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	*ár**kok**-árok*[a]	24*
2. Lowering n = 71	*lyuk**ak**-lyuk*	26
3. Shortening n = 222	*teny**erek**-tenyér*	24*
4. 'Low-V'-final	*mes**ék**-mese*	55**
5. C-final	*bútor**ok**-bútor*	36**
6. 'Nonlow V'-final	*gyűrű**k**-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 $\times$ 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 $\times$ 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.

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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 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 temporo-parietal 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.

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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 over-confirm the undeniable and to overlook the hidden motor of language use