SPANISH STRESS ASSIGNMENT WITHIN THE ANALOGICAL MODELING OF LANGUAGE

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The advent of nonlinear phonology has resulted in an explosion of studies relating to Spanish syllable structure and stress placement, but most of these studies claim to represent linguistic competence and language structure, not actual mechanisms used by speakers in speech production and comprehension.

The present study is couched within Skousen's ANALOGICAL MODELING OF LANGUAGE (AML) (1989, 1992, 1995). AML attempts to reflect how speakers determine linguistic behaviors such as stress placement. According to AML, when an unfamiliar word needs to be stressed, speakers access their mental lexicon, search for words similar to the word in question, then apply the stress of the word(s) found to the word in question.

The 4,970 most common Spanish words served as the database for the study. AML correctly assigned stress to about 94% of these words. The errors it made closely reflect the pattern of errors made by Spanish-speaking children in a study by Hochberg (1988). Moreover, Aske's nonce word probe (1990) showed that native speakers are sensitive to a certain subpattern in Spanish stress assignment—a subpattern which does not receive representation in rule models. The analogical model of Spanish stress mirrors Aske's findings.*

INTRODUCTION. Within the generative tradition, studies on Spanish stress assignment have been numerous, especially since the advent of nonlinear and autosegmental phonology (e.g. Den Os & Kager 1986, Harris 1983, 1989, 1995, Hooper & Terrell 1976, Lipski 1997, Roca 1988, 1990, 1991, 1997, Saltarelli 1997, and Whitley 1976). The goal of these studies is to provide a concise representation of the linguistic structures involved in Spanish stress placement. Studies such as these usually claim to be relevant to competence—the tacit knowledge that speakers have that allows them to communicate. In this regard, Kiparsky states:

> In phonology, the system of rules and underlying forms might be a representation of the speaker's KNOWLEDGE of the systematic relationships among words in the language; not in any sense a mechanism which is applied whenever words are spoken and heard. (1975:198; see also Chomsky & Halle 1968: 117, Bradley 1980:38)

In other words, the formalisms, rules, and derivations of phonological analyses are not usually thought to mirror psychological mechanisms.

Spanish stress is characterized by commonly occurring patterns that are considered regular, along with numerous exceptions to these patterns. Several proposals on how to account for the generalizations and exceptions have been put forth, and as Farrell (1990:37) notes, studies on the structure of Spanish stress assignment have basically taken one of two approaches:

> The generative approach can be summarized as follows. Either certain patterns are generated or they are not. If the basic parameters are set in too restrictive a manner, a variety of ad hoc mechanisms must be provided to allow for marginal patterns. If the basic parameters are set in such a way as to allow too much freedom, a variety of mechanisms must be provided to restrict the generation of marginal patterns.

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If the formalisms of these analyses do not relate to psychological mechanisms, then the debate about which analysis is most correct is not germane to a psychological theory about how stress assignment may take place.

My study differs quite significantly from previous analyses of linguistic competence as it relates to Spanish stress placement.[1] It is couched within Skousen's ANALOGICAL MODELING OF LANGUAGE (AML) (1989, 1992, 1995). AML is a model that attempts to reflect how speakers determine linguistic behaviors such as stress placement. It is not a complete model of language comprehension and production per se. Rather, it is a model of how memory tokens may be used to predict linguistic behavior. According to AML, when the need arises to stress an unknown word, speakers access their mental lexicon and search for words that are similar to the word in question. They then apply the stress of the word(s) found to the word in question. In this regard, AML has much in common with other exemplar-based models (Aha et al. 1991, Medin & Schaffer 1978, Riesbeck & Schank 1989; see Shanks 1995 for an overview of exemplar models, and Daelemans et al. 1994 for a comparison of AML and Aha et al.).

I will show that for the database in this study analogy correctly assigns stress in about 94% of the instances and is able to thresh out significant subpatterns in Spanish stress placement without resorting to rules or schemas.[2] One of these subpatterns was shown to be significant for native speakers in a study by Aske (1990), though it plays no part in any current rule-based accounts of Spanish stress. Nevertheless, this pattern is successfully accounted for by analogy. Further evidence for analogy is found in a study of stress placement errors. A comparison of the errors made by the analogical model and those made by Spanish-speaking children (Hochberg 1988) demonstrates that analogy produces outcomes consistent with actual language use.

1. ANALOGICAL MODELING OF LANGUAGE. Traditionally, analogy has been used to account for exceptional outcomes. When an outcome does not obey a general rule, a form that is semantically or phonetically similar to the exceptional one is sought; that form is then said to influence the exceptional form in such a way that it does not develop according to the application of the general rules. What makes this sort of analogy suspicious is that it ultimately serves to patch up the inability of rules to derive all forms. In addition, no limits are set either for what forms can serve as analogs or on how similar two forms must be in order for analogy to be invoked.

In contrast to the traditional notion of analogy, AML assumes that all regular as well as irregular forms may be attributed to the analogical influence of other forms. (The reader is referred to Skousen 1989 and 1992 for specific details of the analogical model and the algorithm it employs; this discussion is beyond the scope of the present article.) In AML all forms are attributed to the same mechanism. For this reason it is reminiscent of connectionism. For example, neither model extracts an overall characterization of the data in the form of rules or schemata.

There are, however, significant differences between AML and connectionist models (Chandler 1995, Skousen 1989, 1995). Connectionist networks predict only one outcome for a given context, while AML predicts the probability that one or more outcomes will be chosen. Connectionist networks require extensive training and feedback from a 'teacher', while AML does not entail any sort of training or external teacher. In connectionism, information is stored as patterns of activation in a network of intercon-

[1] AML has been applied to stress placement in Dutch as well (Gillis, Daelemans, and Durieux 1994).

