MORPHOLOGICAL ENCODING VIA PHONOLOGICAL FEATURES: FROM PHONETICS TO GRAMMAR

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ABSTRACT

How can the hearing of an inflected verb with an altered vowel activate the root form of that verb in a language with a reasonable complex productive morphology, which rules out storing all word variants? We proposes a single lexical representation for the present tense root vowel in German irregular (strong) verbs which exhibit a surface alternation between [ɛ]/[a] and [i]/[e] in the 2ND and 3RD PERSON SINGULAR versus other forms. The claim is that the root vowels do not have a place of articulation feature specification in their underlying form. Evidence for this approach comes from two crossmodal priming experiments which compare strong verbs with regular (weak) verbs, the latter without any root vowel alternations. Our hypothesis that the priming pattern solely depends on feature specifications and not on the priming direction (experiment 1: 2ND SG. → INFINITIVE; experiment 2: INFINITIVE → 2ND SG.) was borne out by our data.

Keywords: lexical access, priming, vowel alternation, phonological features, morphology

1. INTRODUCTION

Models of speech recognition encode morphological information differently. Dual Route models represent irregular morphological information via lexical listing while regular processes are handled by a rule processor [2, 9]. In contrast, so-called Single Route models are dominated by connectionist approaches (e.g. [6, 7]) in which morphology emerges through analogies of formal and semantic information.

Relatively untouched by the psycholinguistic discussion is the present tense stem alternation in the *strong* (or irregular) German <a>- and <e>-verbs (we write orthographic stem classes with angled brackets <>). The stem alternation differentiates the 2ND and 3RD PERSON SINGULAR PRESENT (2ND/3RD SG PRES), along with the regular person/number suffixes *–st* and *–t,* with the other present tense forms and the INFINITIVE (INF; [ɛː]~[aː], *schläfst~schlafen* 'sleep-2ND SG PRES~INF'; [iː]~[eː], *siehst~sehen* 'see-2ND SG PRES~INF'). Weak (or regular) verbs, on the other hand, do not exhibit any such alternation ([a], *machst~machen* 'make-2ND SG PRES~INF'; [eː], *lebst~leben* 'live-2ND SG PRES~INF').

Within the Dual Route approach of Clahsen and colleagues [2, 3, 9], a morphological flat structure is assumed for weak verbs, while strong verbs are inherently complex and hierarchically organized. The weak verbs have a single root and all forms access the root equally efficiently. Although the strong verbs have a single base root (identical to the INF), the alternating forms are on a lower level in the hierarchy. The access to the base via a lower-level form is claimed to be more efficient than the other way around.

We assume that the surface alternation in the present tense of the strong verbs is resolved in the lexical representations and not by listing every surface form. Thus, strong and weak verbs are accessed in the same way. The crucial reason for this is that the root vowels of strong verb roots are underspecified and have the same flat structure as the weak verbs. The morphophonological assumptions formulated in the framework of the Featurally Underspecified Lexicon (FUL, [5]) are the following:

- the coronal place of articulation (ART) is not specified for front vowels in the mental lexicon;
- [CORONAL] and [DORSAL] are mutually exclusive, and conflict;
- strong <a>-roots are specified as [LOW], while weak <a>-roots are [LOW] *and* [DORSAL];
- the <e>-roots in strong and weak verbs have identical placeless representations.

The consequences for lexical access are as follows. If [DORSAL] is specified in the strong <a>-verbs (e.g. *schlafen*, cf. *machen*) the inflected form *schläfst* with a surface [CORONAL] vowel [ɛ], contains a mismatching ART feature, and word recognition would be disrupted. Therefore, we assume that the root vowel of *schlafen* has no ART specification underlyingly, such that *schläfst* does *not nomismatch* with *schlafen*. The difference between <a>- and <e>-verbs is that the latter are a priori underspecified for ART, while the former are underspecified for ART if they belong to the morphological class of strong verbs. In this respect, morphological information is encoded in the phonological form and directly accessed by the phonetic shape of the vowel in the corresponding surface forms.

2. PRIMING PREDICTIONS

There is convincing evidence that priming is based on the successful pre-activation of particular lexical representations through an appropriate prime which is somehow related to that representation [4]. It is likely that this activation is sensitive to whether there are mismatches between features in the signal and features in the lexical representation. With respect to the root vowels, *schläfst* activates its infinitive *schlafen* (underspecified for ART, no mismatch) equally well as *machst* activates *machen* (DORSAL ART, match). There is also no difference in the access of strong and weak <e>-verbs via the 2ND SG PRES. A strong verb form such as *siehst* is a nomismatch regarding the place information ([iː] in the signal versus underspecified /eː/ in the lexical representation). The difference in vowel height (high vs. mid [i]~[e], and mid vs. low [ɛ]~[a]) constitutes a nomismatch in FUL. The vowel in the weak verb form *lebst* compared to the infinitive *leben* similarly involves nomismatches in the ART dimension. Thus, priming between strong and weak verbs should be equally strong.

