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Morphological Priming by Itself: A Study of Portuguese Conjugations

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ABSTRACT

Does the language processing system make use of abstract grammatical categories and representations that are not directly visible from the surface form of a linguistic expression? This study examines stem-formation processes and conjugation classes, a case of 'pure' morphology that provides insight into the role of grammatical structure in language processing. We report results from a cross-modal priming experiment examining 1st and 3rd conjugation verb forms in Portuguese. Although items were closely matched with respect to a range of non-morphological factors, distinct priming patterns were found for 1st and 3rd conjugation stems. We attribute the observed priming patterns to different representations of conjugational stems, combinatorial morphologically-structured ones for 1st conjugation and unanalyzed morphologically-unstructured ones for 3rd conjugation stems. Our findings underline the importance of morphology for language comprehension indicating that morphological analysis goes beyond the identification of grammatical morphemes.

KEYWORDS: Morphological priming, stem formation, conjugation classes, Portuguese morphology

Introduction

One important property that distinguishes human language from simple collections or strings of words is that linguistic expressions convey complex meanings that are not directly inferable from their surface forms. A sentence such as *Visiting relatives can be a nuisance* has one surface form but expresses different meanings. Chomsky (1957) argued that sentences of this kind have two distinct syntactic representations, as can be seen by replacing *can be* by *is* or *are*, and consequently two different interpretations, indicating that mappings between form and meaning are indirect, mediated by grammatical representations. Many linguists have argued that grammatical representations consisting of abstract categories such as N(oun), V(erb), stem or affix are needed to properly understand language and language behaviour, and that, to capture the productivity of linguistic expressions, the grammar invokes combinatorial rules that manipulate variables for such categories (Chomsky, 1995; Jackendoff, 1997; among others). There is, however, an alternative tradition in cognitive science research on language which seeks to explain language behaviour in terms of direct associations between forms and meanings. This research has led to accounts of grammatical phenomena implemented in distributed connectionist network models (Elman, 1993; Seidenberg & Gonnerman, 2000; among others) which encode the sounds, letters, and meanings of linguistic expressions, but have no explicit representation of their syntactic and morphological structure. Consequently, a grammar may not be needed as a distinct component of language and language processing since what appears to be grammatical in nature can supposedly be dealt with in terms of associative generalizations and memory.

Over the last 30 years, the study of morphologically complex words has been at the heart of this controversy, most prominently in experimental research on the English

past tense. Whilst some have provided evidence, for example from priming experiments, that regular past-tense forms are morphemically represented, and decomposed during processing (Pinker & Ullman, 2002; Marslen-Wilson, 2007), others have attributed such effects to the formal and semantic overlap between prime and target (e.g., between *walked* and *walk*; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997), without invoking abstract morphemes or morphemic decomposition (McClelland & Patterson, 2002; among others). There is indeed a large body of research on morphological processing including studies of typologically different languages and more complex morphological systems than the English past tense, but the controversy on whether morphological structure (and more generally grammar) is required as a distinct organizing element of linguistic representation and processing remains unresolved.

One reason for this state-of-affairs is that much previous work on morphological processing has been confined to a restricted set of morpheme-based concepts and phenomena. Morphemes are pairings of a phonological form and a meaning or grammatical function and are considered to be the smallest meaningful units of a word. The word *cats*, for example, consists of two morphemes (cat+-s), each with their own phonological form and their own meaning or function. Since in addition to being units of a word's morphological structure, morphemes also have a surface form and a meaning, it is difficult to decide whether a particular experimental finding, for example a priming effect between an inflected form and its corresponding stem (*cats* → *cat*), is due to morphemic decomposition or whether it results from phonological, orthographic, or semantic overlap between prime and target. What is sometimes lost sight of in this research is that there are many morphological properties of inflected words that go beyond the basic notion of morphemes. One case in point comes from

languages that have inflectional classes. Consider, for example, inflected verb forms in Portuguese.

