McCarthy, G. (1994) Word recognition in the human inferior temporal lobe. *Nature* 372:260–63. [MTU]
Noccioli, N. (1998) Tuscan children's learning of Italian past tense. Degree dissertation. University of Rome "La Sapienza." [MO]
Olsen, S. (1990) Konversion als ein konkatenativer Wortbildungsprozeß. *Linguistische Berichte* 127:185–216. [aHC]
Orsolini, M. & Marslen-Wilson, W. (1997) Universals in morphological representation: Evidence from Italian. *Language and Cognitive Processes* 12(1):1–47. [MO]
Orsolini, M., Fanari, R. & Bowles, H. (1998) Acquiring regular and irregular inflection in a language with verb classes. *Language and Cognitive Processes* 13:425–64. [MO]
Osterhout, L. & Holcomb, P. (1992) Event-related brain potentials elicited by syntactic anomaly. *Journal of Memory and Language* 31:785–806. [aHC]
(1995) Event-related potentials and language comprehension. In: *Electrophysiology of mind: Event-related brain potentials and cognition,* ed. M. Rugg & M. Coles. Oxford University Press. [aHC]
Osterhout, L. & Mobley, L. (1995) Event-related brain potentials elicited by failure to agree. *Journal of Memory and Language* 34:739–73. [aHC]
Pandya, D. N. & Yeterian, E. H. (1985) Architecture and connections of cortical association areas. In: *Cerebral cortex. Vol. 4: Association and auditory cortices,* ed. A. Peters & E. G. Jones. Plenum Press. [FP]
Park, T. (1978) Plurals in child speech. *Journal of Child Language* 5:237–50. [WUD]
Paul, H. (1877) Die Vocale der Flexions- und Ableitungs-Silben in den aeltesten germanischen Dialecten. *Beiträge zur Geschichte der deutschen Sprache und Literatur* 4:315–475. [DF]
Penke, M. (1998) *Die Grammatik des Agrammatismus: Eine linguistische Untersuchung zu Wortstellung und Flexion bei Broca-Aphasie.* Niemeyer. [aHC]
Penke, M., Janssen, U. & Krause, M. (1999) The representation of inflectional morphology: Evidence from Broca's aphasia. *Brain and Language* 68:225–32. [GW; JPB]
Penke, M. & Krause, M. (1999) Broca's aphasia and German plural formation. *Brain and Language* (to appear). [rHC, DW]
Penke, M., Weyerts, H., Gross, M., Zander, E., Münte, T. & Clahsen, H. (1997) How the brain processes complex words: An ERP-study of German verb inflections. *Cognitive Brain Research* 6:37–52. [arHC, MFJ]
Perlmutter, D. (1988) The split morphology hypothesis; evidence from Yiddish. In: *Theoretical morphology,* ed. M. Hammond & M. Noonan. Academic Press. [GB]

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Peterson, S. & Fiez, J. (1993) The processing of single words studied with positron emission tomography. *Annual Review Neuroscience* 16:509–30. [aHC]
Peterson, S., Fox, P., Posner, M., Mintun, M. & Raichle, M. (1989) Positron emission tomographic studies of the processing of single words. *Journal of Cognitive Neuroscience* 1:153–70. [aHC]
Pfeffer, J. (1964) *Grunddeutsch: Basic (spoken) German word list.* Prentice Hall. [aHC]
Phillips, C. (1996) Order and structure. Unpublished Ph. D. dissertation, MIT. [aHC]
Pinker, S. (1984) *Language learnability and language development.* Harvard University Press. [arHC]
(1991) Rules of language. *Science* 253:530–35. [HB]
(1997) Words and rules in the human brain. *Nature* 387:547–48. [arHC, MFJ, TFM]
(1999) *Words and rules: The ingredients of language.* Basic Books. [rHC]
Pinker, S. & Prince, A. (1988) On language and connectionism: Analysis of a parallel distributed processing model of language acquisition. *Cognition* 28:73–193. [aHC]