[2] Similar results were found for stress placement in Dutch using an exemplar-based model (Daelemans et al. 1994, Gillis et al. 1994, Gillis et al. 1993).

nected nodes; there is no representation of individual words. In AML, the information is contained in a database of exemplars representing the contents of the mental lexicon. This database may be added to at any time. In contrast, connectionist networks cannot readily accept new data without having to be completely retrained to include the new data.

To understand AML it is useful to compare it to the more familiar rule model. Rule models derive surface forms from underlying forms by the application of rules. AML uses a database of fully specified words, and a mechanism for searching and comparing those words.[3] The behavior of the words most similar to the word in question generally predicts the behavior, although the behavior of less similar words has a small chance of applying as well. The influence of groups of similar words that behave in the same manner is well attested in the psycholinguistic literature (e.g. Stemberger & MacWhinney 1988), and AML provides a specific algorithm for measuring gang effects (Skousen 1989:67–71).

A concrete example should clarify the differences between AML and rule accounts. In Spanish, stem-final /k/ is retained before some suffixes beginning with front vowels, such as the diminutive: /pok + o/ + -ito > /pokito/ 'few, dim'. Other suffixes appear to cause /k/ to become a fricative: Costa Rica + *ense* > /kostarriθense/ 'Costa Rican'. A rule-based approach can account for this by postulating a rule to the effect that k > θ / —] that applies in the strata in which *-ense* is affixed, but not in the strata in which *-ito* is affixed. In AML, in contrast, all affixed and unaffixed words are stored as wholes in a database corresponding to the mental lexicon. When the need arises to determine the phonetic shape of a word, a search of the lexicon is conducted based on the attributes of the word in question (i.e. the given context). The basic algorithm is the following:

> We first search for actual examples of that context and then move outward in contextual space looking for nearby examples. In working outward away from the given context we systematically eliminate variables, thus creating more general contexts called *supracontexts*. (Skousen 1995:217)

The probability that a word is chosen as an analog for the given context is dependent on three derived properties (Skousen 1995:217).

(1) *proximity*: the more similar the example is to the given context, the greater the chances of that example being selected as the analogical model;

(2) *gang effect*: if the example is surrounded by other examples having the same behavior, then the probability of selecting these similarly behaving examples is substantially increased;

(3) *heterogeneity*: an example cannot be selected as the analogical model if there are more similar examples, with different behavior, closer to the given context.

These derived properties are important since they constrain what examples can constitute analogs, and they decide between competing analogs. These are precisely the factors that traditional appeals to analogy lack.

According to AML, all of the words contained in homogenous supracontexts constitute the analogical set. It is the words from this set that can serve as analogical models for a given context. The amount of influence that a word or gang of words will have on the given context is expressed in terms of the probability that the given context will adopt the behavior of one group or another. In the example given above, retention of stem-final /k/ is one behavior, and its replacement by /θ/ is another.

[3] In this study, the phonemic attributes of words are assumed to be the relevant variables. AML, however, can also incorporate other variables, such as sociolinguistic variables. (Skousen 1989:97–100).

The probability that a given context will be assigned the behavior of another word is based on the degree of similarity between the given context and the word. Each member of a group of words with similar characteristics may also affect the behavior of the given context.[4] However, the members of the group affect the given context individually. No global representation of the group's collective behavior is extracted from the data, although behavior may result that appears rule- or schema-based.

Once the analogical set is determined, there are two ways in which its contents can influence the behavior of the given context (Skousen 1989:82). The first is that a word could be randomly selected from among those in the analogical set, and the behavior of that word applied to that of the given context. The other possibility would be to determine which behavior is most frequent among the words in the set, and assign that behavior to the given context. In dealing with probabilistic data, people appear to take advantage of both of these methods (Messick & Solley 1957). The latter method is assumed in the current study.

Returning to the example from Spanish, AML can predict that for any given context, /k/ will be retained before certain suffixes and replaced by /θ/ before others. This prediction is based on the simple fact that, in the words of the database, /k/ appears before some suffixes and /θ/ before others. Thus, the generalization that exists among the words of the database is applied to the given context. If we were interested in knowing what would happen to the /k/ of *loco* 'crazy' in its diminutive form, and the analog chosen from the set of homogenous supracontexts were *poco*, then the behavior of *poco* > *po/k/ito* would be extended analogically to produce *lo/k/ito*, instead of *lo/θ/ito* from *loco*.

The proposal that stored exemplars of past experience determine language use may appear counterintuitive to many. Surely, a global characterization of linguistic data in the form of a rule, schema, or prototype would be more plausible given the constraints on memory. Nevertheless, there is evidence that behavior may be based on stored exemplars (Chandler 1995, Hintzman 1986, 1988, Hintzman & Ludlam 1980, Medin & Schaffer 1978, Nosofsky 1988). In addition, performing rapid searches of memory for stored exemplars is not unfeasible. Robinson (1995) demonstrates how indexing in the form of database inversion may play a role in such searches.

Many current models of human cognition assume that the brain processes information in a massively parallel manner (Marslen-Wilson & Welsh 1978, Seidenberg & McClelland 1989, Stemberger 1985, 1994; see Kirchner 1999 for a discussion of how exemplars may figure into such models). A lexicon as envisioned by Bybee (1985, 1988), in which phonetically and semantically similar items are interconnected, would greatly enhance searching and processing speed. In an interactive activation model, hearing, seeing or saying the word *fat*, for example, partially activates hundreds of different words or parts of words: words that begin with *f*, or that have three phonemes, or that are related to obesity, or that rhyme with *fat*, and so on. In other words, all of the attributes of a given context partially activate all the words in the lexicon that have an attribute in common. It is not necessary to inspect each and every word in the lexicon, only those that have been most highly activated as a result of their similarity to the given context.