(1) a.	*cant*	*á*	*sse*	*mos*
	‘sing’	class marker	imperfect subjunctive	1st plural
b.	*corr*	*ê*	*sse*	*mos*
	‘run’	class marker	imperfect subjunctive	1st plural
c.	*resist*	*í*	*sse*	*mos*
	‘resist’	class marker	imperfect subjunctive	1st plural

These verb forms consist of a root and three segments, two of which can be conceived of as morphemes, *-sse-* encoding Tense and *-mos* agreement. The segments *-a-*, *-e-*, and *-i-*, however, are not morphemes under any sensible definition because they do not have any meaning or function. Instead, these segments define three arbitrary classes, 1st conjugation for *-a-* forms, 2nd conjugation for *-e-*, 3rd conjugation for *-i-*. All verb roots fall into one of these classes, and novel verbs borrowed from other languages need to be assigned to one of these classes before they can be inflected. The forms in (1) are segmentable into various component parts. The verb roots (*cant-*, etc.) together with conjugation class markers (*-a-*, *-e-*, *-i-*) form *stems* which in turn are combined with inflectional suffixes. The formal spell-out of an inflectional morpheme may differ depending on a verb’s conjugation class. Portuguese, for example, has two suffixes for expressing the features [past tense, imperfect aspect], *-va* and *-a*, the former for 1st conjugation verbs (e.g., *cant-a-va* ‘sing-imperf.’) and the latter for 2nd and 3rd conjugation verbs (e.g., *resist-i-a* ‘resist-imperf.’). More generally, if a language has more than one form for the same set of morphosyntactic features, then it

has inflectional classes. With these properties, inflectional classes and conjugational stems belong to what Aronoff (1994) called 'morphology by itself', irreducible morphological categories which do not have any reflex in the semantics, the phonology, or the syntax. Thus, stems and inflectional classes are perhaps better suited to examine whether morphology is required for understanding how inflected words are processed than the commonly studied inflectional morphemes.

In previous research, the role of inflectional classes and stem-internal morphological structure has mainly been examined in off-line production and simulation studies (e.g., Albright, 2002; Clahsen, Aveledo, & Roca, 2002; Colombo, Stoianov, Pasini, & Zorzi, 2006). Little is known about how the stems of the different conjugational classes are processed in real time, for example, whether they are decomposed or processed as wholes. The only available study that bears on this question is Rodríguez-Fornells, Clahsen, Lleó, Zaake, and Münte (2001), but this study examined incorrect stem+affix combinations. How existing combinatorial stems are processed is still an open question.

We can think of three possibilities regarding the processing of the stems in (1). Following linguistic treatments of Portuguese morphology (e.g., Villalva, 2000) according to which verbal stems of all three inflectional classes are combinatorial [root + class marker] forms, one may find that the stems in (1) are decomposed into their morphological constituents during processing. A second possibility is that stems are not processed in morphological terms and that the segments *-a-*, *-e-* and *-i-* simply represent additional phonological and orthographic material (Colombo et al., 2006). A third possibility (Say & Clahsen, 2002) is that only 1st conjugation stems are processed according to their morphological structure, but that 2nd and 3rd conjugation stems are stored and accessed as wholes. The motivation for this distinction is a

