The Mental Representation and Processing of Spanish Verbal Morphology

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1. Motivation and Background

In the literature on the mental representation and processing of verbal morphology there has been a debate between two broad theoretical frameworks: the connectionist perspectives ("single system" models) and various symbolic perspectives ("dual system" models). According to the first approach, morphological processing depends on input frequency and phonological associations, and does not involve the use of symbolic features such as word classes (Rumelhart and McClelland 1986; Daugherty and Seidenberg 1992, 1994). According to dual system models, two different systems are involved in the representation and processing of morphology: while regular morphology generally depends on symbolic rule computation independently of input frequency, the processing of irregular morphology depends on an associative memory that is sensitive to input frequency and phonological similarity (Pinker and Prince 1991, Pinker 1999, Ullman et al. 1997, Ullman 2001a).

This debate has not been settled. There are at least two main unresolved issues. First, the debate has focused mainly on the representation of English past tense morphology by native English speakers, and both theoretical approaches have claimed to be able to accommodate much of the empirical data. Thus, research in other domains may be helpful to empirically distinguish the theories. Recently, there have been two areas of research that may contribute to the debate: the study of the representation of English as a second language (Ellis and Schmidt 1997; Flege et al. 1999; Birdsong and Flege 2001, Brovetto 2002), and the representation and processing of languages with different morphological systems, such as Spanish (Sonnenstuhl et al. 1999; Rodriguez-Fornells et al. 1999). The second problem relates to the difficulty in isolating properties such as word class or rhyme from effects of lexicality such as frequency. To get around this problem some studies have worked with novel (made-up) words, which allow for the isolation of potential representational properties (class, rhyme) from the effects of frequency.

This paper reports the results of two experiments testing the mental representation and processing of Spanish Past Imperfect and Spanish Present Tense novel verbs. The goal is to explore the role of symbolic categories (conjugational class) and associative memory factors (phonological similarity) in the mental representation and processing of Spanish morphologically complex forms. The research questions that this paper tries to answer are: (a) Can Spanish verbal morphology be accounted for exhaustively by either symbolic procedures or associative memory procedures?, and (b) If both procedures take part in the representation and processing of Spanish verbs, how do they interact?

2. Spanish Past Imperfect Experiment
2.1. Participants

Thirty-three adult native Spanish speakers participated in the study, 16 males and 17 females. Participants were all right handed, between 21 and 45 years of age (mean 33), and with at least 12 years of formal education (mean 19). The study was run at Georgetown University and volunteers were paid for their participation.

2.2. Design

Spanish Past Imperfect verbs (1st person singular) are formed in the following way:
- Conjugational class I verbs (infinitival ending in *–ar*): **root + *–aba***
Example: *cantar – cantaba* 'to sing – I sang'
- Conjugational classes II and III (infinitival ending in *–er* or *–ir*): **root + *–ía***
Example: *comer – comía* 'to eat – I ate'