[4] Prasada and Pinker (1993) provide evidence that gang effects disappear where type frequency is high, as in regular English past tense forms. In their nonce word study, no gang effects were found for regular items. The connectionist simulation of the same items, though, erroneously demonstrated gang effects. In contrast to the connectionist outcome, AML produces outcomes consistent with the nonce word study (Eddington 2000).

By means of such parallel processing and interactive activation, analogical sets could theoretically be constructed and evaluated at the speed required by comprehension and production.

2. STRESS PLACEMENT IN SPANISH. Stress may fall on any of the last three syllables of a Spanish word. In general, penult stress on vowel-final words is the norm (e.g. *tiéne* 's/he has'), while consonant-final words with final stress are considered regular (e.g. *mantél* 'table cloth'). Antepenult stress is always regarded as irregular (e.g. *crédulo* 'gullible') since it runs counter to the first two more general tendencies. Preantepenult stress is rare, and occurs only when certain verbal forms are followed by two clitic pronouns (e.g. *guardándoselos* 'saving them for him/her').

The generalization that vowel final words are normally penult stressed, and consonant-final words are normally final stressed is complicated somewhat when word-final *-s* is considered. Hooper and Terrell (1976) observe that in nonverbal morphology, when *-s* functions as the plural marker, stress is normally penult not final. The same also holds true in verbal morphology when *-s* indicates second person singular.

WORD ENDING	FINAL STRESS	PENULT STRESS	ANTEPENULT STRESS
Vowel	178	2494	178
Consonant	798	1085	96
/s/	20	909	94
Consonant (except /s/)	778	176	2

TABLE 1. Stress placement in most frequent Spanish words.

The fact that penult stress is the norm in words ending in *-s* is illustrated in Table 1. The data come from the 4,829 most frequent polysyllabic words in the Alameda and Cuetos frequency dictionary (1995). That penult stress is the norm for vowel-final words is clearly demonstrated, but consonant-final words are almost as likely to be stressed on the penult as on the final syllable. That is, of course, until final *-s* words are removed, since they pattern more closely with vowel-final words. In short, penult stress is viewed as the norm for words ending in *-s* or a vowel, while final stress is considered regular for words ending in all consonants except *s*.

It is important to note that Spanish stress is contrastive: *sabána* 'savannah', *sábana* 'sheet'. This is especially evident in verbal forms: *encontrára* 's/he found, imp. subj.', *encontrará* 's/he will find'; *búsco* 'I search', *buscó* 's/he sought'. It is for this reason that many studies of Spanish stress consider the effects of morphology as well as those of phonology. Some studies even suggest that verbal and nonverbal stress assignment are governed by different rules (e.g. Roca 1988), while others strive to achieve a unified analysis (e.g. Harris 1989). I will return to this issue in §4.

3. THE DATABASE.

3.1. ITEMS INCLUDED IN THE DATABASE. To test stress placement within AML, it was necessary to construct a database of Spanish words that would serve as the rough equivalent of a Spanish speaker's mental lexicon. Of course, the question of whether regular polymorphemic words have individual representation in the mental lexicon is a hotly debated issue. Pinker and his colleagues have adduced evidence that these words have no individual entries, but are derived online (Jaeger et al. 1996, Pinker 1991, Pinker & Prince 1994, Prasada & Pinker 1993). If this is the case, such words could not exert analogical influence as AML would require.

Other evidence, however, suggests that all, or at least the most frequent morphologically complex words are stored as wholes (Alegre & Gordon 1999, Baayen et al. 1997a, Butterworth 1983, Bybee 1995, Manelis & Tharp 1977, Sereno & Jongman 1997). Even Pinker and Prince have hedged their bets somewhat and acknowledged this possibility (1994:331). Furthermore, Chandler (1993), Chandler and Skousen (1997), and Seidenberg and Hoeffner (1998) have demonstrated that the data cited in support of Pinker's model of language may be reinterpreted to support a ruleless model as well. Perhaps the best way to reconcile the apparently conflicting evidence is to assume a lexicon in which at least the most frequently occurring morphologically complex words have individual representation, but are stored or organized in such a way that their morphological relationships are transparent (Bybee 1985, 1988, Feldman & Fowler 1987, Katz et al. 1991). Of course, most of the evidence in favor of massive storage of morphologically complex words comes from languages with simple to moderately complex morphological systems. Future studies will need to focus on the role of storage in highly agglutinating languages such as Turkish.

Another issue to be resolved is how large a lexical database needs to be assumed in an analogical analysis. The answer depends in part on the goal of the analysis. If one's aim is to correctly predict the linguistic behavior of the largest number of instances, larger databases are more efficient. For example, the work by Gillis et al. 1992 on Dutch stress assignment indicates that more correct predictions are made as the size of the database increases. And Baayen and his colleagues (Baayen et al. 1997b, Bertram et al. 1999, de Jong et al. 1999, Schreuder & Baayen 1997) found that one would have to consider a database large enough to include even the least frequently occurring words in order to account for subjective frequency ratings and reaction times to visually presented simplex words. But extensive databases are not required in an analysis designed to model language usage. For instance, language acquisition phenomena, error prediction, and historical shifts may be modeled using databases consisting of only several hundred instances (Derwing & Skousen 1994, Skousen 1989).

I opted for a medium-sized database, partly because of the processing restrictions of the computer program used, which allowed only about five thousand instances.[5] The 4,970 most frequent words in the Alameda and Cuetos frequency dictionary were chosen as the database. This includes words with a frequency of 6.6 per million or more. The resulting database consisted of base forms, inflectional variants of base forms, and verb plus clitic pronoun combinations.