striking discrepancy between the 1st conjugation, on the one hand, and the 2nd and 3rd conjugations, on the other. In the Portuguese verb lexicon, the 1st conjugation is the most productive class. A count of type frequencies in a large lexical database of Portuguese (Nascimento, Casteleiro, Marques, Amaro, Barreto, & Veloso, 2000) showed a predominance of 1st conjugation verbs in both the whole corpus (3,396 1st conjugation, 380 2nd conjugation, and 348 3rd conjugation verbs) and amongst the verbs with the lowest lemma frequency (0.37 per million; 123 1st conjugation verbs, but only 10 2nd or 3rd conjugation verbs). More importantly, the formation of 1st conjugation stems in Portuguese (as well as in other Romance languages) qualifies as a default process according to the criteria laid out in Marcus, Brinkmann, Clahsen, Wiese, & Pinker (1995:197). The 1st conjugation exhibits *unrestricted* productivity in that it can apply to any kind of verb irrespective of its phonological or semantic properties. Consequently, neologisms or foreign loan verbs are always assigned to this class (e.g., *blogar* 'to blog'). Furthermore, whilst all 1st conjugation stems display the *-a-* class marker, 2nd and 3rd conjugation verbs exhibit more stem allomorphy. Say and Clahsen (2002) observed similar contrasts for Italian and accounted for them by proposing distinct representational mechanisms for 1st conjugation and 2nd/3rd conjugation stems, a default stem-formation rule that generates morphologically structured 1st conjugation stems from any verbal root and lexically stored forms for 2nd and 3rd conjugation stems. More generally, an inflectional class or pattern that exhibits unrestricted productivity and morphological regularity is likely to be rule-based, whereas forms that are lexically restricted and comprise allomorphy are likely to be stored as wholes (e.g., Marcus et al., 1995; Pinker & Ullman, 2002). If Say and Clahsen's (2002) account of Italian stem formation applies to the processing of verbal stems in Portuguese, one would expect that experiments that tap into the internal

structure of central lexical entries reveal decomposition effects for 1st, but not for 2nd or 3rd, conjugation stems indicating that for 1st conjugation verbs only the basic root is stored, whereas the lexical entries for 2nd or 3rd conjugation verbs contain additionally stored stem forms.

However, class membership might not be the only factor affecting lexical representation and processing. Many verbs in Portuguese, including some 1st conjugation ones, have forms that display phonological changes in their roots, some of which are not fully predictable. In such cases, a verb's lexical entry, even if it belongs to the 1st conjugation, may contain an additional form for the alternated root that affects processing in the same way as a lexically stored stem of a 2nd or 3rd conjugation verb. To examine this possibility, the present experiment not only included verbal stems that belong to different classes, 1st versus 3rd conjugation (both without phonological changes), but also an additional condition with 1st conjugation vowel change verbs that have allomorphic roots.

Cross-modal priming of Portuguese verbal stems

The experimental paradigm we used is cross-modal immediate priming with lexical decision, in which subjects hear a spoken prime immediately followed by a visually presented target form for which they make a word/non-word decision. Previous studies have shown that the recognition of a target word is facilitated if a morphologically related prime is presented before the occurrence of the target. Because in cross-modal priming, participants receive auditory primes and visual targets, any priming effect is thought to take place at a level of lexical representation that is relatively independent of low-level form properties of the prime and target words (Marslen-Wilson, 2007).

In each verb category (1st conjugation, 3rd conjugation, vowel change), targets were root-based, 1sg present indicative forms consisting of a root and the inflectional affix *-o* (see Table 1). Primes were infinitives marked by the inflectional affix *-r*, with stems consisting of a root and a 1st (*-a-*) or 3rd (*-i-*) conjugation class marker.

Table 1: Experimental conditions with an example stimulus set

	Prime Types			
Verb Category	Identity	Test	Control	Target
1st conjugation	limito 'I limit'	limitar 'to limit'	desejar 'to desire'	LIMITO 'I limit'
3rd conjugation	adquiro 'I acquire'	adquirir 'to acquire'	investir 'to invest'	ADQUIRO 'I acquire'
Vowel change	af[ɔ]go afogo 'I drown'	af[u]gar afogar 'to drown'	soprar 'to blow'	AFOGO 'I drown'

