

Spanish verbal inflection: A single- or dual-route system?¹

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Abstract

Four studies of Spanish morphology are examined that seem to support the dual-route model because they demonstrate an asymmetry between regular and irregular verbal inflections. In Rodriguez-Fornells et al. (2002), ERPs were measured during a priming study. Regular targets demonstrated an increased positivity between 250 and 450 ms after the presentation of the stimulus, but irregulars did not. However, these findings are suspect because it is not possible to control for the effects of previous knowledge of the word, orthographic overlap, and semantic similarity at the same time.

Yaden's subjects (2003) produced inflected forms of nonce infinitives. They resulted in many errors that regularized irregular inflections, but few that irregularized regulars. Clahsen et al. (2002) also found more regularization than irregularization errors in children. Single-route analogical simulations of Yaden's test items and of errors in acquisition yielded the same dissociation between common regularization uncommon irregularization.

The experiment by Brovotto and Ullman (2005) also entailed inflecting nonce verbs. They argue that two factors influence the inflection, one concrete and the other abstract: 1) phonological similarity of the nonce stem to extant stems and, 2) conjugational class. Phonological similarity only influenced irregularization of words with irregular rimes, but not words with regular rimes. However, stem similarity and conjugational class are represented phonologically in the nonce words making them both available to influence the nonce words analogically. A simulation of the test items produced outcomes similar to Brovotto and Ullman's.

Because a single-route model can produce the same dissociation between regular and irregular inflections, the data from the cited experiments do not demonstrate the superiority of the dual-route model.

0. Introduction. In the field of morphological processing, the past two decades have been characterized by the ongoing debate between dual-route and single-route approaches. The dual-route model holds that morphologically regular words are processed by rules of inflectional concatenation while irregular words are thought to be stored as wholes and accessed from lexical memory. Single-route models, on the other hand, assume that regular and irregular morphology are processed by a single mechanism. The debate between those who espouse single- versus dual-route models is extensive and a thorough review merits a book in and of itself (e.g. Pinker (1999). The issues discussed by Pinker and Ullman (2002a, b) and McClelland and Patterson (2002) provide a sense of where each side currently stands. Nevertheless, the crux of the controversy originally centered on the processing of the English past tense and other English language phenomena (Bybee 1985, 1988; Daugherty and Hare 1993; Daugherty and Seidenberg 1992, 1994; Eddington 2000; Elman et al. 1996; Jaeger et al. 1996; Marchman 1997; Marcus 1995; Pinker 1991, 1997; Pinker and Prince 1988, 1994; Prasada and Pinker 1993; Prasada, Pinker, and Snyder 1990; Rumelhart and McClelland 1986; Seidenberg, 1992; Seidenberg and Bruck 1990; Seidenberg and Hoeffner 1998; Sereno and Jongman 1997; Stemberger, 1994; Stemberger and MacWhinney 1986, 1988; Ullman 1999; Ullman et al. 1997; Westermann 1997). However, morphological processing in other languages such as German (Bybee 1991; Bybee and Newman 1994; Clahsen et al. 1992, 2001; Hahn and Nakisa 2000; Marcus 1995; Nakisa and Hahn 1996, Penke et al. 1997) and Italian (Albright 2002; Burani et al. 1984; Caramazza et al. 1988; Eddington 2002; Matcovich 2000; Orsolini et al. 1998; Say and Clahsen 2001) have been cited as evidence for and against both models as well.

The purpose of the present paper is to review some recent studies that suggest that a dual-route model accounts for verbal inflection in the Spanish language (Brovetto and Ullman 2005; Clahsen, Avelo, and Roca 2002; Rodriguez-Fornells, Münte, and Clahsen. 2002; Yaden 2003). I will demonstrate that these studies either have fatal flaws or that their results are also replicable within a single-route model.

1. ERP repetition priming experiment. Rodriguez-Fornells et al. (2002) carried out a priming study in which Spanish speakers were presented strings of letters on the computer screen that either were or were not extant Spanish words. The subjects' task was to press one key if they recognized the string as a legitimate word and other if the string was not a word. This method allowed reaction times and error rates to be measured. During the experiment the subjects event-related brain potentials were also measured through a series of electrodes that had been placed on the scalp.

Test items were varied along a number of parameters. Spanish verbs can be divided into regular and irregular categories. Regular verbs suffer no changes in the stem when inflectional endings are added. For instance, when the first person singular present suffix *-o* is added to the stem *beb-* 'drink' of the infinitive *beber* the result is *bebo* 'I drink'. However, when *-o* is added to the stem *rog-* 'plead' of the infinitive *rogar* the result is *ruego* 'I plead,' hence the verb is irregular. In addition to extant regular and irregular verbal forms the authors included regular and irregular nonce words. Test words were matched on frequency and length. The crucial test cases involve primes consisting of first person singular present tense forms that were followed five to nine items later by their corresponding infinitive targets:

	Prime	Gloss	Target	Gloss
Irregular extant	<i>entiendo</i>	I understand	<i>entender</i>	to understand
Regular extant	<i>ando</i>	I walk	<i>andar</i>	to walk
Irregular nonce	<i>miero</i>		<i>merer</i>	
Regular nonce	<i>poto</i>		<i>potar</i>	

Priming occurs when the presentation of a previously presented word speeds or slows recognition of a target that is related to the prime.

Rodriguez-Fornells et al. interpret any differences in reaction time or error rate between the regular and irregular items to indicate different modes of mental processing. For example,

significantly more errors were made on existing irregular words than on existing regular forms which they take as evidence in favor of differential processing of regular and irregular items; however, no significant differences in reaction time to regular versus irregular targets were observed. Regular and irregular inflections primed their infinitive forms equally well. Rather than discuss this as evidence against the dual-route model, they attribute the lack of priming differences to the fact that attempts to get irregular words to prime have been “notoriously variable and difficult to replicate” (449). Since the reaction time data does not support the dual-route theory, Rodriguez-Fornells et al. emphasised the results of the ERP measurements.