The most frequent words were chosen, since experimentation has shown that high-frequency words are accessed more rapidly than low-frequency words (e.g. Allen et al. 1992, Scarborough et al. 1977), and are less subject to error (e.g. MacKay 1982). This suggests that frequent forms are more readily available, and therefore, more likely to be selected as analogs.

3.2. Variables included in the database. The next issue was selecting the variables to use in encoding the 4,970 words. Skousen (1989) and Derwing and Skousen (1994) note that variable selection is one of the major challenges with AML. Skousen suggests some guidelines (1989:51–53). Whenever possible, enough variables should be used so that each instance is distinct from every other. One should also use the variables closest to the variable whose behavior is being predicted. By encoding the phonemic content and syllable structure of the final three syllables these guidelines were largely

[5] I am most grateful to Gert Durieux of the University of Antwerp for allowing me to use his version of Skousen's AML program to undertake this study. His version greatly increases the number of variables and instances in the database that may be used.

followed. Since none of the entries contained preantepenult stress, it was not necessary to encode more than the final three syllables.

The process of selecting variables in an AML analysis is not a matter of predetermining which variables are most important to the task at hand. It is in fact desirable to include many variables that may seem irrelevant at the outset. For example, the most important variable in determining whether the indefinite article *a* or *an* will precede a given English noun or adjective is whether the word begins with a vowel or consonant. If this is the only variable in the analysis, the correct article will be always be chosen. However, if other seemingly irrelevant variables are included—the phonemic make up of the noun following the article, and the word preceding the article—AML begins to predict leakage toward *a* (Skousen 1989). That is, it correctly predicts that errors always involve the use of *a* in place of *an* (e.g. *a apple*), not vice versa (e.g. *an chair*).

The need to include variables that may seem unimportant is further evidenced in Skousen's simulation with a group of Finnish past tense forms. For most of these verbs, the choice of the past tense morpheme appears to be dependent on what the final two phonemes of the stem are, or if the vowel of the verb stem is *a*. However, *sorta-* 'to oppress' appears to be an exceptional case. It does not become *sorsi* as a rule-based analysis would predict; instead, it becomes *sorti*. Nevertheless, AML correctly predicts this outcome, but the prediction is made on the basis of the *o* in the stem, which *sorta-* has in common with a group of other verbal stems, each of which has a past tense form ending in *-ti*. A stem-internal *o* may be an irrelevant variable for the majority of these verbs, but not for *sorta-*. This would not have become evident if only the variables that appeared most relevant were included in the analysis. This suggests that speakers do not make a global determination of which variables are relevant in advance, as rules imply. Instead, all variables take part in the analogical search, and the crucial variables can only be determined indirectly after the analogical set is constructed and inspected.

Returning to the issue of variable selection in Spanish, one could argue that the most relevant variable for stress assignment is a word's final phoneme, or whether the penult syllable is closed or open. Nevertheless, all of the phonemes in the final three syllables were included. Given the contrastive nature of stress, especially in verbal forms, it was also necessary to include some variables that could distinguish between phonemically equivalent forms. Therefore, variables indicating the person and the tense form of each verb were included. These variables also served to distinguish verbs from nonverbs. Unfortunately, the entries in the Alameda and Cuetos dictionary are not tagged for part of speech,[6] and I was obliged to assign the words verbal or nonverbal status by hand. In the majority of cases, the verbal status of the entries was readily apparent. In those few cases where a word could be either a verb or a nonverb, (e.g. *encuentro* 'encounter', or 'I find'), I assigned it what seemed to me to be the most common use of the word. For *encuentro* the meaning 'I find' seemed to be the most common use of the word. In four cases, one meaning did not seem to be more common than another, and the assignment was made randomly.

Allowing category-ambiguous words such as *encuentro* into the database could be viewed as problematic. It may be that neither *encuentro* as a verb nor *encuentro* as a nonverb is frequent enough by itself (i.e. 6.6 words per million or above) to merit inclusion in the database. Yet, because of their combined frequency, such words are

[6] The frequency dictionary by Juilland and Chang-Rodríguez (1964) is tagged for part of speech, but does not include frequency information on all of the tokens that appeared in their database. In contrast, Alameda and Cuetos (1995) list the frequencies of all tokens.

included either as a verb or a nonverb. This means, in essence, that the database may contain several items with a frequency below 6.6 words per million.

In one respect, the inclusion of a few lower-frequency words in the database is not a critical problem. Since the database cannot contain all possible Spanish words, it was necessary to limit the size of this artificial mental lexicon in some principled way. This in no way implies that lower frequency items are irrelevant to the task at hand, only that frequency was chosen as the limiting factor. In reality, the only problem with including these category-ambiguous words is their arbitrary assignment as either nonverbs or verbs. However, of the thirteen variables used to encode *encuentro* as a verb and as a nonverb (see below), the nine variables that indicate the phonemic content of each syllable are identical in both forms. In other words, the word's phonological structure is frequent enough for inclusion, but not its verbal or nonverbal status.

In addition to the above mentioned variables, I also experimented with various combinations of other morphological variables. I was particularly interested in finding a way to allow vowel-final preterit forms to be assigned final stress. The best results were obtained when verbal forms included three variables indicating the tense form of the verb, instead of one. Repeating a variable more than once is the only way to weight one variable heavier than another. This implies that the tense form of the verb is considered three times more important that any single onset, nucleus or coda.

This sort of variable weighting is, admittedly, ad hoc and somewhat unorthodox for an AML analysis, but nevertheless, it produces the desired outcome. When the members of the database were removed one at a time and AML's algorithm used to search for analogs from the remaining items in the database, the error rate for polysyllabic preterit forms was 32% (of 156) if the tense variable was included only once. The rate decreased to 15% when the variable was included three times, but including it more than three times did not result in any further decrease in the error rate. In essence, 27 fewer errors occur on preterit verbs with final stress when this variable is weighted, while none of the rest of the items in the database are affected. For this reason, I left these duplicate variables in the analysis. The reader is invited to incorporate an additional 27 errors into the ensuing analysis if this weighting of variables is too ad hoc for his or her taste.