Morphologically related primes and targets (Test condition) differed only in that they were different inflected forms of the same verbs. As such, their semantic overlap was constant across the three verb categories. The same applies to the amount of phonological and orthographic overlap in the 1st and 3rd conjugation conditions, because Test primes and targets were based on the same root. In the vowel change condition, however, morphologically related pairs contained a phonological alternation: the root vowel *o* is pronounced [u] in the Test primes and [ɔ] in the targets. Although this type of alternation can be attributed to the (phonological) raising of stressed [ɔ] to unstressed [u] (Mateus & d'Andrade, 2000), the reverse relation does not hold. Thus, verbs displaying [u] in the infinitive may have the [ɔ], [o], or [u] root vowels in the 1sg Pres. Ind. (e.g., f[u]mar 'to smoke', f[u]mo 'I

smoke'). Because there is no one-to-one mapping in the prime-target direction, both root forms for these verbs are likely to be lexically stored.

In addition to the morphological Test condition, two other types of prime were used for each target, a form that was identical to the target (Identity condition), and an unrelated verb form (Control condition). These baseline conditions reflect the minimum and maximum amount of priming for a given item. We will refer to a pattern in which there are no differences between Test and Identity and in which both conditions have shorter response times (RTs) than in the Control condition as 'full' priming. If RTs following Test primes are shorter than in the Control condition but longer than in the Identity condition, this will be referred to as 'partial' or 'reduced' priming. We assume that full priming is obtained when the same lexical representation is activated by prime and target, and that partial priming is obtained if distinct, but related, representations are activated in memory. Hence, if conjugation class markers are simply phonological and orthographic segments without any morphological significance, all verb types should yield the same partial priming effect, reflecting the degree of prime-target overlap. Alternatively, if 1st (or 1st and 3rd) conjugation verbs have morphologically structured [root + class marker] stems, they should elicit full priming effects on the recognition of root-based forms. Finally, if the alternated roots of vowel change verbs are represented in their lexical entries, they should display a partial priming effect, despite belonging to the 1st conjugation.

Method

Participants

Fifty-seven adult native speakers of European Portuguese between the ages of 17 and 35 (mean age: 26.12, 27 males) participated in this experiment. All participants were

from mainland Portugal, had normal or corrected-to-normal vision and hearing, and at least 12 years of schooling. None of them had ever experienced language or literacy-related difficulties. The participants were naïve with respect to the purpose of the experiment.

Materials

Sixty-three pairs of morphologically related primes and targets were selected, 21 for each of the three conditions. Critical targets in all conditions were between five and eight letters long, had between two and four syllables, an orthographic neighborhood size of two to four (as measured by Coltheart's N; Coltheart, Davelaar, Jonasson, & Besner, 1977), and were not homographic with any existing form in Portuguese. Test and Control primes were matched to each other and across target types with respect to lemma frequency, word-form frequency, number of syllables, number of phonemes, and number of letters. Targets were matched across conditions for the same variables and for Coltheart's N (see Table 2). The critical prime-target pairs were distributed over three experimental versions with each target appearing only once in each version.

Table 2: Stimulus properties of the control primes, test primes and targets

Verb Category		Lemma freq. (per million)	Word freq. (per million)	No. Phonemes	No. Letters	No. Syllables	N
1st conj.	Control	32.17	6.91	7.10	7.52	3.00	
	Test	33.23	7.39	7.00	7.43	2.90	
	Target	33.23	0.30	6.00	6.43	2.90	2.76
3rd conj.	Control	29.95	7.43	7.00	7.48	2.86	
	Test	29.60	7.43	7.00	7.48	2.86	
	Target	29.60	0.33	6.00	6.48	2.86	2.71
Vowel change	Control	28.60	7.64	7.19	7.52	3.14	
	Test	28.22	7.63	7.19	7.52	3.00	
	Target	28.22	0.32	6.19	6.52	3.00	2.62

A set of 273 filler pairs was added to the 63 critical prime-target pairs. Whilst all primes were existing verb forms, half of the 336 targets were existing words and half pseudowords. The set of 168 word-word pairs consisted of the critical prime-target pairs (42 related in the Test and Identity conditions, and 21 unrelated in the Control condition) and 105 unrelated filler pairs. Likewise, the set of 168 word-pseudoword pairs consisted of 21 identical, 21 phonologically related, and 126 unrelated pairs. Related primes and targets made up 25% of the stimuli encountered by the participants.