Items: The task comprised 120 items (40 real and 80 novel verbs). In this paper we report the results of the analysis of novel verbs only. Novel verbs were created manipulating two properties: the verb's ending (*–ar*, and *–er*), and rhyme. Rhyme is considered in this study as defined in The Clement Wood Rhyming Dictionary (1992): "Rhyme is the identity in sound of an accented vowel in a word, usually the last one accented, and of all consonantal and vowel sounds following it; with a difference in the sound of the consonant immediately preceding the accented vowel (e.g. *ate, plate, mate, abate*)." For Spanish verbs, we take the third person singular present tense form as the base to determine the rhyme. For example, the rhyme of the verb *canta* (3ps of *cantar* 'to sing') is *-ant-*. Other class I verbs rhyming with *canta* are *planta, quebranta, amamanta*. In Spanish verbs, there are certain rhymes that are more present in class I verbs, and others that typically appear in class II and III verbs. To create the novel verbs, the real verbs' rhymes were identified and classified in class I or class II/III.
There were four groups of novel verbs:
20 novel verbs with suffix *–ar* and class I rhymes (e.g., *vantar*)
20 novel verbs with suffix *–er* and class II rhymes (e.g., *tonder*)
20 novel verbs with suffix *–ar* and class II rhymes (e.g., *corbar*)
20 novel verbs with suffix *–er* and class I rhymes (e.g., *balter*)
Neighborhood calculation: The neighborhood of a given verb was a value obtained by summing all the verbs that share the given verb's rhyme and inflectional pattern, and then subtracting the number of verbs that contain the same rhyme but are inflected with the other suffix. For example, the class I verb *tomar* 'take' inflects as *tomaba*, and its rhyme is *-om-*. A friend of *tomar* is *domar – domaba* 'tame', and an enemy is *comer – comía* 'eat'.
Procedure: Subjects were asked to provide inflected forms of the verbs in appropriate sentence contexts. A sequence of two sentences was presented on a computer screen; the first sentence presented the infinitival form of the verb and therefore gave the information about the conjugational class; the second sentence created an obligatory context for the use of the imperfect. For example:

comer. A Juan le gusta comer chocolate.
Cuando era joven, yo también *comía* chocolate.
'John likes to eat chocolate. When I was young I also *ate* $_{IMP}$ chocolate.'

Participants were instructed with several examples of class I and class II real verbs. After the examples of real verbs, novel verbs ending in *–ar* or *–er* were presented in the instructions. For example:

crostar. A Juan le gusta crostar las copas.
Cuando era joven, yo también *crostaba* las copas.
'John likes to *crostar* the glasses.' 'When I was young, I also *crostaba* the glasses.'

After a few examples, participants were shown cases with blanks and were asked to inflect the verb of the second sentence in the same way that appeared in the instructions. The contexts for the novel verbs were created trying to avoid obvious associations with real verbs. Real and novel verbs of both classes were presented in random order.

Type of Analysis: In the analyses we observed the choice of suffix as a function of (1) the class of the novel: whether it was presented as class I or II; and (2) the neighborhood strength: relevance of phonological shape in the determination of the inflectional pattern.

2.3. Possible outcomes

This is a preliminary experiment with the goal of exploring the mental representation of Spanish verbs. For this reason we will not state a set of predictions but rather some possible outcomes and their theoretical consequences.

In general, we might expect that, if symbolic procedures are responsible for the mental representation of Spanish verbs, the inflectional pattern of the novel verbs should be determined by grammatical features such as conjugational class, independently of the verb's phonological shape. Thus, a verb that is presented as conjugational class I should be inflected in the imperfect using the suffix –aba, regardless of the type of rhyme that it contains. Similarly, the verbs presented as class II are expected to be inflected with the class II suffix –ía. However, conjugational class I and II do not have the same status in Spanish. Most Spanish verbs belong to class I, which is also considered the default class since it is the only productive one (new words or words taken from other languages are inflected as class I). Classes II and III, on the other hand, each constitute a smaller and closed list of verbs.

If associative memory procedures based on phonological similarity are dominant in the mental representation of Spanish verbs, similar sounding forms should be represented together. Inflectional patterns should be determined by the strength of these phonological groups (called neighborhoods), yielding "neighborhood effects," regardless of the conjugational class marker of the novel verb. Neighborhood effects are obtained if there is a correlation between the size of the neighborhood and the presence of a specific inflectional pattern on the novel verb, such as, the larger the neighborhood, the more likely the presence of the inflectional pattern in the novel verb. Neighborhood effects are expected if the units in lexical memory are represented in an associative memory system with distributed representations, where similar sounding units, in particular, forms with the same rhyme, share representational bits, and similar forms overlap in memory.

2.4. Results

The rates of responses with –aba and –ía in the Spanish Past Imperfect task are shown in Table 1. The table shows the percentages of responses using one or the other suffix, depending on the type of verb (conjugational class I or II, and type of rhyme).