In sum, the encoding of each word consists of 13 variables (see Table 2).

		Variables												
WORD	STRESS	13	12	11	10	9	8	7	6	5	4	3	2	1
personal	Final	–	–	–	0	p	e	r	s	o	–	n	a	l
hablaron	Penult	6	pt	pt	pt	–	a	–	bl	a	–	r	o	n

Note: 6 indicates third person plural; pt indicates preterit tense. – indicates that a variable does not apply.

Variables:

1. The coda of the word's final syllable, if there is one.
2. The nucleus of the word's final syllable.
3. The onset of the word's final syllable, if there is one.
4. The coda of the penult syllable, if there is one.
5. The nucleus of the word's penult syllable, or 0 if the word is monosyllabic.
6. The onset of the penult syllable, if there is one.
7. The coda of the antepenult syllable, if there is one.
8. The nucleus of the antepenult syllable, or 0 if the word is bisyllabic or monosyllabic.
9. The onset of the antepenult syllable, if there is one.
10. Tense, or 0 if the item is not a verb.
11. Tense, if the item is a verb.
12. Tense, if the item is a verb.
13. The person the verb is conjugated for, if the item is a verb.

TABLE 2. Variables used to encode words in database.

4. ANALOGICAL CONSISTENCY. As noted, AML assumes that all known words are stored in the mental lexicon with their inherent stress. Therefore, if AML is asked to assign stress to a known word, the probability that the correct stress will be assigned is 100 percent. But if the word is novel or memory conditions are imperfect, stress placement is determined on the basis of the neighbors of the word in question.

Analogical consistency involves the extent to which similarly behaving words have similar characteristics. For example, if most words that are finally stressed are also morphologically and phonemically similar, there is a high degree of analogical consistency. Where there is a high degree of consistency, the stress placement of a word can usually be determined on the basis of the stress placement of its neighbors, that is, on the basis of other items that share characteristics with the word in question. In order to determine the analogical consistency of Spanish stress placement, a tenfold cross-validation was performed. This consisted of dividing the database of 4,970 words into ten sections of 497 words each. The members of each group were then treated as the test items, while the members of the remaining nine groups comprised the training set from which analogs were chosen.

Given the fact that the database contained several inflectional variants of many words, a possible confound exists. If the given context is the adjective *rójas*, its inflectional variants *rójo*, *rója*, and *rójos* will be included in the analogical set and influence it to receive penult stress. The idea behind determining the analogical consistency of the database is to see how analogy responds to an unknown word. If *rójo*, *rója*, and *rójos* are allowed to serve as possible analogs for *rójas*, the system is not actually treating it as a completely novel item. A simple way of controlling for the effect of items that share the same root was to alphabetize the database prior to partitioning it for the tenfold study. In this way, inflectional variants were grouped together in the same test set, and were unable to serve as analogs for each other.

		STRESS ASSIGNED BY AML		
WORD	ACTUAL STRESS	FINAL	PENULT	ANTEPENULT
dominánte	penult	.000	1.000	.000
podrán	final	.992	.007	.000
plástico	antepenult	.000	.006	.993
preguntó	final	.674	.326	.000
pesádo	penult	.000	1.000	.000
débil	penult	.673	.327	.000

TABLE 3. Probability of stress placement according to AML.

Once the database was partitioned, the stress placement of each word was determined according to AML's algorithm. Table 3 contains a sampling of outcomes computed by AML. The outcome for a given word is expressed as the probability that the word will be assigned stress on a certain syllable. As can be seen, *débil* 'weak' is incorrectly assigned final stress. The preterit verb *preguntó* 's/he asked' is correctly assigned final stress, but also shows the influence of having several neighbors with penult stress.

Under these conditions, the success rates on the 10 groups ranged from 92.2% to 96.8%. In total, 94.4% of the 4,970 words tested were correctly stressed, indicating a very high degree of consistency. Penult stress was most consistent with 98.9% of penult stressed words correctly assigned stress. Word-final stress followed closely at 93.6, while only 40.1% of antepenult stressed words were most heavily influenced by other words that also have antepenult stress.

Another possible objection to the study is that it considers only the highest frequency lexical items. In general, the majority of the irregularly behaving words in a language are also among the most frequent ones. In other words, there is less analogical consistency among high-frequency items, and, arguably, they would not be the optimal group to use to achieve the highest degree of accuracy in predicting stress assignment.

This property of high-frequency words becomes evident when the database is used to predict the stress of a group of low-frequency items. Four hundred ninety-seven items with a frequency of one (0.2 per million) in the Alameda and Cuetos dictionary were tested against the ten training sets used in the initial tenfold cross-validation study. The resulting success rates ranged from 91.1% to 92.6%, with an average of 91.8%. This result falls slightly below the average found when testing the high frequency items alone (94.4%). The reduction in the number of items correctly stressed is probably due to the large number of irregular items in the high-frequency training sets.

I concede that there are fewer irregularities among the less frequent lexical items and that it is highly possible that the stress of a larger number of items could be correctly assigned given a training set of low-frequency items, instead of high-frequency items. Nevertheless, significant facts about language usage would be ignored if such a step were taken. High-frequency irregular items should be included since they play a role in linguistic cognition.