Procedure

The prime words were spoken by a female native speaker of Portuguese and digitally recorded at a rate of 44.1Khz. Participants were tested individually in a dimly lit, quiet room. DMDX (Forster & Forster, 2003) was used for stimulus presentation and data collection. Each trial followed the same sequence. First, an auditory attention tone was presented for 200 ms immediately followed by the auditory prime word. At

the offset of the prime, the visual target word was displayed on the centre of a 15'' screen, in size 20 Courier New, in upper-case white letters against a black background. The measuring of RTs started with the presentation of the target, which remained on screen for 750 ms. After the target disappeared, participants were allowed a further 1,200 ms to respond. At the end of this period, the next trial started with the presentation of the attention tone. Participants were asked to perform a lexical decision task on the visual targets. The experiment started with a practice phase with four existing and four pseudoword targets. Two further breaks were provided, each after 112 trials. The whole experiment lasted approximately 30 minutes.

Data analysis

One participant was excluded from all analyses for not having responded to any item in one part of the experiment. For pseudowords, the by-participant average RT of correct rejection was 800.02 ms, with mean error and timeout rates of 8.78% and 1.39%, respectively. Regarding the analysis of critical targets, two items had to be removed, one (*melhoro* 'I improve', vowel change condition) due to experimental error, the other (*instituo* 'I create', 3rd conjugation) due to a disproportionately slow mean RT (866.63 ms), which was more than 4 standard deviations (SDs) above the average of mean RTs across all critical items (662.56 ms, SD = 48.41 ms). Incorrect responses (4.31%) and timeouts (0.40%) were also removed from further analyses. The influence of potential outliers was reduced by plotting the data and eliminating RTs that were below 250 ms or above 1,500 ms, which accounted for 0.43% of the remaining data. Mean error rates and RTs for each participant (F_1) and each item (F_2) were submitted to Analyses of Variance (ANOVAs) with the factors Verb Category

(1st conjugation, 3rd conjugation, vowel change) and Prime Type (Identity, Test, Control).

Results

Overall RT means and error rates for each condition (based on the participant analysis) are displayed in Table 3. One-tailed planned comparisons by participants (t_1) and by items (t_2) are displayed in Table 4.

Table 3: Mean RTs (in ms), SDs (in parenthesis), and error rates

	Prime Type					
	Identity		Test		Control	
Verb Category	RT(ms)	Error(%)	RT(ms)	Error(%)	RT(ms)	Error(%)
1st conjugation	641 (137)	3.40	635 (114)	2.34	721 (151)	10.08
3rd conjugation	627 (133)	3.57	646 (136)	2.25	697 (129)	8.20
Vowel Change	603 (115)	0.55	638 (124)	1.70	709 (144)	8.05

Table 4: Pairwise comparisons of the mean RTs

Verb Category	Control - Identity	Control - Test	Test - Identity
1st conjugation	$t_1(55) = 6.600$, $p < .001$	$t_1(55) = 7.253$, $p < .001$	$t_1(55) = -.522$, $p = .698$
	$t_2(20) = 6.354$, $p < .001$	$t_2(20) = 8.657$, $p < .001$	$t_2(20) = -.102$, $p = .540$
3rd conjugation	$t_1(55) = 6.819$, $p < .001$	$t_1(55) = 4.721$, $p < .001$	$t_1(55) = 1.746$, $p = .043$
	$t_2(19) = 6.972$, $p < .001$	$t_2(19) = 4.914$, $p < .001$	$t_2(19) = 1.672$, $p = .056$
Vowel Change	$t_1(55) = 8.168$, $p < .001$	$t_1(55) = 5.211$, $p < .001$	$t_1(55) = 3.214$, $p = .001$
	$t_2(19) = 9.783$, $p < .001$	$t_2(19) = 9.414$, $p < .001$	$t_2(19) = 3.365$, $p = .002$