The ERP results are the focus of their discussion. Most importantly, they discuss a crucial difference in the ERP measurements taken at the central and posterior scalp sites during the presentation of the target. Regular targets demonstrated an increased positivity between 250 and 450 ms after the presentation of the stimulus which is called the N400 effect. No such increased positivity was observed for irregular targets. They attribute this difference to morphology. They conclude that for regular words morphological decomposition occurs (*and + o*) and the stem is accessed directly from the lexicon. For irregular words such as *entiendo*, the irregular stem *entiend-* is a subentry of the stem *entend-* and as such the stem *entend-* is not directly related to *entiendo* but only indirectly via *entiend-*, hence the ERP differences. In other words, “the lack of an N400 effect for the irregular verbs . . . suggests that the memory trace that was formed by the prime did not activate the representation of the target sufficiently to yield an N400 reduction” (449).

The authors are aware that there is an alternate explanation for their findings, namely differences due to orthography rather than to different mode of morphological processing; the stem in regular forms such as *and+ar* and *and+o* are orthographically identical while the stems in irregular forms such as *entend+er* and *entiend+o* are not. In order to reduce the effect of orthography, the primes and their corresponding targets were presented in different cases (upper and lower), and five to nine stimuli separated each prime and target. While these manipulations

may REDUCE the influence of orthography they do not ELIMINATE it completely. As further evidence against an orthographic explanation of the results they cite the outcome for the nonce verbs which contained the same sort of regular and irregular patterns as found in existing Spanish verbs. Real regular verbs elicited an N400 effect while real irregulars did not. Neither the irregular nor the regular nonce verbs demonstrated an N400 effect in spite of the fact that the irregulars contained the same orthographic differences as the real verb; therefore, they suggest that the difference must not be due to differences in orthography but to differences in morphological processing.

It is my contention that this reasoning is unsound. The real and nonce words used were indeed equated in terms of orthography; however, they differ in other crucial aspects that were not controlled for: familiarity with the words and semantic similarity. Real words have entries in the mental lexicon prior to the experiment, nonce words do not. Real words such as *entender* and *entiendo* have a semantic relationship to each other that nonce words such as *miero* and *merer* do not. Therefore, comparing the priming effect of nonce forms that have only orthographic similarity with verbal inflections that share orthographic and semantic traits and that form part of the speakers' mental lexicon is tantamount to comparing apples to oranges. They are both fruit, but the results of a study on oranges does not necessarily give any insight into how apples may fare under the same conditions.

The difficulty with this study is that it is impossible to find real inflections with irregular morphology that are not orthographically different from their infinitives as well. Showing that orthographically regular and irregular nonce words result in identical N400 measurements does not factor out the possibility that orthography is responsible for the N400 differences found when the test subjects processed real words. Morphology is the intersection of semantic and orthographic/phonetic characteristics. The authors assert differences in morphological processing yet this particular experimental design simply does not allow one to control for the subjects' pretest knowledge of the test words, their orthographic similarity, and their semantic

similarity at the same time; as a result these findings should be viewed with a great deal of suspicion. In short, the results of a nonce words study does not reveal much about how speakers process real words. The best evidence for a dissociation between regular and irregular inflection is that irregulars items yielded more errors than regular items.

2.0. Online inflection experiment. In Yaden's experiment (2003), native Spanish speakers and advanced L2 learners were presented infinitive verbal forms on the computer screen. Their task was to say aloud the first person singular present form of the infinitive. Response times were measured with a voice key and error rates were calculated. Test items included high and low frequency regular and irregular forms. Following the dual-route model, Yaden hypothesized that frequency effects would be found between high and low frequency irregulars but not between high and low frequency regulars since irregular inflections are assumed to be stored as wholes in the mental lexicon while regular inflections do not have a separate entry in the mental lexicon. The dual-route model also predicts that irregulars will be regularized to a much higher degree than regulars are mistakenly assigned an irregular form because "if morphology was produced solely on analogy with other stored forms, we would expect speakers to more often make mistakes both in terms of overapplying the regular and irregular patterns" (Yaden 2003: 308).

The resulting reaction time evidence for Yaden's native speakers does not support the stronger prediction of the dual-route hypothesis that irregular inflection should demonstrate frequency effects while regular should not (Pinker and Prince 1994: 327). However, the frequency effects observed for irregular items were more robust than those of the regular forms which coincides with a weaker prediction of the dual-route model (Pinker 1999). The L2 speakers, on the other hand, demonstrated frequency effects for regulars but not for irregulars which completely contradicts that dual-route model. However, one should be cautious about judging models of native competence against data from non-fluent language learners.

The analysis of the error rates appears to provide the best evidence in favor of the dual-

route model. Regularization of irregular inflections (e.g. *oír* ‘to hear’ > erroneous **oyo* rather than standard *oigo* ‘I hear’) was much more common than irregularization of a regular form (e.g. *soplar* ‘to blow’ > **sueplo* rather than *soplo* ‘I blow’). Native speakers had a 10% rate of regularization and made no errors that irregularized a regular inflection. L2 speakers regularized 55% of the regular forms but irregularized to a much lower degree (3%). For Yaden, this is prima facia evidence that verbal inflection is carried out via a dual-route model and cannot have been performed on the basis of analogy to stored forms in the mental lexicon which would supposedly yield similar error rates on both categories of verbs. I demonstrate in the next section that a single-route model of analogy is able to account for these results.