(1991/1994) Regular and irregular morphology and the psychological status of rules of grammar. *Proceedings of the 17th Annual Meeting of the Berkeley Linguistics Society,* Berkeley, CA. [aHC] Also in: *The reality of linguistic rules,* ed. S. D. Lima, R. L. Corrigan & G. K. Iverson. John Benjamins, 1994. [AL]
Plaut, D. C., McClelland, J. L., Seidenberg, M. S. & Patterson, K. E. (1996) Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review* 103:56–115. [MFJ, MZ]
Pléh, C., Palotás, G. & Lörik, J. (1994) A new screening method for Hungarian language impaired children. Manuscript, Budapest. [AL]
Plunkett, K. & Marchman, V. (1991) U-shaped learning and frequency effects in a multilayered perceptron: Implications for child language acquisition. *Cognition* 38:1–60. [aHC]
(1993) From rote learning to system building: Acquiring verb morphology in children and connectionist nets. *Cognition* 38:43–102. [aHC]
Pollard, C. & Sag, I. (1987) *Information-based syntax and semantics.* CSLI Lectures Notes, vol. 13. Stanford University. [RW]
Prasada, S. & Pinker, S. (1993) Similarity-based and rule-based generalizations in inflectional morphology. *Language and Cognitive Processes* 8:1–56. [aHC]
Prasada, S., Pinker, S. & Snyder, W. (1990) Some evidence that irregular forms are retrieved from memory but regular forms are rule generated. Paper presented at the 31st Annual Meeting of the Psychonomic Society, New Orleans, November 16–18. [rHC]
Priestly, T. M. S. (1993) Slovene. In: *The Slavonic languages,* ed. B. Comrie & G. G. Corbett. Routledge. [GGC]
Prince, A. & Smolensky, P. (1993) *Optimality theory: Constraint interaction in generative grammar.* Rutgers University Center for Cognitive Science, Technical Report No. 2. [RW]
Pulvermüller, F. (1998) On the matter of rules. Past tense formation as a test-case for brain models of language. *Network: Computation in Neural Systems* 9:R1–51. [FP]
(1999) Words in the brain's language. *Behavioral and Brain Sciences* 22:253–336. [FP]
Pulvermüller, F., Lutzenberger, W. & Birbaumer, N. (1995) Electrocortical distinction of vocabulary types. *Electroencephalography and Clinical Neurophysiology* 94:357–70. [FP]
Quartz, S. R. (1993) Neural networks, nativism, and the plausibility of constructivism. *Cognition* 48:223–42. [GW]
Quartz, S. R. & Sejnowski, T. (1997) The neural basis of cognitive development: A constructivist manifesto. *Behavioral and Brain Sciences* 20(4):537–96. [aHC, GW]
Rhee, J., Pinker, S.& Ullman, M. T. (1999) *A magnetoencephalographic study of English past tense production.* Paper presented at the Proceedings of the 6th Annual Meeting of the Cognitive Neuroscience Society, Washington, DC. [MTU]
Roberts, I. (1993) *Verbs and diachronic syntax.* Kluwer. [DL]
Roelofs, A. (1997) Morpheme frequency in speech production: Testing WAEVER. *Yearbook of Morphology 1996:*135–54. [rHC]
Rohrbacher, B. (1994) *The Germanic languages and the full paradigm: A theory of V to I raising.* Ph. D. dissertation, University of Massachusetts. [DL]
Rueckl, J. G., Mikolinskis, M., Raveh, M., Miner, C. S. & Mars, F. (1997) Morphological priming, fragment completion, and connectionist networks. *Journal of Memory and Language* 36:382–405. [aHC]
Rugg, M. (1987) Dissociation of semantic priming, word and non-word repetition by event-related potentials. *Quarterly Journal of Experimental Psychology* 39A:123–48. [aHC]
Rumelhart, D. & McClelland, J. (1986) On learning the past tenses of English verbs. In: *Parallel distributed processing: Explorations in the microstructure of cognition. Vol 1: Foundations,* ed. J. McClelland, D. Rumelhart & the PDP Research Group. MIT Press. [aHC, MZ]
Ruoff, A. (1981) *Häufigkeitswörterbuch gesprochener Sprache.* Frankfurt. [aHC]