Table 1. Novel verbs with –aba and –ía by conjugational class and class of the rhyme

SPANISH IMPERFECT NOVEL VERBS	CONJUGATIONAL CLASS AND CLASS OF THE RHYME			
	Conjugational Class I		Conjugational Class II	
	Rhyme I	Rhyme II	Rhyme I	Rhyme II
Novels with –aba	92%	84%	17%	11%
Novels with –ía	8%	16%	83%	89%

The importance of conjugational class on the novel verbs is clear. The table shows that 92% of the verbs presented as conjugational class I and with class I rhymes were inflected using *–aba*. Similarly, 89% of the verbs presented as conjugational class II and with class II rhymes were inflected using *–ía*. Even among the verbs of class I that had rhymes of class II, 84% were inflected in *–aba*; and 83% of the verbs of class II with class I rhymes were inflected in *–ía*.

To determine the effect of the different properties of the verb in the selection of the suffix, we ran ANOVAs. The analyses showed that conjugational class was the best predictor of the choice of suffix ($F(3, 79) = 658.01$, $p<.00001$). Thus, there was a strong tendency to inflect in *–aba* the verbs presented as class I, and to inflect in *–ía* the verbs presented as class II. These tendencies seem to be similar in strength since a *t*-test yielded no significant differences between class I verbs inflected in *–aba* and class II verbs inflected in *–ía* ($t(78)=0.65$, $p=.51$).

These analyses suggest that conjugational classes have psychological reality, i.e., they are not mere descriptive generalizations, but are operative in the mental representation of Spanish verbs. This would indicate the existence of two productive processes operating in the inflection of novel verbs: a general rule of *–aba* suffixation, and a local rule of *–ía* suffixation (productive within a domain).

The table also indicates, however, that verbs with class II type rhymes *of both classes* were more likely to take *–ía* than verbs with class I type rhymes. If pure symbolic procedures were responsible for the computation of class I verbs in the Past Imperfect experiment, then there is no reason to expect any difference in the choice of suffix between those that have class I type rhymes and those that have class II type rhymes: all of them are expected to be inflected with the class I suffix *–aba*. However, a difference was found (8% vs. 16%). Thus, although the conjugational class was the factor that showed the strongest effect, there was an effect of type of rhyme, which also affected the choice of suffix, at a much lower level ($F(3, 79) = 6.46$, $p<.01$). Interestingly, the effect of rhyme was different across classes, as shown in Table 2:

Table 2. Neighborhood effects: Correlations between suffixations rates and neighborhood

SPANISH IMPERFECT	SUFFIXATION RATES x NEIGHBORHOOD		
	r	p	n
Class I Rhyme I novels inflected with –aba	.03	.88	20
Class II Rhyme II novels inflected with –ía	.45	.04	20

The table shows that for the novels inflected with *–aba*, among class I verbs containing rhymes of class I, neighborhood did not affect the response. In contrast, for the novels inflected with *–ía*, among class II verbs containing rhymes of class II, neighborhood and *–ía* suffixation correlated significantly. These results suggest that associative mechanisms based on phonological similarity also affect the representation of Spanish verbs, but mainly in class II.

Taken together and considering the possible outcomes stated in section 2.3, these results are somehow puzzling: if the system is exhaustively explained by the operation of rules, why do we still find neighborhood effects?

A possible explanation is that associative memory procedures operate mainly in the domain of conjugational class II, probably in the representation of the verbal roots.

3. Spanish Present Tense Experiment

3.1. Participants

The same group of subjects (thirty-three adult native Spanish speakers) participated in the study (see section 2.1).

3.2. Design

Spanish Present Tense regular verbs (1st person singular) are formed in the following way: **root + –o**.

There are a group of verbs that contain –e– in the rhyme that are irregular in that the rhyme changes to –ie– when inflected in the 1ps.