2.1. Analogical simulation of the online inflection experiment.

2.1.1. Analogical algorithm.

The algorithm I selected for the simulations is Analogical Modeling (AM; Skousen, 1989, 1992, 1995) which is a model of how relationships between stored lexical items may be used to predict linguistic behavior. It is similar to other instance-based models and to connectionism in that none of these models extract overall characterizations of the data in the form of a rules or constraints for either regular or irregular inflections. (For a discussion of the differences between AM and these other models see Chandler 1995, 2002; Jones 1996; Skousen 1989, 1995). Analogy exploits the idea that even morphologically complex words are stored as wholes, a concept that has psycholinguistic support (Baayen, Schreuder, de Jong, and Krott 2002; Bertram, Laine, Baayen, Schreuder, and Hyönä 1999; Sereno and Jongman 1997). In AM, when the need arises to determine some linguistic behavior (in this case the correct first person singular present form of the verb—the *yo* form), a search of the database representing the mental lexicon is conducted beginning with the entries most similar to the infinitive in question and then extending to less similar entries. The algorithm contains an explicit procedure for assembling an analogical set from which analogs may be chosen and

subsequently applied to the test infinitive. In general, database entries most similar to the test infinitive will appear in the analogical set. However, unlike other nearest neighbor models, less similar items have some chance of being included as well. AM calculates the probability that one or more outcomes is possible. The regular relationship between an infinitive and present tense *yo* form is that the suffix *-o* appears directly after the stem (*escribir~escribo* ‘to write~I write’). A different relationship holds between pairs such as *entender~entiendo* ‘to understand~I understand’ and between *servir~sirvo* ‘to serve~I serve.’ Each different relationship is specified in the database along with the phonemic make up of the final three syllables of the infinitive.

Consider *morder~muerdo* ‘to bite~I bite.’ If a search of the database is done for *morder* and *morder* appears in the database, it is obviously the most similar item to itself; therefore, the relationship between the infinitive and *yo* form will be applied correctly predicting *muerdo*. If *morder* does not appear, words that are similar to it will be sought. Assume that the most influential neighbors of *morder* are *mover* and *poder* both of which have the same relationship: *mover~muevo* ‘to move~I move,’ *poder~puedo* ‘to be able to~I can.’ One possible mechanism for deriving the *yo* form can be conceived of as a sort of proportional analogy: *mover* is to *muevo* and *poder* is to *puedo* as *morder* is to ___?² One could assume that the process involves adding *-o* to the stem *mord-* and replacing the stem vowel with *ue*. Another possibility would be to assume the entire infinitive form is considered and that the final *-er* has to be deleted and replaced by *-o*, the *o* of the stem is converted into *u* which is then followed by epenthesizing an *e*. The point here is that the exact procedure speakers employ in order to modify *morder* so that it bears the same relationship that *mover* and *poder* bear to their *yo* forms is irrelevant as long as the output is the same. In fact, the exact mechanism may vary from one speaker to another. Another important point is that the procedure employed to produce the correct outcome is devised on the fly; it is not recalled from memory as a preestablished or prefabricated rule although it is possible that repeated calculation of an analogical set allows the set itself to be stored in memory thus eliminating the need to perform a full search each time.

In the course of predicting the *yo* form of *morder* the algorithm finds all infinitives that begin with /m/ and considers them together. It also compares all database items with /o/ as the nucleus of the stem in another group. Other groupings would contain the items beginning with *mo-*, *mor-*, or *m-* and whose stem ends in *d* and so on until all possible groupings of all variables are considered. These groups, called supracontexts, are then inspected in order to calculate disagreements. A disagreement occurs when not all of the infinitives in a supracontext bear the same relationship to their present tense *yo* forms. For example, if the supracontext of items ending in *-der* contained *entender* ‘to understand’ and *vender* ‘to sell’ there would be some disagreement because the relationship between these two infinitives and their corresponding *yo* forms is different (*entender~entiendo*, *vender~vendo*). Under certain conditions, members of a supracontext containing disagreements will be eliminated from consideration. In this example, the algorithm determines that infinitives ending in *-der* do not form a cohesive enough group from which to draw analogs on which the *yo* form of *morder* may be predicted. Bear in mind that the more similarities a database item has to *morder* the more supracontexts it will appear in. This means that it has a greater chance of appearing in supracontexts that are not eliminated due to disagreements.

In general, a word with more in common with the test item exerts more analogical influence on that item than a word that has less in common. I will not go into exact details about precisely what conditions must be met in order for a supracontext with disagreements to be excluded (see Skousen 1989 for details). The important part of this example is that database items that remain comprise the analogical set which is used to predict the *yo* form in this case. For each possible outcome in the analogical set a probability that the outcome will apply is calculated. For the present simulation, the outcome with the highest probability is assumed to apply.

2.1.2. Data set. The 2097 most frequently occurring verbal lemmas were extracted from the

LEXESP corpus (Sebastián Gallés et al. 2000).³ The phonemic make of the final three syllables of the infinitive form of each verb was encoded on a syllabic template. For instance, *contratar* and *lucir* appeared as *k,o,n,t,r,a,0,t,a* and *0,0,0,l,u,0,θ,i* where ‘0’ indicates empty onsets and codas. All infinitives end in *-r* which is why it was not included. Along with the phonemic representation of the infinitive a specification variable was included that indicated which of 17 relationships exists between the infinitive and *yo* form. The regular inflection is occurs when *-o* follows the stem, and the stem form is the same as the stem of the infinitive. Other relationships are exemplified in the pairs *venir~vengo* ‘to come~I come’ and *tener~tengo* ‘to have~I have’ have one kind of relationship while *conocer~conozco* ‘to know~I know’ and *lucir~luzco* ‘to excel~I excel’ have another.⁴ The type database consisted of one entry for each 2097 items. A token database was constructed by including multiple entries for each item depending on their frequency in LEXESP.⁵ Entries with a lemma frequency of 100 or less were included once. The number of entries for the remainder of items was determined by dividing the frequency by 100, therefore, an item with a frequency of 9328 had 93 identical entries in the token database.

2.1.3. Simulations and results. In the first simulation, the *yo* form of each of Yaden’s 63 test items was predicted by analogy to the relationships that hold in the 2097 database items. However, exact matches were not allowed. These conditions simulate predictions being made as if each test item were new and unknown to a speaker. If exact matches were allowed the item being tested would find itself as the closest analog in the database and predictions would be 100% correct, which is not a very informative result. AM outputs a probability that a given relationship will apply. For example, the *yo* form of *sembrar* ‘to sow’ is incorrectly predicted to be **sembro* at a rate of 92% and the correct form *siembro* at 8%, therefore, the majority wins and *sembrar* is a case of overregularization. The *yo* form of *vertir* ‘to pour’ is correctly predicted to be *vierto* at 91% while two other possibilities (**verto*, **virto*) are only predicted at a rate of about 4% each. Under these conditions 55% of the irregular test items were regularized while

only 3% of the regular items were predicted to take some kind of irregular form.

