A computational approach to resolving certain issues in Spanish stress placement[1]

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Abstract

Previous research into Spanish stress assignment suggests that accentuation involves learning and storing individual word tokens along with their inherent stress patterns, and analogizing on stored words when the need arises to determine the stress pattern of an unknown or unavailable word. Exactly what variables are most relevant to stress assignment has been hotly debated. In the present study, a number of analogical simulations were carried out to determine whether elements of the CV tier, syllable weight, phonemic representation, or a combination of these, best accounts for accentuation in Spanish.

Syllable weight and CV representation alone were able to predict the stress of 4970 extant Spanish words to a significant degree, especially if some phonemic information was included. However, the stress pattern of the words was best accounted for when all the phonemes in the final three syllables of each word were considered. This may be explained by the fact that the more abstract CV and syllable weight representations are derived from the phonemic composition of a word.

In contrast to these results, a separate nonce word experiment demonstrated that the phonemic make-up of the words alone did not result in the highest correlations between the predictions made by the analogical model and the test subjects' intuitions regarding the stress placement on the nonce words. The highest correlation was found when the variables considered were the syllable weight of each of the final three syllables and a specification each of the word's final phoneme. CV elements were also highly correlated with the subjects' preferences. These findings suggest that the role of abstract entities such as CV elements and syllable weight should not be discounted, but warrant further investigation.

1. Introduction Spanish stress placement has been the topic of numerous linguistic analyses, especially within the generative tradition and its offshoots (e.g. Bailey 1995; Den Os and Kager 1986; Harris 1983, 1989, 1995; Hooper and Terrell 1976; Lipski 1997; Roca 1988, 1990, 1991, 1997; Saltarelli 1997; Whitley 1976). The framework within which these studies are couched, generally assumes that such accounts are relevant to the linguistic competence of an ideal speaker-hearer, and that the formal representations utilized (i.e. rules, derivations, constraints, constraint rankings) do not necessarily relate to the actual processing of language (Bradley 1980: 38; Chomsky and Halle 1968: 117; Kager 1999: 26; Kiparsky 1975: 198; 1982: 34).[2] In other words, most formal models do not purport to relate to linguistic performance but only competence, although it is not uncommon for them to be described in terms that appear performance oriented.

The present study is concerned with performance aspects of Spanish stress assignment, or in other words, models of how stress may be represented and processed in the course of language comprehension and production. I submit that language processing is largely a matter of learning and storing individual word tokens along with their inherent stress patterns. This view is consistent with empirical evidence that supports massive lexical storage of words, as well as word combinations and whole sentences (Alegre and Gordon 1999; Baayen, Dijkstra, and Schreuder 1997; Bod 1998; Butterworth 1983; Bybee 1995, 1998, 2002; Manelis and Tharp 1977; Pawley and Syder 1983; Sereno and Jongman 1997). This sort of lexicon appears to include, not only unpredictable information, but also a great deal of redundant data as well, including detailed phonetic information about individual word tokens (Brown and McNeill 1966; Bybee 1994, 2000, 2002; Frisch 1996, Goldinger 1996, 1997; Palmeri, Goldinger and Pisoni

1993; Pisoni 1997). Acquisition, in this view, entails storing and categorizing linguistic experience, rather than subconsciously gleaning generalizations from linguistic input in the form of rules, parameters, or constraints (Ellis 2002). Therefore, linguistic cognition is largely a matter of lexical access, analogy, and recombination of previous linguistic experiences which have been stored.

A number of extant models assume that language processing involves storage and analogy to stored entities (Daelemans, Zavrel, van der Sloot, and van den Bosch 2001; Nosofsky 1988, 1990; Pierrehumbert 2001; Skousen 1989, 1992). Such models have been applied to investigate a wide variety of linguistic phenomena such as word recognition (Goldinger 1996), Arabic and German plural formation (Nakisa, Plunkett, and Hahn 2000), linking elements in Dutch noun compounds (Krott, Schreuder, and Baayen 2002), phonological alternations in Turkish stems (Rytting 2000), Dutch stress assignment (Gillis, Daelemans, Durieux, and van den Bosch 1993), Italian verb conjugations (Eddington 2002b), and phonotactic knowledge in Arabic and English (Frisch, Large, Zawaydeh, and Pisoni 2001). The present study is a continuation of an earlier investigation into Spanish stress placement (Eddington 2000) and will be structured as follows. I begin by reviewing the findings of the previous study. In the remainder of the paper, I describe a number of simulations which were designed to determine what factors are most relevant to Spanish accentuation. Of particular interest is the role of syllable weight and the CV tier in determining word stress.