Clahsen and his colleagues [2, 3, 9] would predict an asymmetric priming pattern. Their claim is that both the verb class (i.e. *strong* versus *weak*) and the prime-target direction (2ND SG PRES→INF, experiment 1; INF→2ND SG PRES, experiment 2) affect the amount of facilitation. First, weak verbs access their bases directly and should show more priming than strong verbs which access their bases indirectly due to their inherently hierarchical structure. Second, *machst* and *machen* would activate each other equally well, since the verb has a flat structure, but *schläfst* would facilitate *schlafen* more than the other way around due to the strong verb's hierarchical representation. They provide evidence for their claims from a series of experiments involving PAST versus PRESENT TENSE forms. However, they did not test the PRESENT TENSE alternations of strong German verbs which is the focus of our paper. We predict that a reversal of the prime-target direction does not change the type of feature matching between the signal and the lexical representation. As shown in Table 1, there is always a *match* (same ART features in the signal as in the lexical representation) or a *nomismatch* (ART feature in the signal, but not in the mental lexicon).

Table 1: Lexical and surface vowel representations in strong and weak German verbs. Priming predictions are based on matches versus nomismatches.

	PRIME	**TARGET**	
EXP. 1	2ND SG	INFINITIVE	PREDICTION
VERB CLASS	EXTRACTED FEATURES	LEXICAL FEATURES	PRIMING
strong	*schl*[ɛː]*fst* [COR]$_{\text{ART}}$	*schl*[aː]*fen* [ ]$_{\text{ART}}$	yes *nomismatch*
	s[iː]*hst* [COR]$_{\text{ART}}$	*s*[eː]*hen* [ ]$_{\text{ART}}$	yes *nomismatch*
weak	*m*[a]*chst* [DOR]$_{\text{ART}}$	*m*[a]*chen* [DOR]$_{\text{ART}}$	yes *match*
	l[eː]*bst* [COR]$_{\text{ART}}$	*l*[eː]*ben* [ ]$_{\text{ART}}$	yes *nomismatch*
EXP. 2	INFINITIVE	2ND SG	
strong	*schl*[aː]*fen* [DOR]$_{\text{ART}}$	*schl*[ɛː]*fst* [ ]$_{\text{ART}}$	yes *nomismatch*
	s[eː]*hen* [COR]$_{\text{ART}}$	*s*[iː]*hst* [ ]$_{\text{ART}}$	yes *nomismatch*
weak	*m*[a]*chen* [DOR]$_{\text{ART}}$	*m*[a]*chst* [DOR]$_{\text{ART}}$	yes *match*
	l[eː]*ben* [COR]$_{\text{ART}}$	*l*[eː]*bst* [ ]$_{\text{ART}}$	yes *nomismatch*

3. PRIMING STRONG AND WEAK VERB FORMS

3.1. Experimental design

Our task was a crossmodal immediate repetition priming with lexical decision. For experiment 1, primes were always inflected 2ND SG PRES forms of German strong and weak verbs while targets were their corresponding INF forms. Experiment 2 reversed the prime-target direction such that primes were infinitives and targets the corresponding 2ND SG PRES forms. Primes occurred in three different conditions and had a morphological, a semantic or no relation to their targets. In all experiments, priming was determined as the lexical decision time advantage in the test condition (semantic, morphological) compared to the control condition.

20 strong and 20 weak <a>– and <e>–verbs were chosen and matched for their frequency based on CELEX [1]. Primes were always presented auditorily, while targets were displayed visually at the offset of the primes for 200 ms. Additionally, there were 360 filler pairs including pseudowords. Altogether, the experiment consisted of 200 word and 200 pseudoword pairs. Subjects had to decide whether the visually presented targets were words in German or not. The reaction times were measured from the onset of each visually presented target.

3.2. Results

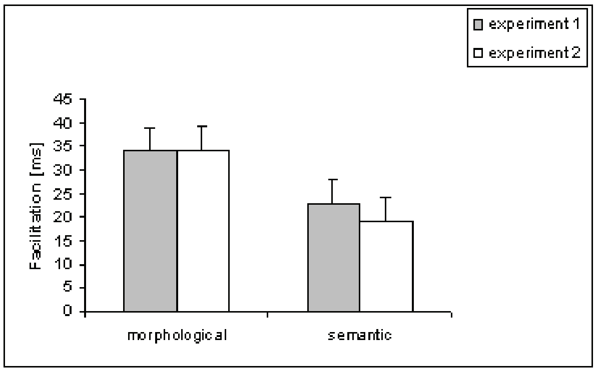
3.2.1. Experiment 1 (50 subjects)

Reaction times differed significantly within CONDITION (control, morphological, semantic; F[1,2579]=24.19, p<0.001). Morphological and semantic priming was significant (morphological *t*=6.82, p<0.001; semantic *t*=4.65, p<0.001), but morphological facilitation was stronger in magnitude (*t*=2.27, p<0.04, cf. Figure 1). The priming effects were independent of the VERBCLASS (strong, weak; CONDITION X VERB CLASS, F[4,2579]=0.45, p<0.77). Morphological priming was significant for all verbs (strong <a>: *t*=2.08, p<0.04; strong <e>: *t*=2.31, p<0.03; weak <a>: *t*=4.13, p<0.001; weak <e>: *t*=2.18, p<0.03). Weak <a>-verbs showed the strongest priming effect and differed from weak <e>-verbs (*t*=2.04, p<0.05; cf. Figure 2).