For the error data, the only significant effect was a main effect of Prime Type ($F_1(2,110) = 38.051$, $MSE = .006$, $p < .001$; $F_2(2,116) = 29.157$, $MSE = .003$, $p <$

.001), driven by higher average error rates following Control primes (8.78%) than following Test (2.10%; $t_1(55) = 7.844$, $p < .001$; $t_2(60) = 6.578$, $p < .001$; one-tailed) and Identity primes (2.51%; $t_1(55) = 6.265$, $p < .001$; $t_2(60) = 5.188$, $p < .001$; one-tailed). That is, participants were more likely to correctly classify targets as real words when they were preceded by related forms.

For the RTs, there was a main effect of Prime Type ($F_1(2,110) = 74.529$, $MSE = 4635.582$, $p < .001$; $F_2(2,116) = 115.863$, $MSE = 1167.131$, $p < .001$), a main effect of Verb Category that was significant by subjects only ($F_1(2,110) = 3.815$, $MSE = 2704.141$, $p = .025$; $F_2(2,58) = 1.020$, $MSE = 4388.274$, $p = .367$) and, more importantly, an interaction between Verb Category and Prime Type ($F_1(4,220) = 2.915$, $MSE = 3300.440$, $p = .022$; $F_2(4,116) = 2.528$, $MSE = 1167.131$, $p = .044$).

Whilst in all three verb categories, target RTs following both Identity and Test primes were significantly shorter than those following (unrelated) Controls, comparisons of RTs in the Test and Identity conditions yielded a dissociation between verb categories. Targets in the 1st conjugation condition had similarly short RTs after a Test prime as after an Identity prime, but for 3rd conjugation and vowel change targets the former were significantly longer than the latter (see Tables 3 and 4). Moreover, one-tailed *t*-tests revealed that the average difference between RTs following Test and Identity primes, that is, the advantage of repetition priming relatively to morphological priming, was significantly smaller in the 1st conjugation condition (-5 ms) than in the 3rd conjugation (19 ms; $t_1(55) = 1.874$, $p = .033$; $t_2(39) = 1.347$, $p = .093$)[1] and vowel change conditions (35 ms; $t_1(55) = 2.641$, $p = .006$; $t_2(39) = 2.652$, p

[1] Although the comparison of Test minus Identity differences between the 3rd and 1st conjugation conditions was only marginally significant in the item analysis, its effect size was slightly larger in the by-item ($d = .42$) than in the by-subject analysis ($d = .31$) (using the necessary adjustment procedure for repeated measures;

= .006). We also note that this contrast cannot be attributed to differences in the magnitudes of repetition priming, as two-tailed *t*-tests showed these to be similar in the 1st conjugation condition (80 ms) compared to the 3rd conjugation (71 ms; $t_1(55) < 1$; $t_2(39) < 1$) and the vowel change conditions (106 ms; $t_1(55) = 1.437$, $p = .156$; $t_2(39) = 1.170$, $p = .249$). Thus, stem-based forms of 1st conjugation verbs facilitated the recognition of root-based forms as much as the root-based forms themselves, yielding a full priming effect. However, stem-based forms in the 3rd conjugation and vowel change conditions elicited a partial priming effect, with longer RTs than for Identity primes, and a larger Test minus Identity difference than in the 1st conjugation condition.