Consider the English past tense, the majority of whose irregular forms are high frequency. It may be the case that better predictions would be made about the phonological shape of the past tense form if only lower frequency items were analogized on, but significant facts would be missed. A common error among children, for example, is the use of *brang* instead of *brought* as the past tense of *bring*. This error comes about as a result of the influence of certain high-frequency irregular forms such as *sang*. The historical move from *stinged* to *stung* is also due to the analogical pressure of high-frequency irregular verbs such as *stunk*. It is data such as these that lead me to conclude that restricting the database to the most frequent items is the most principled way to limit its size in order to carry out analogical simulations (see also §3.1).

4.1. VERBAL VERSUS NONVERBAL STRESS PLACEMENT. One reason for determining analogical consistency involves the idea that stress may be determined differently for verbs and nonverbs (e.g. Roca 1988). This opinion is not universal of course (e.g. Harris 1989). Therefore, it is of theoretical interest to investigate the matter more closely. If verbal and nonverbal stress assignment is processed separately, that would suggest that verbs have mainly verbal neighbors, while nonverbs must be influenced mainly by nonverbs. If this is true, the analogical consistency of verbs alone should be greater than the consistency of verbs and nonverbs combined. In the same vein, the consistency of nonverbs, when considered separately, should be greater than the consistency of verbs and nonverbs combined.

To test this notion of consistency, the database was divided into two parts: one containing only verbs, the other containing only nonverbs. The words were again alphabetized and a tenfold cross-validation was performed. The procedure entailed randomly eliminating seven items from each new group so that the groups would be evenly divisible by ten. Table 4 shows that assigning verbal stress on the basis of similar verbs

	ENTIRE DATABASE			
	VERBS	NONVERBS	VERBS ALONE	NONVERBS ALONE
# OF ERRORS	42	235	45	228
% OF ERRORS	3.0	6.6	3.2	6.4

TABLE 4. Error rates analogizing entire database, verbs or nonverbs alone.

slightly increased the verbal error rate (i.e. the percentage of incorrectly stressed words) from 3.0% to 3.2%, but the error rate for nonverbs decreased from 6.6% to 6.4% under the same conditions.

If verbs and nonverbs are allowed to influence only members of their own class, the total number of errors varies very little. From an analogical perspective, there appears to be no significant benefit in considering verbal and nonverbal stress assignment as separate processes, as Roca (1988) suggests. In the remainder of this article, therefore, the results of the corpus as a whole are considered.

5. Initial results. AML is able to correctly assign the stress on about 94% of the most frequent Spanish words, and the words that are incorrectly assigned stress by AML are generally those that traditional analyses have treated as exceptional as well. That is, 80.1% of the errors in stress assignment occur on words that either have antepenult stress, 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*. What this indicates is that analogy 'recognizes' stress patterns without having to extrapolate a global generalization about the data in the form of a rule.

AML is also quite adept at fleshing out subpatterns. There is, for example, a fairly large group of words, mainly adjectives, that end in *-ico(s)* or *-ica(s)* and have antepenult stress (e.g. *público* 'public'). In spite of the 'marked' status of antepenult stress, 99 out of 107 of these words are correctly assigned antepenult stress. In contrast, all 7 verbal forms that end in *-ica* (e.g. *significa, critica, dedica*) were correctly assigned penult stress.

In spite of AML's ability to correctly assign stress, a critic may argue that AML is not an accurate model of Spanish stress assignment because its success rate is not one hundred percent.[7] Rule models appear to be much better suited to accounting for all the data, since they can be formulated in such a way as to account correctly for one hundred percent of the data. While this is true, one must ask what rule-based accounts must do to achieve such accuracy. To account for exceptional patterns and varying degrees of regularity, rule models must make use of formal mechanisms such as extrametricality, odd morphological parsings, and other abstract formalisms that in essence serve as diacritics (Farrell 1990, Gillis et al. 1993). The use of such formalisms is common in theories of competence and linguistic structure, but their status as psychological mechanisms, and whether they have actual correlates in the minds of speakers, is highly questionable (Eddington 1996).

It would be possible, however, to construct a rule-based account without diacritics. Such an account would simply state that words ending in a vowel or *s* are stressed on the penult syllable, while those ending in a consonant, except *s*, receive final stress. The application of these rules to the items in Table 1 would yield 648 errors for a success rate of 86.6%, which falls far short of AML's 94.4% success rate. If antepenult words are discounted, the rate climbs to 91.8% for the rule account, and to 97.6% in the AML simulation. In either case, AML appears more adept at assigning stress correctly.

6. Empirical evidence. In §4, we saw that the analogical consistency of Spanish stress assignment is quite high. While analogical consistency is employed as a test of performance of a language processing model (e.g. Daelemans et al. 1994), there are

[7] It could be countered that people do not invariably produce the expected forms either (see Berko 1958, Schnitzer 1996).

others, and it is entirely conceivable that some linguistic behaviors have a low degree of consistency. In that case, many similarly behaving items would not have a great deal of features in common, and would not serve as analogs for each other: there would be a great deal of irregularity in the system. In AML, this is not problematic, since all known items are stored as individual units in the mental lexicon. Therefore, another test of AML is whether it helps explain empirical evidence, such as the formation of neologisms, language acquisition data, slips of the tongue, and historical developments, resulting from language usage. Such evidence may be found for Spanish stress assignment.

6.1. ASKE'S STUDY OF NEOLOGISMS. Most words ending in *-n* have final stress, which is why generative analyses derive final stress as the unmarked case for such consonant-final words.[8] Aske (1990:35), however, noticed that in Spanish, about 62% of 55 common nonverbs ending in *-en* have penult stress (e.g. *vírgen* 'virgin', *exámen* 'test'). This contrasts with 135 common nonverbs that end in another vowel plus *n* ($V_{(-e)}$), 90% of which have stress on the final syllable (e.g. *canción* 'song', *según* 'according to').