2. Previous computational findings The database used in Eddington (2000) consisted of the 4970 most frequent Spanish words extracted from a frequency dictionary. These included inflected

forms, uninflected forms, and verb plus clitic combinations. Each word was converted into a series of variables that included the phonemes of the three final syllables, as well variables indicating the person and tense of the verbal forms. Each entry was also marked to indicate which syllable was stressed. This database served as an approximation of the contents of the mental lexicon. The simulation essentially consisted of removing each word from the database, and determining its stress placement based on analogy to the stress placement of similar words in the database. The algorithm used to calculate similarities and determine stress was Analogical Modeling of Language (Skousen 1989, 1992, 1995).

The simulation was highly successful and correctly predicted stress in 94% of the cases. This demonstrates the predictive power that an explicit algorithm of analogy has in modeling linguistic phenomena. The analysis of the errors produced during the simulation is also telling because 80% of them involved regularizing irregular stress.[3] This is reminiscent of Face's (2000) nonce word study in which 64% of the errors produced by the subjects involved regularization. In other words, an analogical model of accentuation is able to recognize regular stress patterns without relying on a global generalization about the data in the form of a rule or constraint. One interesting finding is that correct assignment of words stressed on the antepenultimate syllable reached 40%. While this may not appear particularly impressive at first glance, it is important to note that this was achieved without incorporating any diacritic marking into the antepenultimately stressed words. This contrasts with the formal accounts of Spanish stress placement cited in the introduction, all of which require some sort of diacritic mark on antepenultimately stressed words in order to correctly assign stress to them.

The validity of the analogical approach is supported by other empirical data as well. In her study of stress acquisition, Hochberg (1988) elicited words with different stress patterns from preschoolers. The children performed two tasks. The first was to name various objects shown to them in a picture book. In another task, they were asked to repeat nonce words that they heard. The types of errors the children made on both tasks were tabulated. The children made fewer errors on penultimate stress followed by final stress, while the highest error rates occurred on antepenultimately stressed words. This exact hierarchy of difficulty was evident in the errors produced by the analogical simulation as well.

Hochberg also noticed that the error rate on regularly stressed words remained virtually unchanged for all of her subjects ages three to five. However, the five-year-olds produced significantly fewer errors on irregular items than did the four-year-olds. The difference between the mental lexicon of a younger versus and older child is arguably the size of the vocabulary. Therefore, in order to imitate this difference, a simulation was performed with analogs drawn from only the most frequent half of the database items. Nevertheless, stress was predicted for all 4970 original database items. When the error rates of the two simulations are compared, the percentage of errors made on regularly stressed words did not differ significantly. However, significantly fewer errors were made when the entire database was available to analogize on, compared to when only the most frequent half of the database was utilized. This again corresponds quite well with the developmental data presented by Hochberg.

3.0. Simulations In the previous study (Eddington 2000), I hope to have demonstrated that from a performance perspective, accentuation may be considered an analogically governed process. However, a number of questions about the specific factors that are most relevant to stress assignment in Spanish remain unanswered. The simulations presented below are designed to address these questions.

3.1. Database and variables used in the simulations Because the object of the present study is to determine which variables are most relevant to stress placement, the exact variables used differ in each simulation, and are specified below. Nevertheless, each simulation was based on the 4970 most frequent words from a frequency dictionary of Spanish (Alameda and Cuetos 1995). Both the test items and analogs were drawn from this database.

3.2. Analogical algorithms used in the simulations One algorithm utilized is the Tilburg Memory-based Learner (henceforth TiMBL; Daelemans, Zavrel, van der Sloot, and van den Bosch 2001). TiMBL works by taking a test word and determining which items in a database of exemplars are the most similar to it — the word's nearest neighbors. During the training session, the model stores in memory series of variables which represent instances of the words in the database. These words are stored along with their stress pattern. In the case that the same word is encountered more than once in the database, a count is kept of how often each word is associated with a given behavior. During the testing phase, when a test word is presented, the model searches for it in the database and applies the behavior that it has been assigned in the majority of cases. If the word is not found in the database, a similarity algorithm is used to find the most similar words in the database. The behavior of the nearest neighbor(s) is then applied to the test word in question. If two or more words are equidistant from the word in question, the most frequent behavior of the tied database items is applied to the test word in question.