In order to more directly compare the magnitude of morphological priming across verb categories, the differences between mean RTs in the Control and Test conditions were also computed for each participant and item. One-tailed *t*-tests revealed that the amount of priming in the 1st conjugation condition (85 ms) was significantly larger than in the 3rd conjugation condition (52 ms) ($t_1(55) = 2.287$, $p = .013$; $t_2(39) = 2.042$, $p = .024$). However, the amount of morphological priming in the vowel change condition (70 ms) did not significantly differ from that in the 1st conjugation ($t_1(55) < 1$; $t_2(39) = 1.388$, $p = .087$) or 3rd conjugation conditions ($t_1(55) = 1.289$, $p = .102$; $t_2(38) < 1$). It is true that in numerical terms, priming for 1st conjugation vowel change verbs was larger than for 3rd conjugation verbs (70 ms vs. 52 ms). However, an additional analysis revealed that whilst the by-participant magnitude of morphological priming in the vowel change condition was positively correlated with that in the 3rd conjugation condition ($r(54) = .31$, $p = .02$), there was no such correlation for the magnitude of morphological priming between the vowel change and the 1st

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Dunlap, Cortina, Vaslow, & Burke, 1996). We attribute the discrepancy in significance values to the smaller number of items than participants.

conjugation condition ($r(54) = .13$, $p = .34$), suggesting that in terms of morphological priming, vowel change verbs pattern with 3rd conjugation verbs.

In sum, the magnitude of stem to root priming for targets in the 1st conjugation condition was not only as large as the repetition priming effect, but also larger than for 3rd conjugation targets. Vowel change and 3rd conjugation verbs, on the other hand, displayed a partial priming effect, with significantly less morphological facilitation than repetition priming.

Discussion

The most important finding from the present study is that stem forms of the 1st and the 3rd conjugation produced different priming effects on root-based target forms, full priming for 1st conjugation verbs (without vowel changes) and partial priming for 3rd conjugation verbs, despite the fact that the primes and targets in both conditions were parallel in terms of their orthographic, phonological, and semantic relatedness. This finding is not compatible with accounts that postulate that both 1st and 3rd conjugation verbs have combinatorial stem representations (Villalva, 2000). Likewise, accounts that interpret morphological priming as the additive or interactive effects of formal and semantic priming (e.g., Gonnerman, Seidenberg, & Andersen, 2007) cannot explain this contrast, because the degree of prime-target overlap was exactly matched in the 1st and 3rd conjugation conditions.

An alternative explanation of morphological priming was proposed by Plaut and Gonnerman (2000). In this account, the magnitude of morphological priming is not only determined by the formal and semantic overlap between primes and targets, but also by the overall consistency of form-meaning mappings across the whole language. In two simulations, Plaut and Gonnerman showed that a connectionist network trained

on a "morphologically rich" artificial language in which there was a higher proportion of transparent forms showed greater morphological priming (that extended to targets with semantically opaque representations) than a network trained on a "morphologically impoverished" language. In Portuguese, 1st conjugation forms are more frequent than 3rd conjugation ones, and the 3rd conjugation also displays more stem allomorphy than the 1st. Thus, the 1st conjugation has a higher degree of consistency between form and meaning, which may lead to more efficient priming for forms of this class, similarly to the contrast obtained between morphologically "rich" and "impoverished" languages in Plaut and Gonnerman's (2000) study[2]. There are, however, two important difficulties in applying this account to the present findings. Firstly, it is hard to see how the full priming effect we found for 1st conjugation can be simulated in a network of this kind. Plaut and Gonnerman (2000) state that the identity condition used in their simulations (which showed faster RTs than the morphological conditions) should not be taken as a direct analogue of identity conditions in studies with human participants, because the simulation did not involve any change in stimulus between prime and target. Nevertheless, even if the processing costs of a proper identity condition are modelled in their network, it is highly likely that this condition will produce more priming than morphological ones, due to the complete prime-target overlap in an identity condition. Secondly, and more importantly, Plaut and Gonnerman's results concern differences between two networks, each trained on a different language and do not necessarily extend to a case in which several conjugation classes are simultaneously learned by the same network. The deeper problem is that it is hard to see how the nature of inflectional classes can be captured in terms of a model of direct form-meaning mappings. In Portuguese, for

[2] We are grateful to an anonymous *Cognition* reviewer for pointing out this possibility.