	Regular verbs (1ps)	Irregular verbs (1ps)
	root + –o	**root with diphthong + –o**
Class I	pegar – pego	pensar – pienso
	'to hit – I hit'	'to think – I think'
Class II	vender – vendo	perder – pierdo
	'to sell – I sell'	'to lose – I lose'

Items: The task comprised 160 items (80 real and 80 novel verbs). In this paper we report the results of the analysis of novel verbs only. Similarly to the previous task, novel verbs were created by manipulating two properties: the verb's ending (–ar and –er / –ir) and the type of rhyme. Differently from the previous task, real verb rhymes were classified depending on their being more frequent in regular or irregular verbs. There are certain rhymes that are more present in regular verbs, and others that typically appear in irregular verbs.

The following four groups of verbs were created:

20 novel verbs with suffix –ar and regular rhymes (*atrecar*)

20 novel verbs with suffix –ar and irregular rhymes (*efemblar*)

20 novel verbs with suffix –er / –ir and regular rhymes (*polever*)

20 novel verbs with suffix –er / –ir and irregular rhymes (*aferder*)

Neighborhood calculations: In this experiment there were two neighborhood calculations:

Neighborhood 1: friends minus enemies within the same class. For example, the verb *vender – vendo* 'sell' has a friend: *pretender – pretendo* 'intend', and an enemy: *entender – entiendo* 'understand'.

Neighborhood 2: friends minus enemies across classes. For example, the same verb *vender – vendo* 'sell' has as friends: *pretender – pretendo, refrendar – refrendo*, and as enemies: *entender – entiendo, enmendar – enmiendo.*

Procedure: Participants were asked to provide inflected forms of the verbs in appropriate sentence contexts. For example:

pensar. A mí me gusta pensar en el futuro.
Por eso yo siempre *pienso* en el futuro.
'I like to think about the future. That's why I always think about the future.'

Participants were instructed with examples of class I and class II or III real verbs. After the examples of real verbs, novel verbs with different endings were presented. For example:

neler. A mí me gusta neler alcancías.
Por eso yo siempre *nelo* alcancías.
'I like to *neler* piggy banks. That's why I always *nelo* piggy banks.'

As in the previous task, participants were instructed first with complete sentences and then with sentences containing a blank in the place of the required inflected form. Also similarly to the Past Imperfect experiment, the sentence contexts for the novels were created trying to avoid associations with real verbs. Real and novel verbs of all types were presented in random order.

Type of Analysis: In the analyses we observed the irregularization of the 1ps (presence of –ie– in the rhyme of the novel) in relation to (1) the class of the novel: whether it was presented as class I or II/III; and (2) the neighborhood strength: relevance of phonological shape in the determination of the inflectional pattern.

3.3. Results

The goal of this task was to explore the relative influence of rhyme and conjugational class in the inflectional pattern of novel verbs; in particular, to observe whether or not subjects irregularized novel verbs by generalizing the irregular pattern in the stem (–e– to –ie– transformation), and how this irregularization related to conjugational class and type of rhyme.

Table 3 presents the irregularization rates of present tense novel verbs, i.e., the percentage of verbs that were inflected with the diphthong –ie– in their rhymes.

Table 3. Irregularization rates by conjugational class and type of rhyme

SPANISH PRESENT TENSE	CONJUGATIONAL CLASS AND TYPE OF RHYME						
	CONJUGATIONAL CLASS I				CONJUGATIONAL CLASS II/III		
	Regular Rhyme		Irregular Rhyme		Regular Rhyme		Irregular Rhyme	
	mean		mean		mean		mean	
Irregularization Rates	6%		10%		15%		43%	
	min	max	min	max	min	max	min	max
	0%	23%	0%	34%	0%	36%	18%	73%

The table indicates that the highest irregularization rates were obtained among verbs of conjugational class II/III with irregular rhymes (43%). This group also presented the highest minimum and maximum rates (18% and 73% respectively). The lowest rates appeared among class I novels with regular rhymes. In the middle, there were class I novels with irregular rhymes and class II/III novels with regular rhymes.