Sánchez Miret, F., Koliadis, A. & Dressler, W. U. (1997) Connectionism vs. rules in diachronic morphology. *Folia Linguistica Historica* 18:149–82. [WUD]
Say, T. (1998) Regular and irregular inflection in the mental lexicon: Evidence from Italian. *Essex Graduate Student Papers in Language and Linguistics* 2:55–70. [rHC]
Say, T. & Clahsen, H. (1999) Words and rules in the Italian mental lexicon. Unpublished manuscript. University of Essex. [rHC]
Schaner-Wolles, C. (1993) Plural- vs. Komparativerwerb im Deutschen. In: *Experimentelle Studien zur deutschen Flexionsmorphologie,* ed. H. Günther. Buske. [WUD]
Schleicher, A. (1860) *Die deutsche Sprache.* Cotta. [BN]
Schnelle, H. (1991) *Die Natur der Sprache.* de Gruyter-Mouton. [HS]
Schreuder, R. & Baayen, H. (1995) Modelling morphological processing. In: *Morphological aspects of language processing,* ed. L. Feldman. Erlbaum. [aHC]
Sedlak, M., Klampfer, S., Müller, B. & Dressler, W. U. (1998) The acquisition of number in Austrian German. *Antwerp Papers in Linguistics* 95:51–76. [WUD]
Seidenberg, M. S. (1997) Language acquisition and use: Learning and applying probabilistic constraints. *Science* 275:1599–603. [aHC]
Seidenberg, M. S. & Hoeffner, J. (1998) Evaluating behavioral and neuroimaging data on past tense processing. *Language* 74:104–22. [rHC, MFJ]
Seidenberg, M. S. & McClelland, J. (1989) A distributed, developmental model of visual word recognition and naming. *Psychological Review* 96:523–68. [MFJ, MZ]
Selkirk, L. (1982) *The syntax of words.* MIT Press. [aHC]
Sereno, J. & Jongman, A. (1997) Processing of English inflectional morphology. *Memory and Cognition* 25:425–37. [RS, JS]
Shallice, T. (1988) *From neuropsychology to mental structure.* Cambridge University Press. [MZ]
Skousen, R. (1989) *Analogical modelling of language.* Kluwer. [BN]
Slobin, D. I. (1966) Grammatical transformations and sentence comprehension in childhood and adulthood. *Journal of Verbal Learning and Verbal Behavior* 5:219–27. [aHC]
(1985) *The cross-linguistic study of language acquisition.* Erlbaum. [LS]
Sonnenstuhl, I. (1999) The mental representation of German noun plurals (in preparation). [rHC, DW]
Sonnenstuhl, I., Eisenbeiss, S. & Clahsen, H. (1999) Morphological priming in the German mental lexicon. *Cognition* 72(3):203–36. [arHC]
Stanners, R., Neiser, J., Hernon, W. & Hall, R. (1979) Memory representation for morphologically related words. *Journal of Verbal Learning and Verbal Behavior* 18:399–412. [aHC, AL]
Stemberger, J. P. (1985) An interactive activation model of language production. In: *Progress in the psychology of language, vol. 1,* ed. A. Ellis. Erlbaum. [JPS]
(1996) The dance of the defaults: The acquisition of morphology within phonology. Unpublished manuscript, University of Minnesota. [JPS]
Stemberger, J. P. & MacWhinney, B. (1986) Frequency and the lexical storage of regularly inflected forms. *Memory and Cognition* 14:17–26. [JB, arHC, MFJ]
Stromswold, K., Alpert, N., Rausch, S. & Caplan, D. (1996) Localization of syntactic comprehension by Positron Emission Tomography. *Brain and Language* 52:452–73. [aHC]
Stump, G. T. (1993) On rules of referral. *Language* 69:449–79. [AS]
Taft, M. (1978) Evidence that auditory word perception is not continuous: The DAZE effect. Paper presented to the Australian Experimental Psychology Conference, LaTrobe University, May 1978. [CEC]
(1979) Recognition of affixed words and the word-frequency effect. *Memory and Cognition* 7:263–72. [aHC, ED, RS]
Ullman, M. T. (1993) The computation of inflectional morphology. Unpublished Ph. D. dissertation, Massachusetts Institute of Technology. [rHC]