The other memory-based algorithm used is Analogical Modeling of Language (hereafter AM; Skousen 1989, 1992). AM also conducts a search of a database looking for words similar to the test word. In AM, however, the search begins with the database entries most similar to the test word whose behavior is being predicted, and then extends to less similar entries. The members of the database are grouped into sets called subcontexts whose members share similarities with the test word. For example, in determining the stress of the word *comen* 'they eat', one subcontext would be comprised of all database items ending in /n/, another would contain those that end in /en/, another all items whose final syllable begins with /m/, another all items whose final syllable begins with /m/ and ends in /n/, and so forth until all possible combinations of variables are explored.

One derived property that results from dividing the database in this manner is that of proximity. Database items that share more features with *comen* will appear in more subcontexts and will therefore have a higher likelihood of influencing the probability that *comen* will be assigned a certain stress. Gang effects also fall out of this architecture. Groups of similar words that display the same behavior will increase their chances of influencing the test word.

Heterogeneity is another important property of AM. It suggests that a word in the database cannot be chosen as an analog if there are intervening words, with a different behavior that are more similar to the test word. Calculating heterogeneity involves determining disagreements. A disagreement occurs when one member of a subcontext has a behavior that is different from the behavior of another member of the same subcontext. For example, *andén* 'platform', and *viven* 'they live', share a final /en/, but are stressed on different syllables. As a result, when they appear in the same subcontext, they disagree in terms of their stress pattern.

Under certain conditions, the analogical influence of the members of a subcontext that contains disagreements will be reduced or eliminated. AM's output is given in terms of the statistical probability that one or more behaviors will apply to the test word.

3.3. Simulations 1 and 2: Syllable weights In Simulations 1 and 2, as in all other simulations presented below (except where noted otherwise), TiMBL was used to predict stress placement. However, TiMBL allows a number of different measures of similarity to be calculated. In the present simulations, the similarity between the values of each variable is precalculated and used to adjust the search for nearest neighbors accordingly (modified value difference metric). This precalculation permits certain values of a variable to be regarded as more similar to each other than other values. TiMBL may also calculate the outcome on the basis of one or several nearest neighbors, but in the present simulations, calculations were based on only one nearest neighbor. In a previous study (Eddington 2002a), these settings not only proved to be the most efficient, but also mirrored those produced by the AM algorithm as well.

The purpose of Simulation 1 is to test the strongest hypothesis about syllable weight, which is that the actual phonemic content of the words themselves is not important, only whether the syllables that comprise them are open or closed.[4] This sort of abstraction may be modeled by converting the final three syllables of all of the database items into three variables. The variables simply encode whether each of the three final syllables are open or closed. In the case of monosyllabic and bisyllabic words, another variable value of ‘non-existent’ was allowed for the antepenultimate and/or the penultimate syllable. For example, *comprenden* ‘they understand’, and *reloj* ‘watch’ appeared as:

(1) *Comprenden*: Penultimate stress, closed antepenultimate, closed penultimate, closed final

Reloj: Final stress, non-existent antepenultimate, open penultimate, closed final

++Insert Table 1 here++

In the simulation, each database item was removed one at a time, while the remaining items served as the training set from which analogs were drawn, and the stress placement of the test word was determined. The accentuation of each of the 4970 items was calculated in this manner. The second column of Table 1 indicates that syllable weights alone allow penultimate stress to be predicted with a high degree of accuracy. However, no antepenultimately stressed words were correctly stressed, and only 16.9% of the words with final stress were predicted. The overall success rate reached 72.6%. One reason that weights alone are poor predictors of stress may be because not all consonants that close a final syllable produce equal effects. For example, only 2% of the database items ending in /s/ are stressed on the final syllable. In contrast, 81.4% of the words ending in a consonant other than /s/ have final stress.

In order to address this issue, Simulation 2 was run. Simulation 2 differs from Simulation 1 in that the database contained an additional variable indicating which consonant, if any, appears in the coda of the final syllable. In column 3 of Table 1, it can be seen that the specific consonant that closes the final syllable is extremely important to the prediction of final stress in that it significantly raises the success rate from 16.9% to 80.4% ($\chi^2(1)=8235.88$, $p < .0005$). However, the improvement in penultimately stressed words (from 95.5% to 96.3%) is not significant ($\chi^2(1)=0.65$, $p < .42$). This suggests the that addition of this variable is not particularly useful in predicting penultimate stress. In neither simulation is any case of antepenultimate accentuation predicted.