One difficulty with this first simulation is that in actual language processing exact matches are a reality which must be dealt with. This explains the need for the second simulation which used the token database and allowed for exact matches. Actually 10 separate simulations were performed. In each simulation, predictions were made for the 63 test items using a randomly selected 10% of the database (about 210 items) as possible analogs. Since high frequency items had more instances in the token database they were more likely to appear as part of the randomly selected 10%. Low frequency items were more likely not to make the cut. Averaging across the 10 simulations the regularization rate was 21% and only 4% of regulars were predicted to have an irregular form.

2.1.4. Discussion. A comparison of the present simulations with Yaden's results appears in Table 1.

	Regularization Rate	Irregularization Rate
Yaden-Native Speakers	10	0
Yaden-L2 Speakers	55	3
Simulation 1	55	3
Simulation 2	21	4

It is clear that regularization is a much more common process for speakers than irregularization, at least for the 63 words tested. This dissociation has been presented as evidence that regular and irregular inflection are carried out by different mechanisms. Moreover, it is thought that a single-route model of analogy would be unable to produce this dissociation. Of course, both of the present simulations demonstrate that a single-route model of analogy produces the exact dissociation that only a dual-route model was thought capable of. Therefore, Yaden's

experimental results do not support the superiority of the dual-route model over single-route analogy.

3.0. Child acquisition data. Clahsen et al. (2002: 596) assume much the same hypothesis as Yaden:

If the dual-mechanism model extends to Spanish, we would expect Spanish children to show a regular/irregular asymmetry with respect to both stem formation and inflectional affixation. That is, regular patterns, whether they be stems or inflectional affixes, should overgeneralize to irregular items, whereas generalizations of irregular patterns to regular verbs should be rare or non-existent.

They examined the spontaneous speech of 15 children ages 1;7 to 4;7 years old and noted all errors in verbal inflection. These data were taken from the CHILDES project (MacWhinney 2000). Overall they observed that 4.6% of irregular inflections were regularized while only .001% of regular inflections were made irregular. They did not consider diphthongizing stems involving the common *ie~e* and *ue~o* alternations (*tiene~tener* 'he has~to have,' *cuezo~cocer* 'I cook~to cook') as either regular or irregular but as a separate class. Nevertheless, all errors they registered in this class involved eliminating the diphthong and no non-diphthongizing stem was produced with a diphthong (**cueme* for *come* 's/he eats'). They also noted that overregularization rates were lower in older children. In sum, they observed a dissociation between regular and irregular inflection in error production.

3.1. Analogical simulation of errors in children. What I intend to demonstrate is that the same dissociation between regular and irregular inflections that Clahsen et al. (2002) found in childrens' errors is obtainable in a single-route analogical model as well. To the end, I applied

the algorithm described in section 2.1.1. However, this task is much more complex than that of modeling Yaden's experimental data (Section 2.0), which only entailed predicting the first person singular present tense form of a verb given its infinitive form, which is a relationship between only two inflectional forms. The errors recorded in the CHILDES database could potentially be made on any of the approximately 35 to 40 verbal inflections in Spanish (depending on the dialect). Simulations of all these possibilities is beyond the scope of the present paper, which is why I focused on only four which represent a sampling of different tense, number, person, and mood: (1) third person singular imperfect, (2) second person singular imperative, (3) third person plural preterite, (4) first person singular present.

3.2. Data sets. I accessed the CHILDES databases created by Diez-Itza and Pérez-Toral (1996), López Ornat (1997), Marrero and Albalá, and Montes (1992) for data on children between 1;0 and 4;11 years of age.⁶ I divided the children into three age groups ((1) 1;0-2;6, (2) 2;7-3;6, and (3) 3;7-4;11) and extracted all verbal forms for each group. A fourth database is based on the one described in Section 2.1.2 consisting of 2097 verbs.

It was important to code each verb in such a way that all of its inflectional stems were represented. The idea is that the form of one inflection is not necessarily related to one other form such as the infinitive, but to one or many different inflections. One way of representing a complete verbal paradigm would be to completely encode all 35-40 different inflections. This which would require hundreds of variables and make the simulation too computationally intense. In addition, much of the information for each inflection would be redundant. Instead, the principal parts of every stem were identified and placed into a template where '0' indicates empty onsets and codas.

Verb	Part 1	Part 2	Part 3	Part 4
<i>doler</i>	<i>0 0 0 d o 0 l e</i>	<i>ue 0 l o</i>	<i>o 0 l i ó</i>	<i>ue</i>
<i>estar</i>	<i>0 0 0 0 e s t a</i>	<i>e s t o i</i>	<i>e s t u</i>	<i>e</i>

<i>hacer</i>	0 0 0 0 a 0 θ e	a 0 g o	i 0 θ o	a
<i>seguir</i>	0 0 0 s e 0 g i	i 0 g o	i 0 g i ó	i
<i>peinar</i>	0 0 0 p e i 0 n a	e i 0 n o	e i 0 n ó	e i

Only a few inflectional suffixes are encoded in this manner, yet all inflectional stems are represented by one of the three parts or a combination of elements from each part. For example, Part 1 encodes inflections such as *dolemos*, *doler*, *dolían*, etc., as well as the theme vowel *e*. Part 2 represents *duelo*, *duelas*, etc. Part 3 is found in inflections such as *dolió*, *dolieron* and Part 4 is the last nucleus of the stem seen in forms such as *duele*, *duelan*, *duelo*, etc. These variables allow verbs to be grouped and categorized based on the similarity of their stems and inflectional paradigms. This representation of verbal paradigms implies that when one inflection appears in the CHILDES database (e.g. *sigo*), the speaker is assumed to know at least one other form of the verb that contains the other stem variants (e.g. *seguir*, *sigió*). What this encoding may lack in elegance it makes up for in computational practicality.