Aske hypothesizes that when a speaker is faced with making a decision about where to stress an unfamiliar word ending in *-n*, the speaker may make use of either generative-type rules or analogy to determine stress placement. Generative rules would assign all *-n*-final words final stress, since words that are unfamiliar to the speaker could not have been previously marked as exceptions. However, if speakers searched their lexicons for words similar to those in question, and applied the stress of the word(s) accessed by the search, *-en* words would be less likely to receive final stress than $\textit{-}V_{(-e)}n$ words.

In order to test his hypothesis, Aske devised six final *-en* nonce words and six $\textit{-}V_{(-e)}n$ nonce words. He then embedded them in sentences in which they appeared in a nonverbal context and asked Spanish speakers to read them. The sentences were presented using only capital letters. Since Spanish orthography allows written accent marks to be deleted over capitals, this presentation thereby controlled for any effect of a written accent mark.

The results clearly favor the analogical model. Of the responses to his $\textit{-}V_{(-e)}n$ words, 96.8% favored final stress, while only 55.6% of the responses to *-en* words received final stress (1990:37). The subjects were clearly not applying a rule that places final stress on all *-n* final words. The close relationship between the preferred stress patterns and the stress patterns that exist in actual words suggests that stress assignment was determined on the basis of similar words that were known to the subjects.

Although Aske attributes his findings to analogy, his experiment was not based on any specific model of analogy. It is therefore of interest to determine if his findings can be supported by an analysis based on AML. To this end, the twelve nonce items from Aske's study were processed using the database described in §3. The results appear in Table 5. Words ending in *-en*, and those in $\textit{-}V_{(-e)}n$ are assigned quite different patterns, as Aske hypothesized, and his experiment bore out. All *-en* words were assigned penult stress, while all but one of the $\textit{-}V_{(-e)}n$ words (*seboran*) received final stress.

In the AML simulation, I assume that the behavior with the highest predicted probability applies, meaning that none of the nonce items ending in *-en* would be assigned final stress. Aske's subjects, though, predicted final stress on 55.6% of the responses.

[8] For example, 60% of the polysyllabic words ending in *-n* in the database are stress final.

NONCE WORD	PROBABILITY OF FINAL STRESS: ALL WORDS	PROBABILITY OF FINAL STRESS: NONVERBS ALONE	PROBABILITY OF PENULT STRESS: ALL WORDS	PROBABILITY OF PENULT STRESS: NONVERBS ALONE	PROBABILITY OF ANTEPENULT STRESS: ALL WORDS	PROBABILITY OF ANTEPENULT STRESS: NONVERBS ALONE
besoren	.006	.011	.994	.989	.000	.000
corumen	.005	.098	.995	.901	.000	.000
petaben	.006	.610	.994	.387	.000	.003
faden	.017	.298	.983	.702	.000	.000
merasen	.009	.173	.991	.827	.000	.000
gorquen	.003	.004	.998	.996	.000	.000
seboran	.003	.052	.996	.946	.001	.002
porubon	.830	.975	.169	.024	.000	.001
petamin	.614	.983	.368	.015	.018	.002
tedon	.789	.991	.211	.009	.000	.000
sorquin	.916	.822	.084	.178	.000	.000
perasun	.662	.963	.330	.035	.008	.002

TABLE 5. Probability of stress placement for Aske's nonce words.

On the -$V_{(-e)}n$ items, AML predicts final stress for five out of six items (83.3%), while the subjects preferred final stress in 96.8% of the responses. AML therefore captures the subjects' preferences qualitatively but not quantitatively. Given the variability inherent in survey data, coupled with the fact that the AML database is a limited estimation of a Spanish speaker's mental lexicon, it is sufficient that the simulation captures the major trend, and is not numerically identical.

But there is a possible confound in the data. Aske presented the nonce words in contexts in which they could only be interpreted as adjectives or nouns, never as verbs. It is possible that *seboran* was assigned penult stress in the AML simulation because of the heavy influence of its verbal neighbors in the database (e.g. *ponían*, *fuéran*, *tuviéron*, etc.). In order to test this possibility all twelve nonce words were assigned stress using only the nonverbal items in the database. In this way the nonverbal contexts Aske's subjects were asked to respond to were matched with the nonverbal items in the database. Even under these conditions *seboran* continued to receive penult stress. Furthermore, an additional item (*petaben*) was incorrectly stressed in comparison to the subjects' preferences. It is unclear why the stress placement given to *seboran* by AML does not coincide with that assigned by the subjects. However, the fact that an additional mismatch occurs when only nonverbal items are allowed as analogs lends further credence to the hypothesis that verbal and nonverbal stress assignment should not be treated separately (§4.1).

6.2. HOCHBERG'S STUDY OF ACQUISITION. Hochberg, in her 1988 study, elicited words with different stress patterns from preschoolers. First, she had children name various objects in a picture book. Next they had to repeat nonce words they heard, which were stressed on different syllables. Her hypothesis was that

> if children did in fact learn stress rules, then (a) they should find words with regular stress easier to pronounce than words with nonregular stress; and (b) they should tend to regularize stress in words with nonregular stress, but should not *irregularize* stress in words with regular stress. (1988:690)

Hochberg's hypothesis was partially confirmed. She found that children made significantly more structure-changing errors on nonce words with irregular stress than on nonce words with regular stress patterns.[9] In addition, more of the structure-changing errors regularized stress than made regular stress irregular.

[9] Structure-changing errors are those that entail a stress shift or an alteration of the CV skeleton.