3.4. Simulations 3 and 4: The CV tier In CV phonology (Clements and Keyser 1983), each consonant and vowel is assigned to a consonant or vowel slot on a tier separate from the segmental tier which contains only phonemes. Accentuation is thought to involve access to the CV tier rather than to the phonemic tier. In order to test the utility of assuming a CV tier, the database for Simulation 3 was constructed by converting all consonants and vowels into C or V respectively. The CV variables were ordered so that the onset, nucleus, and rime of each of the final three syllables belonged to the same variable in all words. For example, *comprenden* and *reloj* appeared as:

(2) *Comprenden*: Penultimate stress, C, V, C, CC, V, C, C, V, C

Reloj: Final stress, no onset, no nucleus, no coda C, V, no coda, C, V, C

As in Simulation 1, the CV representation in Simulation 3 is unable to predict any antepenultimately accentuated words, and does a poor job of predicting final stress. Penultimate stress, on the other hand, is correctly predicted to a high degree (Table 1, column 4).

Of course, Simulation 3 suffers from the same difficulty as Simulation 1; it is unfair to consider all word final consonants on equal grounds. In the database used for Simulation 4, therefore, the words' final consonant phoneme, or lack thereof, was included as an additional variable. In this case, the addition of this phonemic information improved the predictions significantly for final stress ($\chi^2(1)=3210.0$, $p < .0005$), as well as for penultimate stress ($\chi^2(1)=11.68$, $p < .0005$), while antepenultimate stress remains completely unpredictable (Table 1).

To summarize thus far, abstractions such as syllable weight and the CV tier by themselves are able to predict stress placement in about three fourths of the cases. However, the addition of some phonetic material improves their predictive ability greatly. This is evidence that specific phonemic information plays an important role in stress placement. In fact, syllable weight and CV elements are both derived from the phonemic structure of the word, while the opposite is not true. Phonemes are the more basic unit, therefore, the apparent influence of syllable weight and the CV tier exert on accentuation may merely be epiphenomenal. That is, the phonemic material itself rather than CV slots or syllable weights, both of which depend on the phonemic representation, are actually the most relevant factors in accentuation. This possibility is addressed in Simulation 5.

3.5. Simulation 5: Phonemic representation For this simulation, each database item was converted into variable vectors which included a specification of what syllable received stress, and a phonemic representation of the final three syllables of each word. For example, *comprenden*, and *reloj* were encoded as,

(3) Penultimate stress, k, o, m, pr, e, n, d, e, n

Final stress, no onset, no nucleus, no coda, rr, e, no coda, l, o, x

Simulation 5 was actually run as a series of nine separate simulations. In the first, the only variable that was included specified what consonant, if any, appeared in the coda of the final syllable. The database for the second simulation included the phonemes in the nucleus and coda of the final syllable. The third included all elements of the final syllable, and so on. In this way, each step added consecutively more and more phonemic information about the words in the database, starting from the end of each word and working toward the left. Therefore, the ninth included all of the phonemes in the final three syllables of each word.

++Insert Figure 1 here++

As Figure 1 demonstrates, phonemic material besides the final phoneme is important to Spanish accentuation (see also Aske 1990). Penultimate stress is predicted at high levels of accuracy no matter how much or how little information is provided. This corroborates the notion that penultimate stress is the unmarked or default case in Spanish (e.g. Face 2000). The prediction of final stress shows improvement as more phonemic material is made available. However, antepenultimate stress appears to rely very little on elements of the final syllable, and depends more on the contents of the penultimate and antepenultimate syllables.

The total success rate obtained in Simulation 5, when the phonemic content of all three syllables was considered reaches 91.0%. This increase, although numerically superior is not statistically significant from the success rate of 88.9% achieved in Simulation 4 in which information from the CV tier and the final phoneme were considered ($\chi^2(1)=1.34$, $p < .25$), nor is it significantly different from the 87.4% success rate attained when syllable weights and the final phoneme were used as variables ($\chi^2(1)=2.53$, $p < .11$). Nevertheless, the purely phonemic representation did correctly predict the stress of 71.1% of the antepenultimately accentuated words, while the other sets of variables tested were unable to predict a single antepenultimate stress. This alone argues strongly that accentuation is phoneme-based rather than based on CV elements or syllable weights, both of which are dependent on the phonemic content anyway.

This finding is reminiscent of a series of connectionist simulations designed to predict the German definite article given information about the following word (MacWhinney, Leinbach, Taraban, and McDonald 1989). In two simulations, the variables specified the presence or absence of 38 carefully chosen pieces of morphological, semantic, and phonological information about the word the article agrees with (e.g. whether the word contains a specific morpheme, or a phoneme in a certain position). Each of these cues is thought to govern definite article usage in German. In another simulation, the only variables were the strings of phonemes that comprise the word. That is, no effort was made to include only those elements thought relevant to the task and separate them from those thought to be irrelevant. Nevertheless, the latter simulation yielded better results than the former ones that carefully eliminated cues that were considered unimportant to the task of definite article assignment. The outcome of the study of German definite articles, when coupled with the Spanish accentuation evidence suggests that speakers do not utilize the sort of generalizations and abstractions (i.e. syllable weight, CV tier) that researchers are able to glean from the data. Instead, they appear to make analogies based on surface-apparent traits such as the words' phonological content.