3.3. 0. Method. Among other things, language acquisition includes an expansion of vocabulary. The simulations exploit that increase by using the vocabulary of older children as test cases and drawing analogies from the lexicon of younger speakers. For each of the four inflections whose form is predicted, six simulations were performed. The first simulations used the database for the 1;0-2;6-year-olds as the data set and the database containing all of the verbs for the 1;0-3;6-year-olds as the test set. Both a type and token data set were used in separate simulations. The type data set contained one entry for each verb while the token data had multiple entries for each verb depending on their token frequency. The type database was always used as the test set. (See Section 2.1.2 for details about how token data sets were constructed.) The second pair of simulations used the vocabulary observed in the 1;0-3;6-year-olds as the data set and the data from the 1;0-4;11-year-olds as the test cases. The final pair of simulations had the data from the

1;0-4;11 group to make analogies from and the test set contained the 2097 verbs used in the simulation in Section 2. In all simulations, exact matches between the test item and members of the data set were disallowed, which means that verbs from the test set that appeared in the data set were treated as if they were not previously known.

3.3.1. Simulations of the imperfect. There are only five distinct imperfect allomorphic relationships in Spanish. Traditional grammars state that the third person singular form is derived by adding *-ía* to the infinitive stem of a verb with a theme vowel of /e/ or /i/, while *-aba* is placed after a stem with /a/ as the theme vowel: *hac+er > hac+ía*; *pein+ar > pein+aba*. Both of these processes are considered regular inflection. This is a sensible way to treat the formation of the imperfect from a pedagogical standpoint. In the present study, rather than assume that only the infinitive can serve as the base form, a relationship may hold between several members of the verbal paradigm: *hacemos~hacía*, *hacéis~hacía*, *hacer~hacía*, *hacían~hacía*, *hacíamos~hacía*, etc. in accordance with Bybee's conception of interrelated lexical entries (1985, 1988). In three cases, any relationship that is made is nearly word specific (i.e. irregular): *ver > veía*, *ir > iba*, *ser > era*. The results of the simulations appear in Table 2. In all three simulations, none of the three irregulars (*ser*, *ir*, *ver*) are correctly predicted. Instead *ver* and *ir* are often regularized and *ser* is sometimes assigned the irregular morphology of *ir*. There are only a few cases of irregularization. In only a few rare instances such as *partir > *part+aba* (rather than standard *part+ía*) was a regular verb assigned an incorrect regular suffix.

Table 2. Results of imperfect simulations.

		Sim. 1	Sim. 2	Sim. 3	Error Examples
Overall Correct	type	.982	.979	.997	
	token	.969	.979	.998	

Overregularized	type	.667	.667	.667	<i>ver</i> > <i>*vía</i> ; <i>ir</i> > <i>*ía</i>
	token	.333	.333	.333	
Irregularized	type	0	0	0	<i>coser</i> > <i>*cosera</i>
	token	.004	0	0	
Regular to reg.	type	.004	.007	.001	<i>partir</i> > <i>*partaba</i> ; <i>ceder</i> > <i>*cedaba</i>
	token	.013	.007	0	
Irreg. to irreg.	type	.333	.333	.333	<i>ser</i> > <i>*iba</i>
	token	.667	.667	.667	

One could argue that the simulations are unfair because the only thing one needs to know to predict all regular imperfects is what the theme vowel is and that vowel is explicitly represented in the encoding of the verbal paradigms. There are two answers to this charge. First, the theme vowel is one of 17 variables and is not weighted differently than any of the other 16 for the purposes of the simulation; its importance over any other variable is not specified beforehand. Second, the assumption the simulation is based on is that a speakers know a number of inflections of the verb *tocar*, for example, but not the imperfect *tocaba*. Since the theme vowel *a* is readily apparent in many of the inflections that the speaker may know (e.g. *toca*, *tocamos*, *tocaron*) it must be included in a database designed to simulate preexisting knowledge of verbal paradigms and is thus available as an analog.

3.3.2. Simulations of the imperative. This simulation was designed to predict the second person singular imperative form of the verb. A number of verbs such as *haber*, *poder*, and *deber* were excluded from the databases since they are not generally used as imperatives. What is traditionally considered the regular imperative form is the one that coincides with the third person singular present inflection. The four irregular relationships are exemplified by *poner* > *pon*, *dar* > *da*, *ir* > *vé*, and *decir* > *di*. The relationship between the imperative and the infinitive

is used in the present discussion for simplicity's sake only. Spanish speakers could derive *pon* by deleting *-er* from the infinitive *poner*, by deleting *-go* from *pongo*, by deleting *-gamos* from *pongamos*, by deleting *-dré* from *pondré*, etc. From an analogical perspective, the task is one of identifying the correct paradigmatic relationship, not of specifying how a speaker derives one inflection from another which could actually vary from speaker to speaker.

Table 3. Results of imperative simulations.

		Sim. 1	Sim. 2	Sim. 3	Error Examples
Overall Correct	type	.954	.964	.987	
	token	.940	.968	.990	
Overregularized	type	.900	.900	.565	<i>hacer</i> > <i>*hace</i> ;
	token	.300	.300	.087	<i>decir</i> > <i>*dice</i>
Irregularized	type	0	0	0	<i>querer</i> > <i>*quer</i>
	token	.029	.011	.006	
Irreg. to irreg.	type	.100	.100	.022	<i>ir</i> > <i>*i</i>
	token	.400	.200	.043	

Table 3 summarizes the results of the three imperative simulations. As the size of the vocabulary increases, so does the rate of correct predictions. On the other hand, a larger mental lexicon results in lower overregularization rates. Few cases of irregularization were predicted compared to overregularization, especially when a more adult-like vocabulary size was used.