(in press) Evidence that lexical memory is part of the temporal lobe declarative memory, and that grammatical rules are processed by the frontal/basal-ganglia procedural system. *Brain and Language.* [MTU]
Ullman, M. T., Bergida, R. & O'Craven, K. (1997a) Distinct fMRI activation patterns for regular and irregular past tense. *NeuroImage* 5(4):S555. [aHC, MFJ, TFM]
Ullman, M. T., Corkin, S., Coppola, M., Hickock, G., Growdon, J. H., Koroshetz, W. J. & Pinker, S. (1997b) A neural dissociation within language: Evidence that the mental dictionary is part of declarative memory, and that grammatical rules are processed by the procedural system. *Journal of Cognitive Neuroscience* 9:266–76. [MFJ, TFM, FP, MTU, MZ]
Ullman, M. T., Corkin, S., Pinker, S., Coppola, M., Locascio, J. & Growdon, J. (1993) Neural modularity in language: Evidence from Alzheimer's and Parkinson's diseases. *Society for Neuroscience Abstracts* 19:1806. [MTU]
(1994) The neural structures subserving language: Evidence from inflectional morphology. Paper presented at the 1st Annual Meeting of the Cognitive Neuroscience Society, San Francisco, CA. [MTU]

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press

Ullman, M. T. & Gopnik, M. (1994) Past tense production: Regular, irregular and nonsense verbs. *McGill Working Papers in Linguistics* 10:81–118. [aHC]
Ullman, M. T., Hickok, G. & Pinker, S. (1995) Regular and irregular inflectional morphology in agrammatic aphasics. *Brain and Cognition* 28:88–89. [MTU]
Ullman, M. T., Izvorski, R., Love, T., Yee, E., Swinney, D. & Hickok, G. (in press) The role of grammar and lexicon in the computation of inflection in anterior and posterior aphasia. *Brain and Language.* [MTU]
Ullman, M. T., Yee, E. & Schmahmann, J. (1998) Cerebellar atrophy leads to a dissociation within language. Poster at the 5th Annual Meeting of the Cognitive Neuroscience Society, Boston, 1998. [TFM]
Van Essen, D. C., Anderson, C. H. & Felleman, D. J. (1992) Information processing in the primate visual system: An integrated systems perspective. *Science* 255:419–23. [TFM]
Van Essen, D. C., Felleman, D. J., DeYoe, E. A., Olavarria, J. & Knierim, J. (1990) Modular and hierarchical organization of extrastriate visual cortex in the macaque monkey. Cold Spring Harbor Symposia Quantitative Biology 55:679–96. [TFM]
Van Ooijen, B., McQueen, J. M. & Cutler, A. (1992) Lexical representation of regular versus irregular inflected forms: Evidence from spoken word recognition. Paper presented to the Linguistics Association of Great Britain, University of Sussex, April 1992. [CEC]
Vollmann, R., Sedlak, M., Müller, B. & Vassilakou, M. (1997) Early verb inflection and noun plural formation in four Austrian children. *Papers and Studies in Contrastive Linguistics* 33:59–78. [WUD]
Wagner, K. (1981) Wieviel sprechen Kinder täglich? *Wirkendes Wort* 31:17–28. [aHC]
Warner, A. (1995) Predicting the progressive passive: Parametric change within a lexicalist framework. *Language* 71(3):533–57. [DL]
Warren, B. (in preparation) The role of links and/or qualia in modifier-head constructions. In: *Polysemy: Patterns of meaning in mind and language,* ed. B. Nerlich, V. Herman, Z. Todd & D. D. Clarke. John Benjamins. [BN]
Wegener, P. (1885) *Untersuchungen über die Grundfragen des Sprachlebens.* Niemeyer. (New edition by E. F. K. Koerner with an introduction by C. Knobloch. John Benjamins, 1991.) [BN]
Weissenborn, J. (1992) Null subjects in early grammars: Implications for parameter- setting theories. In: *Theoretical issues in language acquisition,* ed. J. Weissenborn, H. Goodluck & T. Roeper. Erlbaum. [aHC]