3.6. Simulations 6 and 7: Phonemic representation and weight or CV tier The evidence adduced to this point suggests that syllable weight and the CV tier are simply abstract representations derived from the phonemes that comprise a word, and for this reason may be dispensed with in determining stress placement. However, one possibility that has not been explored is that accentuation does not only consider phonemic make up, but in addition, syllable weights or CV tier elements may also play a part. In order to test this hypothesis, the phonemic variables used in Simulation 5 were augmented to include the open or closed status of each of the final three syllables of each word as in Simulation 1. For example, in Simulation 6 *comprenden*, and *reloj* were encoded as,

(4) Penultimate stress, k, o, m, pr, e, n, d, e, n, closed, closed, closed

Final stress, no onset, no nucleus, no coda, rr, e, no coda, l, o, x, empty, open, closed

In simulation 7, they were encoded with CV variables:

(5) Penultimate stress, k, o, m, pr, e, n, d, e, n, C, V, C, CC, V, C, C ,V, C

Final stress, no onset, no nucleus, no coda, rr, e, no coda, l, o, x, no onset, no nucleus, no coda, C, V, no coda, C, V, C

The success rate achieved with the combination of CV and phonemic variables reached 89.8% which is a statistically equivalent to the 91.0% success rate obtained when only phonemes were considered ($\chi^2(1)=1.58$, $p < .21$). Therefore, adding syllables weights to the phonemic information does not result in more successful predictions either (89.4%; $\chi^2(1)=2.82$, $p < .09$).

3.7. Variable ranking The data presented thus far indicate that stress placement is calculated on the basis of phonemic similarity to existing words, and not to elements of the CV tier or syllable weights. While the purpose of the present paper is to determine what phonological factors determine stress placement, this does not imply that other factors are not relevant. In fact, by adding variables indicating the person and tense of verbal forms to the phonemic variables from Simulation 5, 95.9%[5] of the words are correctly accentuated by the algorithm. TiMBL is also able to calculate how important each variable is to making predictions. As seen below, these morphological variables rank quite high. The most influential variables, in order of descending importance, are:

(6) 1-The consonant in the coda of the final syllable, or lack thereof.

2-The tense of the word if it is a verb.

3-The person of the word if it is a verb.

4-The vowel in the nucleus of the final syllable.[6]

5-The vowel in the nucleus of the penultimate syllable, or lack thereof.

6-The consonant(s) in the coda of the penultimate syllable, or lack thereof.

7-The vowel in the nucleus of the antepenultimate syllable, or lack thereof.

8-The consonant(s) in the onset of the final syllable, or lack thereof.

9-The consonant(s) in the onset of the antepenultimate syllable, or lack thereof.

10-The consonant(s) in the coda of the antepenultimate syllable, or lack thereof.

11-The consonant(s) in the onset of the penultimate syllable, or lack thereof.

The variables specifying the coda consonants of the final and penultimate syllables are among the most influential phonological variables. This lends some support to the hypothesis that syllable weight influences accentuation. However, the vowels in the nuclei of the final and penultimate syllables are also among the most influential phonological variables, yet calculation of syllable weight in Spanish does not involve syllable nuclei.

On another note, it is tempting to conclude from the above ranking that the lowest ranked variables are irrelevant to predicting stress. However, if variables 9, 10 and 11 from (6) are eliminated completely and the simulation run without them the overall success rate drops from 95.9% to 95.3%. While this difference is insignificant, ($\chi^2(1)=0.37$, $p < .54$) it does demonstrate that even the least important variables play a role in assigning stress to some words.

4. Nonce word studies As mentioned previously, one implicit supposition in an analogical analysis of stress assignment is that speakers learn and store words along with their stress pattern. Therefore, an on-line process of stress placement is generally not needed except when novel words are encountered, or in cases in which noise in the system leads to a temporary inability to remember which syllable is stressed. In the simulations discussed to this point, both the test items and the training items were drawn from the same database, which is a common practice in natural language simulations. However, if storage of characteristics such as accentuation is assumed, treating each word in the database as a novel word may be an inappropriate way to model linguistic processing (Ling and Marinov 1993). One way to avoid this potential problem is by utilizing nonce words in place of existing words.

