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

Michael T. Ullman

Georgetown Institute for Cognitive and Computational Sciences, Georgetown University, Washington, DC 20007. **michael@giccs.georgetown.edu**
www.giccs.georgetown.edu/labs/ullman

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

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

Gert Westermann

Division of Informatics, University of Edinburgh, Institute for Adaptive and Neural Computation, Edinburgh EH8 9LW, Scotland. **gert@anc.ed.ac.uk**
www.anc.ed.ac.uk/~gert/

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.