The error analysis for the real words Hochberg elicited differs somewhat. As with the nonce words, more structure-changing errors were made on irregularly stressed words than on regularly stressed words, but there was no significant difference between the percentage of errors that regularized stress and the percentage of errors that converted regular stress into irregular stress. Hochberg concludes that

> The most likely explanation of the difference between the imitated and spontaneous speech data is that the children had mastered both the stress system and individual exceptions to it. Thus, while they did find known irregular words somewhat harder to say than known regulars, their familiarity with these words enabled them at least to stress them correctly. In contrast, when confronted with novel words in the imitation task, the children were led by their rule knowledge to regularize irregulars. (1988:698)

An alternative explanation of her findings is possible from an analogical standpoint. Known words are stored along with their inherent stress pattern. The fact that regularization of irregulars and irregularization of regulars was roughly equal could be attributed to the same types of retrieval problems affecting both types of words indiscriminately. Unknown words, having no lexical entry, would adopt the stress patterns of their neighbors. Of course, this account is plausible only if it can be proven that analogy makes errors that regularize stress more often than it assigns irregular patterns to regularly stressed words.

6.3. HOCHBERG'S ACQUISITIONAL DATA IN AN ANALOGICAL ANALYSIS. Of the 4,970 words in my database, 277 were incorrectly stressed using AML's algorithm. According to these data, the most difficult stress to assign correctly is antepenult, since 59.9% of the antepenult words in the database were incorrectly stressed. Only 6.4% of words stressed on the final syllable were improperly stressed, while penult stress yielded the lowest error rate (1.2%). This same hierarchy of difficulty is also seen in the error rates from the three- and four-year-olds in Hochberg's imitation experiment (1988:700, Fig. 13).

Of the 277 errors produced by AML, 220 involved a move from an irregular to a regular stress pattern (e.g. *acá* to *áca*). This means that 33.9% of the irregularly stressed items (n = 649) were regularized. In contrast, only 54 of the errors made on regularly stressed items (n = 4177)[10] made them irregular (e.g. *papél* to *pápel*), yielding a 1.3% rate of irregularization. Once again, this is precisely the pattern that Hochberg found in her imitated speech study, where 53% of the errors regularized irregularly stressed words, and only 23% of the errors involved making a regular stress irregular (1988: 696).

Hochberg also divided the error rates according to the age of the subjects. The error rate on regular items remained virtually unchanged for all subjects ages three to five, but the error rate on irregular items dropped from the four- to the five-year-olds (Figure 1).

One way of approximating age differences in AML is by varying the number of items in the database (Derwing & Skousen 1994). Exactly how many words a child at a given age has learned is difficult to ascertain. Based on several different estimates, Aitchison (1994:169) assumes that a three-year-old English speaker has an active vocabulary of about a thousand words, while a five-year-old has an active vocabulary of about three thousand words. In any event, in order to determine if the analogical approach could account for the developmental phenomena, the database was divided into two halves, and the half containing the least frequent items was discarded. The remain-

[10] The 144 monosyllabic items were not included.

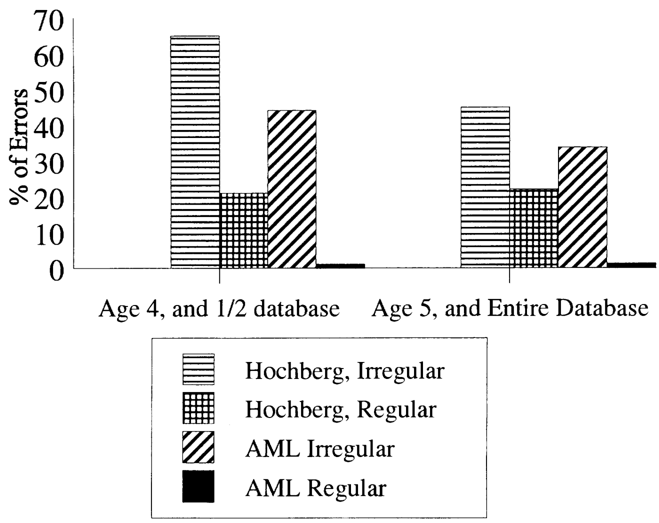

FIGURE 1. Error rates by age and number of words in database.

ing half was assigned stress in a tenfold cross-validation simulation according to AML's algorithm, and the error rates were calculated. These results are also summarized in Fig. 1.

The leftmost group of bars in Figure 1 represents the error rates of Hochberg's four-year-old subjects, and the error rates that resulted when only the most frequent half of the database was included in the analogical experiment. The rightmost bars indicate the error rates for Hochberg's five-year-old subjects, and the error rates that occurred when 4,970 database items were included. In both studies, error rates on regular items varied little, but the error rates on irregularly stressed items declined for older subjects. In the AML simulation, the rate also dropped when a larger mental lexicon was assumed. A proportions test reveals that this drop is significant (Z-statistic $= 7.44$, $p < .01$, 99% confidence interval .0676, .1384)

Hochberg concludes that her findings support the existence of rules that assign stress. Nevertheless, the analogical account mirrors her findings quite closely. The ability of an exemplar-based model to account for stress placement errors is not limited to Spanish. Gillis et al. 1994 demonstrates how stress placement errors in Dutch are better accounted for if stress is determined by analogy to known words, than it is by postulated stress rules.

7. CONCLUSIONS. My purpose was to determine to what extent Spanish stress placement could be handled within AML. The 4,970 most common Spanish words served as a model of the mental lexicon, and as test cases as well. About 94% of these words were correctly stressed by analogy. Extremely low frequency words were correctly stressed in about 92% of the cases. No significant improvement was observed if verbs and nonverbs were allowed to analogize only on members of their own category.

Since AML is a model of language usage, the most important findings are those that involve actual language use. Although the results are not perfect, the analogical account of stress assignment was found to mirror quite closely the results of Aske's nonce word study and Hochberg's study of stress acquisition. The present study therefore lends support to AML as a plausible model of linguistic performance. Moreover, it adds to the growing body of evidence that linguistic generalizations, such as stress placement, are not embodied in rules or similar abstractions, but in exemplars stored in the mind.

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