3.3.3. Simulation of the preterite. In the previous two series of simulations only five relationships exist among the members of the database. In order to predict the form of the third person plural preterite form of the verb it is necessary to specify 18 relationships. Regular inflection entails adding *-aron* to a verb stem whose theme vowel is *a* or adding *-ieron* to a stem

whose theme vowel is *i* or *e*. The remaining 16 relationships involve alternate stems that only appear in the preterite and imperfect subjunctive forms some of which (e.g. *traer*, *decir*) take alternative suffixes as well (*saber* > *supieron*, *ir* > *fueron*, *traer* > *trajeron*, *seguir* > *siguieron*; *tener* > *tuvieron*; *poner* > *pusieron*; *conducir* > *condujeron*; *venir* > *vinieron*; *morir* > *murieron*; *decir* > *dijeron*; *hacer* > *hicieron*; *caber* > *cupieron*; *haber* > *hubieron*; *poder* > *pudieron*; *querer* > *quisieron*; *andar* > *anduvieron*).

Table 4. Results of preterite simulations.

		Sim. 1	Sim. 2	Sim. 3	Error Examples
Overall Correct	type	.876	.908	.961	
	token	.844	.883	.956	
Overregularized	type	.679	.594	.143	<i>poder</i> > <i>*podieron</i> , <i>servir</i> >
	token	.179	.313	.095	<i>*servieron</i>
Irregularized	type	0	.004	.001	<i>aplaudir</i> > <i>*aplidieron</i>
	token	.030	.032	.018	
Reg. to reg.	type	.010	.008	.016	<i>partir</i> > <i>*partaron</i> , <i>vivir</i> >
	token	.727	.004	.005	<i>*vivararon</i>
Irreg. to irreg.	type	.214	.094	.013	<i>decir</i> > <i>*dicieron</i> , <i>tener</i> >
	token	.393	.406	.241	<i>*tinieron</i>

As the data set moves from that representing the lexicon of younger children to one of adult proportions the percent of correct outcomes increases and the proportion of overregularization decreases. Occasionally a regular verb such as *aplaudir* is irregularized (based on analogical pull from *medir*, *pedir*, and *despedir*), but the rates of overregularization are always much higher than those of irregularization.

3.3.4. Simulation of the present. In this simulation, the first person singular present tense inflection was predicted. Seventeen relationships were identified (e.g. *andar* > *ando*, *decir* > *digo*, *hacer* > *hago*, *seguir* > *sigo*, *traer* > *traigo*, *conocer* > *conozco*, *haber* > *he*, *ir* > *voy*, *oír* > *oigo*, *saber* > *sé*, *caber* > *quepo*, *ver* > *veo*). A similar pattern was obtained here (Table 5) as in the previous simulations; overregularizations drop as vocabulary size increases and overall efficiency improves. In all but one simulation overregularization is more common than irregularization. Simulation 4 is discussed below.

Table 5. Results of present simulations.

		Sim. 1	Sim. 2	Sim. 3	Sim. 4	Error Examples
Overall Correct	type	.892	.915	.965	.972	
	token	.844	.887	.952	.940	
Overregularized	type	.273	.243	.137	.129	<i>hacer</i> > <i>*hazo</i> ; <i>apretar</i> >
	token	.076	.110	.071	.085	<i>*apreto</i>
Irregularized	type	0	0	0	.003	<i>convencer</i> > <i>*convenzco</i>
	token	.082	.040	.021	.031	
Irreg. to irreg.	type	.076	.049	.016	.006	<i>saber</i> > <i>*sepo</i> ; <i>hervir</i> >
	token	.273	.183	.107	.115	<i>*hirvo</i>

In Clahsen et al. (2002), present tense forms with stems in which mid-vowels alternate with diphthongs (e.g. *divertir* > *divierto*, *morder* > *muerdo*) were considered in a separate category from regulars and irregulars. I also considered these relationships separately. The data from verbs of this sort appear in Table 6. Overregularization occurs much more frequently than a process that assigns a diphthong to a non-diphthongizing form. It is interesting to note that the diphthongizing verb *erguir* is calculated to take the morphology of another class of irregular verbs and is predicted to be *irgo*. In reality, both *irgo* and the inflection with the diphthong

yergo are considered correct alternatives (Real Academia Española 1985; 287) so this is not technically an error.

Table 6. Results for diphthongizing present tense forms.

		Sim. 1	Sim. 2	Sim. 3	Sim. 4	Error Examples
Overall Correct	type	.882	.978	.963	.932	
	token	.912	.978	.981	.932	
Overregularized	type	.118	.021	.037	.062	<i>jugar</i> > <i>*jugo</i> ; <i>adquirir</i> >
	token	0	0	.012	.031	<i>*adquiro</i>
Reg. to diph.	type	0	0	0	.031	<i>depende</i> > <i>*depiende</i>
	token	.019	.009	.010	.018	
Diph. to irreg.	type	0	0	.006	.006	<i>erguir</i> > <i>irgo</i>
	token	.088	.023	.006	.037	

As discussed in Section 3.2, the encoding of the verbal paradigms explicitly includes a variable stating what the stem-final nucleus of first person singular present tense verbs is. Although this information is not given any preferred status over any of the other 17 variables, it could skew the results as far as diphthongizing and non-diphthongizing verbs are concerned. Simulation 4 was run to address this concern. It uses the same data and test sets as Simulation 3 except that in the data set the stem-final nuclei of first person singular present tense verbs are replaced with ‘=.’ Under these conditions five non-diphthongizing verbs are predicted to have a diphthong, nevertheless, the resulting irregularization rate of .031 is still half that of the regularization rate for diphthongizing verbs (.062), and the overall irregularization rate of .003 (Table 5) is far below the overall overregularization rate of .062.

3.2. Summary. These simulations demonstrate a clear asymmetry between regular and irregular

inflection in Spanish; errors involving overregularization far outnumber errors in which a regular inflection is irregularized. In addition, overregularization decreases as the size of the data set increases. An expanding vocabulary is taken to simulate the increasing linguistic knowledge that comes with more advanced age. These two pieces of evidence are the crucial arguments that Clahsen et al. (2002) present in favor of a dual-route model of morphology, nevertheless, they are attainable in a single-route model as well.