Analysis of variance was performed to assess the relative weight of conjugational class and type of rhyme in the inflectional pattern. Possible interactions between the two conditions were also examined. The ANOVAs yielded highly significant main effects for conjugational class ($F(3, 79) = 57.32$, $p<.00001$), for type of rhyme ($F(3, 79) = 33.42$, $p<.00001$), and also a highly significant interaction between the two variables, ($F(3, 79) = 18.65$, $p<.00001$). (The ANOVA also showed a very high R-squared (0.59), which indicates a powerful model that is able to explain an important part of the speakers' behavior.)

These analyses indicate that both the conjugational class of the novel verb and the type of rhyme affected the inflectional pattern of the novel: conjugational class II novels, and novels with irregular rhymes, were more likely to take the irregular stem. The largest effect corresponds to the conjugational class, followed by the type of rhyme. The fact that the interaction between the variables was significant indicates that the effect of the type of rhyme was not the same across classes: the regular/irregular contrast was more important among class II verbs than among class I verbs. This can be noticed by

comparing the difference in percentage points between the groups. The table shows that among class I novels, the irregularization rate of verbs with irregular rhymes was four percentage points higher than the irregularization rate of verbs with regular rhymes; among class II verbs, the difference was 28 percentage points.

These results indicate that conjugational class and phonological similarity are both relevant factors in the mental representation of verbs, and that there are differences across conjugational classes in the processes that determine the inflectional patterns.

The results of the analyses of the neighborhood effects are presented in Table 4 below:

Table 4. Neighborhood effects: Correlation between Irregularization rates and Neighborhoods

SPANISH PRESENT TENSE	IRREGULARIZATION RATES x NEIGHBORHOODS			
		r	p	n
Irregularizations of novel verbs with regular rhymes	Neighborhood within classes	0.10	0.52	40
	Neighborhood across classes	0.18	0.27	40
Irregularizations of novel verbs with irregular rhymes	Neighborhood within classes	0.37	0.02	40
	Neighborhood across classes	0.29	0.07	40

As shown in the table, verbs across both classes containing *regular* rhymes did not show neighborhood effects, suggesting that regular verbs of both classes are not memorized, but computed in the grammatical system. In contrast, verbs across both classes containing *irregular* rhymes did yield neighborhood effects, and the effects were somewhat stronger for the neighborhood calculation *within* conjugational class. These results suggest that for both classes, irregular verbs are memorized, on the basis of phonological similarity.

Given the results obtained for the present tense, a relevant question is: How do conjugational class and type of rhyme interact? We would like to suggest that conjugational class is the most relevant property in the representation of Spanish verbs, and rhymes and neighborhoods (associative memory procedures) seem to be operative within the domain defined by the conjugational class.

4. Conclusions

The experiments reported in this paper indicate that both symbolic and associative procedures have a role in the mental representation of Spanish verbal morphology.

Both experiments yielded an effect for conjugational classes, indicating that they are not descriptive generalizations, but play a relevant role in the organization of verbs in speakers' minds. Moreover, in both experiments, this variable was the one with the strongest explanatory power. This aspect of the results seems problematic for single system theories of language processing and representation that do not include abstract symbolic features in the explanation of the computation of verbal inflection.

Interestingly, associative memory representations based on phonological similarity were shown to be also operative in the computation of both Past Imperfect and Present Tense verbs, which casts doubts on the accuracy of a pure symbolic approach.

These results suggest that a specific combination and interaction of two different systems (one based on the manipulation of abstract symbolic categories and one an associative memory type of system) are required to account for the representation and processing of Spanish verbal morphology, thus,

supporting dual system perspectives. The precise way in which the two systems interact requires further exploration.

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