3.2.2. Experiment 2 (45 subjects)

As before, there was a main effect of CONDITION (F[1,2048]=22.42; p<0.001). Morphological and semantic priming was significant (morphological *t*=6.69, p<0.001; semantic *t*=3.69, p<0.001), but morphological facilitation was stronger in magnitude (*t*=2.96, p<0.01). Priming was independent of VERBCLASS (CONDITION X VERB CLASS, F[4,2048]=0.20, p<0.94). The amount of morphological priming was significant for all verbs (strong <a>: t=2.35, p<0.02; strong <e>: *t*=2.48, p<0.02; weak <a>: *t*=3.55, p<0.01; weak <e>: *t*=3.00, p<0.01; cf. Figure 2).

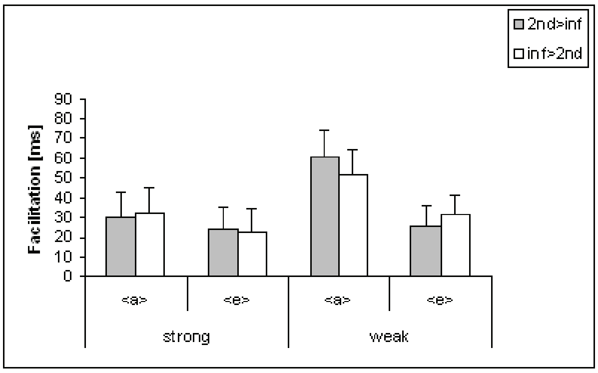
Figure 1: Comparison of morphological (grey bars) and semantic (white bars) priming in experiment 1 and 2 given as Least Square Means in milliseconds (LSM ms).



3.2.3. Comparing the priming directions

In a combined analysis, the priming DIRECTION did not affect the overall priming pattern (CONDITION X DIRECTION: F[2,4626]=0.22, p<0.81; CONDITION X VERB CLASS X DIRECTION: F[4,4626]=0.32, p<0.87).

Figure 2: Morphological priming (LSM ms) in experiment 1 (grey bars; prime: 2ND SG PRES, target: INF) and experiment 2 (white bars; prime: INF, target: 2ND SG PRES).



4. DISCUSSION

The results of experiment 1 and 2 support the view that the lexical representations of root vowels in strong and weak German verbs can be elegantly described in terms of phonological features. Crucially, we did not find any priming differences between strong (stem alternation) and weak verbs (no stem alternation) or between the direction of prime and target (2ND SG PRES→INF; INF→2ND SG PRES) within the PRESENT TENSE.

We claim that the matching algorithm between signal and lexicon correctly accounts for the directional priming symmetry we found in experiment 1 viz-à-vis experiment 2. The fact that we observe the greatest amount of priming for the weak <a>-verbs possibly reflects the full matches between dorsality extracted from the vowel in the prime (signal) and dorsality specified in the target (lexical representation). Thus, the observed priming effects are sensitive to the mapping of phonetic to phonological features and do not depend on the different morphological structures of strong versus weak verbs.

Note that in both experiments, we obtained significant semantic priming as well. Thus, we cannot rule out that semantic relatedness had no effect on the morphological priming. One could therefore argue that the featural nomismatches may have played only a minor role in the facilitation pattern we observed. However, in both experiments, that is, in both priming directions, the semantic facilitation was significantly *less* than the morphological priming. If we assume that the morphological priming is an additive effect of morphological plus semantic relatedness, then the facilitations we observed must also be due to the non-conflict between the surface phonetic and underlying root vowel representations. To ensure that the roots are facilitated only due to morphological relatedness, equally in both directions, it would be necessary to use a delayed repetition priming task as shown in Scharinger [8].

The results do not support the specific Dual Route model that suggests overall flat structures for weak and hierarchical structures for strong verbs and thus differentiates the two classes even in the present tense. The proposed structural differences were not reflected in the factors DIRECTION or VERBCLASS in this experiment and therefore do not support such structural differences. However, this does not rule out that there are no differences in the past tense and participial constructions with respect to the verb root.

Altogether, the experimental results provide evidence that vowel alternations in the present tense of strong verbs in German do not require listing of separate roots nor different hierarchical structures. Underspecified and specified roots are equally directly accessed by the phonetic information extracted from the speech signal. The phonetic surface variants in both 2ND SG PRES and INF forms of strong *and* weak verbs are mapped onto a single lexical representation. Morphological categorization of the <a>-verbs into strong and weak directly follows from the phonological make-up of these stems. In particular, strong <a>-verbs have a root vowel which is underspecified for place of articulation, while weak <a>-verbs have a root vowel specified for dorsal place of articulation. In contrast, strong and weak <e>-verb roots contain identically underspecified front vowels /e/.

In future research, we need to examine further productive morphophonological alternations in other inflectional paradigms.

5. REFERENCES

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