Face (2000, 2002) and Barkanyi (2002) carried out studies in which their subjects' task was to assign stress to nonce words. Barkanyi's subjects were presented orthographic representations of invented words. She found that not every subject assigned final stress to every nonce word ending in a closed syllable, nor did they all assign penultimate stress to every word ending in a vowel. For this reason, she concludes that syllable weight is not an active factor in Spanish stress placement.

In Face (2000), subjects heard recorded nonce words which had been manipulated so that each syllable nucleus was of identical length and intensity. Their task was to determine where they perceived the stress to fall. Face submitted his results to statistical analysis and found that heavy syllables attracted stress. However, in Face (2002), the nonce words were manipulated so that each syllable, not just each syllable nucleus, was of equal length and intensity. Under these conditions, the weight of the final syllable was influential in the subjects' perception of stress placement, but the weight of other the syllables was not.

Waltermire (2002) followed up Face's experiments by presenting the same 60 nonce words from Face (2000) to 41 native Spanish speakers. The speakers were asked to indicate where they felt the words should be stressed. However, in Waltermire's study the words were presented in written rather than auditory form. Nevertheless, the outcome obtained by Waltermire mirrors that of Face quite closely; syllable weight was a significant factor in the subjects' choice of which syllable was accentuated.

Using the nonce words from Face (2002), I performed a study identical to Waltermire's. These 40 nonce words were given in written form to 38 university students studying English, all of whom were natives of Spain.[7] With the exception of three participants who did not give their age, the remaining participants were between the ages of 17 and 26. The results of this study (see

Table 2) were combined with those from Waltermire in order to compare them with a simulation.

++Insert Table 2 here++

The purpose of running analogical simulations with the 100 nonce words was to determine what factors most influence the subjects' choice of stressed syllable by comparing the subjects' responses with those calculated in a number of analogical simulations. To this end, the stress placement of the nonce words devised by Face (2000, 2002) was determined by analogy using the seven different sets of variables:1) CV tier alone, 2) CV tier and final phoneme, 3) syllable weights alone, 4) syllable weights and final phonemes, 5) phonemic representation alone, 6) phonemic representation and syllable weights, 7) phonemic representation and CV elements. All 4970 database items were available as possible analogs for the nonce items. The results of the simulations were correlated with the data from Waltermire's study, and my own study that used Face's 2002 nonce words. These were used to the exclusion of the data gathered by Barkanyi and Face (2000), since the latter do not provide their subjects' responses on each individual test word, making it impossible to calculate correlations between their experimental findings and the analogical simulations.

To this point, all of the simulations reported on were carried out using TiMBL's algorithm. However, I chose to utilize AM for the nonce word simulations. This change of model deserves some justification. The first thing that should be noted is that in a previous study of Spanish stress assignment, AM and TiMBL made predictions that did not differ significantly from each other (Eddington 2002a). However, more importantly, the TiMBL algorithm used in the above simulations calculates the stress placement for a given word in absolute terms. That is, a word is predicted to have either antepenultimate, penultimate, or final stress.[8] AM, on the other hand, predicts the outcome in terms of the probability that one outcome or another will be applied (e.g. *bombilla*: antepenultimate 1%, penultimate 99%, final 0%). This sort of output has the advantage of being interpreted in two different ways. One interpretation, termed 'selection by plurality' (Skousen 1989), involves choosing the outcome with the highest probability (hence, *bombilla* receives penultimate stress). This "winner-take-all" output is the sort calculated by the TiMBL algorithm used in the above simulations, as well as by connectionist networks. With AM's 'random selection', on the other hand, one considers the degree to which two or more outcomes are predicted. This more fine-grained prediction is important when correlating the results of analogical simulations with the results of psycholinguistic experiments which usually entail some degree of variability.

AM's predictions regarding the placement of stress on the two sets of nonce items were based on analogies made on the 4970 database items. Of course, the variables used to encode each word varied in each simulation. These results were correlated with those made by Waltermire's subjects and my own subjects using Face's nonce words (see Table 3).

++Insert Table 3 here++

As is evident in Table 3, the correlations that occur when CV elements and syllable weights are considered alone are greatly improved by adding the final phoneme as a variable. This demonstrates the important role that the word final phoneme plays in accentuation. However, the phonemic information itself is not a particularly good indicator of stress placement. In fact, a better correlation is obtained when syllable weights are added to the phonemic information. The best correlation occurs when the variables considered are syllable weights and the word final phoneme. Taken together, this suggests is that an abstract representation of syllable weight was indeed an influencing factor in stress assignment.