4.0. Nonce word experiment. The goal of Brovotto and Ullman (2005) was to investigate how the two different components of the dual-route model of morphology function in Spanish verbal inflection. They follow the model of Pinker (1999) and Pinker and Prince (1994) quite closely. Accordingly, one route involves associative memory procedures in which inflection is based on similarity to stored lexical items. This mechanism is expected to come into play for irregularly inflected words. Symbolic procedures, on the other hand, call upon rules to concatenate affixes. These procedures do not depend upon similarity to stored words but on abstract grammatical or symbolic features such as conjugational class. Such rules are thought to account for regular inflection.

4.1. Experiment on the imperfect inflection. In this experiment, the authors presented nonce word infinitives in a paragraph and elicited the first person singular imperfect inflection of those infinitives. Test items such as the following were used:

Crosar. A Juan le gusta *crosar* las copas.

Cuando era joven, yo también _____ las copas.

‘Juan likes to *crosar* glasses. When I was young I also _____ glasses.’

Two properties of the nonce words were controlled. The first was whether the infinitive ended

in *-er* or *-ar*, or in other words, its conjugational class. The second is what they call the rime of the infinitive. For *cantar* 'to sing' the rime is *-ant-* and for *lograr* 'to achieve' it would be *-ogr-*. The rime is used as a measure of phonological similarity. Certain rimes are more frequent in verbs of one conjugation while others are more prevalent in the other conjugation. They combined these two factors to create four experimental conditions. Results for each group are given in parentheses.

- a. verbs ending in conjugational class I *-ar* and with common class I rimes (92% *-aba*).
- b. verbs ending in conjugational class II *-er* and with class II rimes (89% *-ía*).
- c. verbs ending in class I *-ar*, but with class II rimes (84% *-aba*).
- d. verbs ending in class II *-er*, but with class I rimes (83% *-ía*).

With the exception of a few verbs (none of which were tested), all imperfect inflections are regular in Spanish. If the words were processed via a symbolic rule of affixation all class I verbs should have been formed by adding *-aba* to the stem, while class II verbs would have been given *-ía*. The outcomes show that this tendency was prevalent, but not categorical. Brovotto and Ullman's statistical analyses revealed that both the conjugational class and the type of rime affected the results, the conjugational class exerting the greatest degree of influence. They also discovered that the effect of the rime type was much stronger for class II. These findings are unexpected in a model in which regular inflection should not depend on similarity (rime type) but only on conjugational class membership and suggest that the dual-route model would need to be modified as far as Spanish is concerned so that associative memory procedures based on similarity are limited mainly to class II verbs. This suggests that the dual-route model may be language specific rather than a universal processing strategy. Nevertheless, the results of the experiment demonstrate that both mechanisms were used for both kinds of verbs.

The principal difficulty with the idea that two different mechanisms are at work is the this. According to the authors, the rime of a nonce verb *esdemar* is *-em-*, which is used to identify members of the mental lexicon that share that particular rime and are therefore

phonologically similar. These associative memory factors influenced the subjects' choice of suffix (*-aba* vs. *-ía*) to a small but significant degree. However, membership in conjugational class I or II is considered to be an abstract, symbolic, or grammatical feature that operates at a completely different level than the rime of the verb. Its influence was much more robust; however, the difficulty with this is that both the rime and the class are clearly marked in the phonological make-up of the infinitive. The rime of *esdemar* is *-em-* while the conjugational class is marked by *-ar*. An *-er* in this same position indicates the verb is class II. Therefore, both the conjugational class marker and the rime are available to be used within associative memory to find what verbs are most similar to the nonce verb and thus how to inflect the verb. The reason the class marker was much more influential than the rime is that only *-ar*, *-er*, and *-ir* may appear in that position. This results in three large gangs with powerful analogical draw: the *-ar* gang all take *-aba*, while the *-er* and *-ir* gangs all take *-ía*.⁷ Gangs composed of rimes such as *-em-* and *-ant-*, on the other hand, are much smaller and less homogenous. For example some verbs with *-em-* take *-ía* and others *-aba* (*temer* > *temía*, *quemar* > *quemaba*). This accounts for the fact that they exert a much less potent analogical force on the inflection of the nonce words.

On the one hand, Brovotto and Ullman recognize that in their experiment a completely regular process of inflection is influenced by phonological similarity, which should not occur according to the dual-route model (Pinker 1991, Pinker and Prince 1994). On the other hand, I argue that the rime and conjugational class are both subsets of the phonology of the nonce words, and as such, both activate the same associative memory factors, but to differing degrees. There is no need to assume an additional mechanism involving symbolic categories; the results lend themselves equally well to explanation within a single-route associative memory-based model.

4.2. Experiment on the present tense inflection. As in the previous experiment, the subjects were presented nonce word infinitives within a paragraph and responded with a first person singular

present tense inflection of those infinitives:

(2) Neler. A mí me gusta *neler* alcancías.

Por eso you siempre _____ alcancías.

'I like to *neler* piggy banks. That's why I always _____ piggy banks.'

Regular inflection would entail affixing *-o* to the stem (*nelo*) while irregular inflection would additionally diphthongize the stem (*nielo*). Test words differed according to their conjugational class (class I *-a-* vs. class II *-e-* and class III *-i-* combined) and according to how frequently the rime occurs in extant regular versus irregular verbs. Irregularization rates for each group are given in parentheses. Responses that demonstrated a stem change other than the irregular diphthong were not considered in their analysis.

- a. verbs ending in conjugational class I *-ar* with regular rimes (6%).
- b. verbs ending in class I *-ar* with irregular rimes (10%).
- c. verbs ending in class II and III *-er/-ir* with regular rimes (15%).
- d. verbs ending in class II and III *-er/-ir* with irregular rimes (43%).