example, verbs of the same conjugation display particular class markers in some (but not in all of their) forms, and they share particular tense, mood, agreement or other inflectional affixes in some of their forms. Thus, whilst conjugation membership is relevant for the correct selection of inflectional morphemes in Portuguese, conjugation classes as such do not involve any kind of form-meaning mapping. This led Aronoff (1994) and other linguists to the view that conjugation class is a purely morphological concept. For a network to take advantage of the overall form-meaning consistency of an entire conjugation class, verbs that belong to the same conjugation class need to be treated in the same way, that is, the network effectively needs to learn inflectional classes. It is not clear whether this is possible with a model such as the one proposed by Plaut and Gonnerman in a way that would account for the distinct stem-to-root priming patterns we found for 1st and 3rd conjugation, especially when both primes and targets display inflectional morphemes that do not discriminate between conjugations.

Whilst accounts which posit the same representations for the verbal stems of the different conjugations are not supported by our findings, the obtained dissociation between 1st and 3rd conjugation stems can be better explained by positing different representations, root-based morphologically-structured ones for the former, and unstructured stem-based representations for the latter (Say & Clahsen, 2002). Assuming that full priming in a cross-modal priming experiment results from repeated activation of the same lexical representation in prime and target, our findings for the 1st conjugation condition suggest that the central lexical entry of these verbs is the basic root, which is activated to the same degree by stem-based and root-based forms. This is consistent with a default stem-formation rule that generates 1st conjugation stems and accounts for the productivity of this class. If, on the other hand, a partial

priming effect in a cross-modal priming experiment is indicative of the activation of distinct, but related, representations, our findings for 3rd conjugation verbs suggest that their lexical entries contain both the basic root and a separate form for the stem. Third conjugation stem-based primes produce a reduced facilitation effect because they match unstructured lexical representations of stems, and activate the associated root representations only indirectly[3].

In addition, we found that 1st conjugation vowel change verbs patterned with 3rd conjugation verbs in that both conditions revealed a partial priming effect relative to repetition priming. This finding is similar to results of cross-modal priming experiments on German (Clahsen, Eisenbeiss, Hadler & Sonnenstuhl 2001) in which inflected verbs with ablauted roots (e.g. *warf-t* → *werf-t* 'threw-2pl' → 'throw-2pl') were also found to produce reduced priming. In derivational word forms, on the other hand, surface form alternations do not seem to modulate the magnitude of cross-modal priming effects (Boudelaa & Marslen-Wilson, 2004; Marslen-Wilson & Zhou, 1999; Clahsen, Sonnenstuhl, & Blevins, 2003). Whilst the potentially different effects of allomorphic changes in derivational and inflected word forms need to be explored in future priming experiments, the present findings suggest that the lexical entries of both 3rd conjugation and 1st conjugation vowel change verbs contain an additional

[3] A reviewer wondered how this account deals with intermediate cases in which a conjugation class varies along a continuum in terms of their productivity and what it would predict with respect to their priming patterns. Whilst this situation does not arise in Portuguese (or other Romance languages) in that 1st conjugation is the only class that exhibits unrestricted productivity and there is no other conjugation that is 'intermediately productive', other languages may have systems of inflectional classes that differ in terms of their degree of productivity. For such systems, the account proposed here would also predict a 'cut-off point' regarding priming effects, namely for a morphologically regular class or pattern that exhibits default properties and is not lexically or phonologically restricted. Such forms should have morphologically structured representations and consequently yield full priming effects.

form (on top of the basic root), a stem form in the case of a 3rd conjugation verbs, and a second (alternated) root in the case of a 1st conjugation vowel change verb.

In conclusion, our findings indicate that the processing of morphologically complex words does not only involve the identification of stems and bound morphemes but also includes an analysis of the internal structure of (conjugational) stems and their morphological properties. At a more general level, the case we examined illustrates that language and language processing invokes purely grammatical structure and cannot be reduced to direct associations between forms and meanings.

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