Westermann, G. (1997) A constructivist neural network learns the past tense of English verbs. In: *Proceedings of the GALA '97 Conference on Language Acquisition,* Edinburgh, UK. HCRC. http://www.anc.ed.ac.uk/~gert/publications/gala97.ps. [GW]
(1998) Emergent modularity and U-shaped learning in a constructivist neural network learning the English past tense. In: *Proceedings of the 20th Annual Conference of the Cognitive Science Society.* Erlbaum. [GW, MZ] http://www.anc.ed.ac.uk/~gert/ppublications/cogsci98.ps. [GW]
Westermann, G. & Goebel, R. (1995) Connectionist rules of language. In: *Proceedings of the Seventeenth Annual Conference of the Cognitive Science Society,* ed. J. Moore & J. Lehmann. Erlbaum. [aHC]
Westermann, G., Willshaw, D. & Penke, M. (1999) A constructivist neural network model of German verb inflections in agrammatic aphasia. In: *Proceedings of ICANN99.* http://www.anc.ed.ac.uk/~gert/publications/icann99.ps. [GW]
Wexler, K. (1999) Maturation and growth of grammar. In: *Handbook of child language acquisition,* ed. W. C. Ritchie & T. K. Bhatia. Academic Press. [rHC]
Weyerts, H. (1997) Reguläre und irreguläre Flexion: Psycholinguistische und neurophysiologische Ergebnisse zu Erwerb, Verarbeitung und mentaler Repräsentation. Dissertation. University of Düsseldorf. [aHC]
Weyerts, H. & Clahsen, H. (1994) Netzwerke und symbolische Regeln im Spracherwerb: Experimentelle Ergebnisse zur Entwicklung der Flexionsmorphologie. *Linguistische Berichte* 154:430–60. [aHC]
Weyerts, H., Penke, M., Dohrn, U., Clahsen, H. & Münte, T. (1997) Brain potentials indicate differences between regular and irregular German noun plurals. *NeuroReport* 8:957–62. [arHC, ED, MFJ]
Wiese, R. (1996) *The phonology of German.* Oxford University Press [JPB, arHC, DW, RW] and Clarendon Press. [RW, DW]
Wilkens, R. (1997) *Spontanes versus relflektiertes Sprachverstehen.* Deutscher Universitäts Verlag. [HS]
Williams, E. (1981) On the notions "lexically related" and "head of a word." *Linguistic Inquiry* 12:245–74. [aHC]
Wulfeck, B., Bates, E. & Capasso, R. (1991) A crosslinguistic study of grammatical judgments in Broca's aphasia. *Brain and Language* 41(2):311–36. [LS]
Wunderlich, D. (1986) Zum Aufbau lexikalischer Repräsentationen. Unpublished manuscript. University of Düsseldorf. [aHC]
(1996) Minimalist morphology: The role of paradigms. *Yearbook of Morphology 1995*:93–114. [aHC, DPJ]
(1999) German noun plural reconsidered. Unpublished manuscript, University of Düsseldorf. [rHC]
Wunderlich, D. & Fabri, R. (1995) Minimalist morphology: An approach to inflection. *Zeitschrift für Sprachwissenschaft* 14:236–94. [aHC, WUD]
Wurzel, W. U. (1990) The mechanism of inflection: Lexicon representations, rules and irregularities. In: *Contemporary morphology,* ed. W. U. Dressler, H. C. Luschützky, O. E. Pfeiffer & J. R. Rennison. Mouton de Gruyter. [RW]
Xu, F. & Pinker, S. (1995) Weird past tense forms. *Journal of Child Language* 22:531–56. [aHC]
Young, M. P., Scannell, J. W. & Burns, G. (1995) *The analysis of cortical connectivity.* Springer. [FP]
Zepeda, O. (1983) *A Papago grammar.* University of Arizona. Press. [JPB]
Zipf, G. K. (1935) *The psychology of language.* Houghton-Mifflin. [JPS]
Zorzi, M., Houghton, G. & Butterworth, B. (1998a) Two routes or one in reading aloud? A connectionist dual-process model. *Journal of Experimental Psychology: Human Perception and Performance* 24:1131–61. [MZ]
(1998b) The development of spelling-sound relationships in a model of phonological reading. *Language and Cognitive Processes* 13:337–71. [MZ]

https://doi.org/10.1017/S0140525X9926222X Published online by Cambridge University Press