5. Conclusions In a number of analogical simulations, test items as well as analogs were drawn from the database of 4970 items. The results of these simulations indicate that a phonemic representation of words may be what speakers use to determine stress placement. When the CV tier and syllable weights are utilized by themselves much lower success rates are attained. Only when some phonemic information is added to the more abstract CV tier and syllable weight representations are success rates achieved that rival those of the purely phonemic representation. However, syllable weights and CV tier elements are derived directly from the phonemic make up of a given word. As a result, it may be that this close relationship is responsible for the ability of these abstract representations to predict accentuation. That is, any effect of these representations may be merely epiphenomenal.

In one regard, the findings of the nonce word study mirrors the results from Simulations 1-7 quite closely; the success rates for the simulations that utilized CV and syllable weight representations alone are improved if the word-final consonants are also included as variables. However, in contrast to the database simulations, the nonce study does provide evidence that the use of abstract units such as syllable weights and CV tier elements may affect accentuation. The purely phonemic representation achieved a correlation of .648 with the subjects' determination of stress placement on the nonce words. This is much lower than the correlation of .834 that resulted when the CV tier plus the final phoneme served as variables. What is more, the highest correlation (.897) occurred when the variables included the syllable weight of the final three syllables, along with a specification of the words' final phoneme. It is this evidence that suggests that the role of CV tier and syllable weights should not be discounted. It is my hope that further psycholinguistic research will clarify the part that these abstract entities play in Spanish stress assignment.

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1. I am particularly indebted to Timothy Face and Mark Waltermire for allowing me to use the data from their studies.

2. However, Bromberger and Halle (2000: 35) take a realist stance: "Do speakers REALLY retrieve morphemes from their memory, invoke rules, go through all these labours when speaking? We think they do."

3. Irregularly stressed words are those that are stressed on the antepeunultimate syllable, or that have final stress and end in a vowel or *s*, or that have penult stress and end in a consonant other than *s*.

4. The major reason given for assuming that Spanish accentuation is sensitive to syllable weight is that antepenultimate stress is not allowed if the penult syllable is heavy (Harris 1983). Hence, words such as **teléfosno* are considered impossible in Spanish. However, this may be a historical relic since Alvord's (2002) subjects considered words such as **teléfosno* as possible Spanish words.

5. This success rate differs insignificantly from the 94.4% found by Eddington (2000). This is due to two factors. The previous study utilized AM's algorithm and was carried out using 10 fold cross validation. The present study was done with TiML's algorithm using a 'leave-one-out' method.

6. Glides were included in the nucleus slot in these simulations. However, in a separate study, I found that whether they are placed together with the nucleic vowel, or in syllable onsets or codas does not significantly affect the outcome (Eddington 2004).

7. I am indebted to José Antonio Mompeán for administering the surveys.

8. TiMBL does have another algorithm whose output is not deterministic. However, TiMBL's predictions are made based on a small sampling of possible analogs, while AM generally allows a large number of database items to affect the outcome to varying degrees. For this reason, I believe AM's results are more similar to those produced by actual speakers.

Table 1. Success rates using different variables

	Weight Alone	Weight + Final C	CV Alone	CV + Final C	All Phonemes
A	0	0	0	0	71.1
P	95.5	96.3	95.0	98.4	94.2
F	16.9	80.4	36.6	80.0	92.9
T	72.6	87.4	76.6	88.9	91.0