Analyses were performed to determine the extent to which these two factors affected the irregularization rate of the nonce verbs in each category. These show that the subjects' responses were influenced by both the conjugational class and the rime type, although the type of rime affected the class II and III verbs to a much higher degree than class I verbs.

Because this experiment elicited both regular and irregular inflections, it was important to determine if they were affected differently. Any dissociation between the two is considered significant because irregulars are thought to be processed by means of associative memory based on phonological similarity, while regulars receive their inflection based on a symbolic rule of affixation that only refers to abstract, symbolic, grammatical information such as conjugational class and not on phonological similarity. The phonological similarity of the nonce verbs was

determined using two measures of phonological neighborhood. The first counted how many Spanish verbs with the same rime and conjugational class are regular minus how many are irregular. The second counted how many verbs with the same rime are regular minus how many are irregular across all three conjugational classes. Correlations between irregularization rates and these calculations of phonological neighborhoods revealed that phonological similarity played a part in the irregularization of nonce words with irregular rimes, but did not effect the nonce words with regular rimes. This is presented as prima fascia evidence that irregulars are processed via associate memory while regulars depend only on abstract symbolic features such as conjugational class.

4.2.1. Simulation of the present tense study. If conjugational class and phonological similarity are truly separate processes, the results of the nonce experiment should not be replicable in a similarity-based model that treats all of the members of the rime along with the vowel that indicates conjugational class as variables of the same type. To this end, I utilized the analogical algorithm described in Section 2.1.1 to predict the first person present tense form of Brovotto and Ullman's nonce words. The database from which analogs were drawn is the same one described in Section 2.1.2 with two modifications. In order to more closely replicate the neighborhood measures of the nonce study, only the variables for the rime and conjugational class vowel/theme vowel were included. Second, exact matches were allowed otherwise a nonce word such as *maneler* would not find words such as *repeler*, *helar*, or *meter* as possible analogs in the database. The resulting irregularization rates appear in Table 7 where the correlations between the two studies is significant ($r = .954$ (2), $p < .046$).

Table 7. Irregularization rates for present tense nonce words.

	Brovetto and Ullman	Simulation
Class I regular rime	0.06	0
Class I irregular rime	0.10	0.24
Class II/III regular rime	0.15	0.05
Class II/III irregular rime	0.43	0.93

A comparison of the correlations between the neighborhoods similarity calculations and the irregularization rates is quite telling (Table 8). In both the simulation and Brovetto and Ullman's nonce word study no neighborhood effects were registered for test items with regular rimes. However, the effects of both measures of neighborhood similarity are observed for irregular items in the nonce study and in the simulation with the within class neighborhood similarity. No correlation resulted from the simulation and the across class measure of neighborhood similarity. Nevertheless, a clear dissociation between test words with regular and irregular rimes and neighborhood similarity emerges. While this is often presented as evidence that regular and irregular morphology is processed with different mental processes, the fact that the same dissociation can be found in a single-route analogical model suggest that a unitary process is equally plausible.

Table 8. Correlation between neighborhood measures and irregularization rates.

Type of Rime and Neighborhood	Experiment	<i>r</i>	<i>p</i>
Regular rimes	Brovetto and Ullman	0.10	0.52
Neighborhood within classes	Analogical Simulation	-0.08	0.62
Regular rimes	Brovetto and Ullman	0.18	0.27
Neighborhood across classes	Analogical Simulation	0.09	0.59
Irregular rimes	Brovetto and Ullman	0.37	0.02*
Neighborhood within classes	Analogical Simulation	0.31	0.05*

Irregular rimes	Brovetto and Ullman	0.29	0.07*
Neighborhood across classes	Analogical Simulation	0.18	0.26

5. Conclusions. I have reviewed four studies whose goal is to shed light on how Spanish verbal morphology is processed. More specifically all four studies demonstrate a dissociation between regular and irregular inflections which is taken to indicate that two distinct mental mechanisms for inflection must exist. Rodriguez-Fornells et al. (2002) elicited a different pattern of ERPs for regular and irregular inflections. The difficulty with their study lies in the experimental design. It is simply not possible to compare regular and irregular items in which orthographic similarity is equated and semantic and morphological relatedness is controlled for. For this reason their findings must be considered inconclusive.

The remaining three studies are well-designed and carried out. Although the authors are puzzled by some of their findings that do not support the dual-route model, each of them convincingly demonstrates some processing differences between regular and irregular verbal forms. Nevertheless, the simulations of the same data described above indicate that a single-route model of analogy is also able to produce the same sort of dissociation between regular and irregular inflections. However, this does not indicate the superiority of the single-route model over the dual-route model, only that the results of the cited studies do not provide evidence in favor of the necessity of two mental processes rather than a unitary one to account for the data.

Notes

1. Royal Skousen, and Mark Allen need to be credited for their valuable input on this paper. I am also grateful to Bridgit Yaden for providing me with a list of her test items and to Claudia Brovetto who provided details about her experiments that are not described in the published article and without which I would not have been able to perform the simulation.
2. The possibility of non proportional analogy in AM is discussed by Eddington (2004: 75) and Skousen (2002: 42-43).
3. This comprised any verb with a lemma frequency of 21 or greater.
4. The other relationships are of the type seen in *divertir* > *divierto*, *contar* > *cuento*, *decir* > *digo*, *hacer* > *hago*, *seguir* > *sigo*, *traer* > *traigo*, *construir* > *construyo*, *haber* > *he*, *ir* > *voy*, *oír* > *oigo*, *saber* > *sé*, *caber* > *quepo*, *ver* > *veo*, *ser* > *soy*.
5. LEXESP contains a great many errors. Rather than use their computer generated frequency counts, I calculated my own based on their raw database. There were discrepancies were due to mistagging. For instance, I had to sum the frequencies of some reflexive verbs and non reflexives because these were counted as belonging to different lemmas.
6. Unfortunately, the databases by Díaz, Shiro, and Posada that Clahsen et al. also consulted were not available on the CHILDES website at the time I performed the simulations.
7. A handful of class II and II verbs (e.g. *ser*, *ver*, *ir*) also undergo stem changes as well.

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