A=Antepenultimate, P=Penultimate, F=Final, T=Total

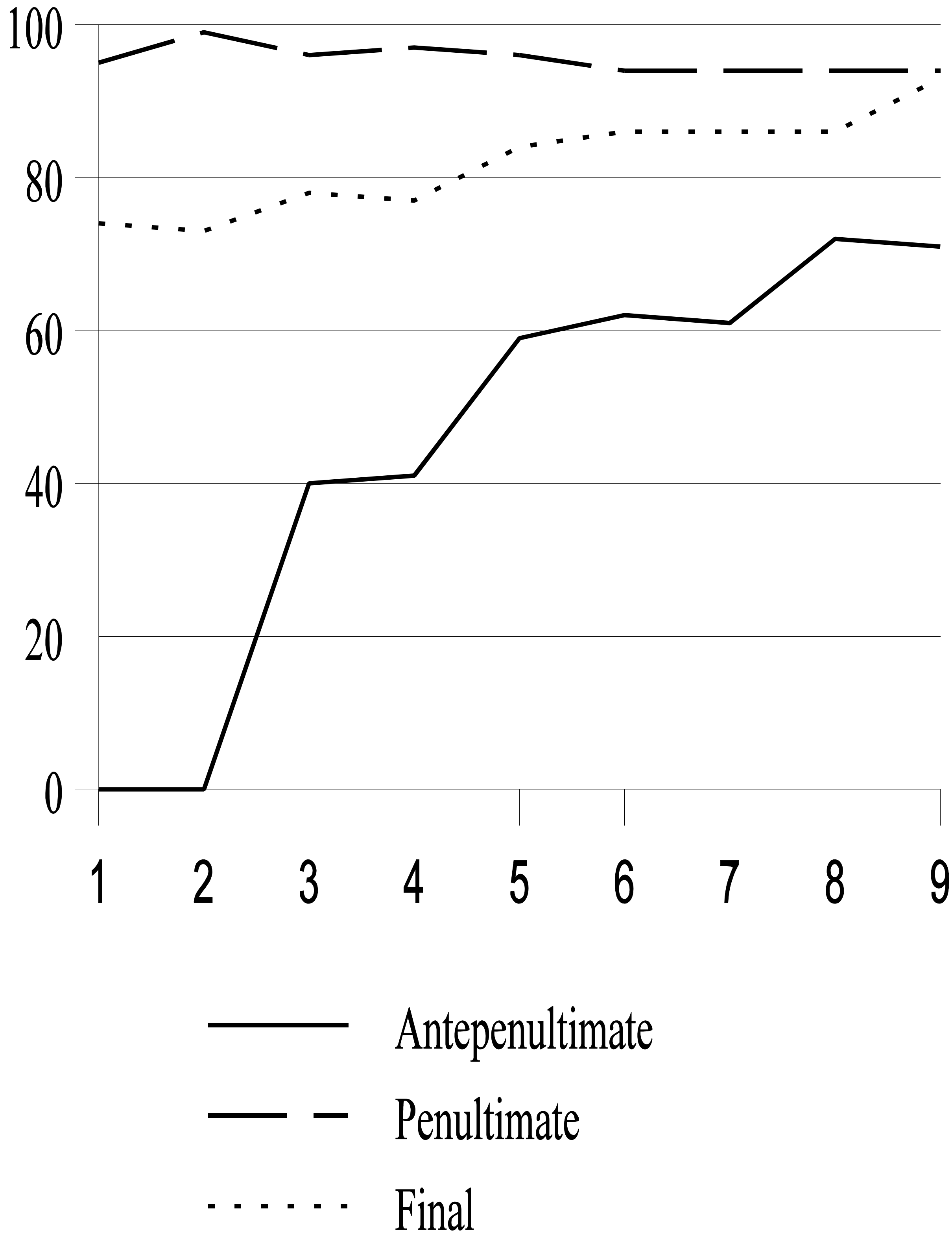
Table 2. Subjects' stress preferences on nonce words

Nonce Word	% A	% P	% F	Nonce Word	% A	% P	% F
bonlandan	5	21	74	badonguel	11	18	71
dombalden	5	29	66	dalandel	13	16	71
landangon	13	0	87	comengon	5	3	92
lanlendol	21	13	66	mobalmal	16	21	63
menlembal	11	26	63	pelandon	5	3	92
bondenda	18	76	7	banenda	3	95	3
bonlamba	8	78	14	gadamba	5	95	0
dantelda	13	87	0	gobolda	9	91	0
malnanga	3	95	3	lomelda	11	86	3
mandolma	5	95	0	molanga	3	97	0
bandemel	19	19	62	dabanel	25	3	72
bondanol	8	13	79	gabadon	3	3	94
galdeman	19	11	69	mananden	11	21	68
gondabel	22	8	70	noguemol	8	39	53
naldelan	11	18	71	polanal	5	11	84
bolnala	16	68	16	beloga	33	61	6
dendana	31	67	3	dagola	89	8	3
galmeda	16	78	5	dalona	19	81	0
ganloda	57	43	0	galema	11	89	0
landola	68	30	3	mamena	8	89	3

Table 3. Correlations to nonce words and success rates with different variable sets

	Correlation with Waltermire	**Success Rates in Simulations**
(1) CV Tier Alone	.503	76.6%
(2) CV Tier Plus Final Phoneme	.834	88.9%
(3) Syllable Weights Alone	.764	72.6%
(4) Syllable Weights Plus Final Phoneme	.897	87.4%
(5) Phonemic Representation	.648	91.0%
(6) Phonemic Representation Plus Syllable Weights	.695	89.4%
(7) Phonemic Representation Plus CV Tier Elements	.649	84.8%

Figure 1. Success rates


100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
Antepenultimate
Penultimate
Final