Are Plurals Derived or Stored?

David Eddington
University of New Mexico

Patricia Lestrade
Mississippi State University

1. Introduction.

The ability to produce and comprehend human language involves at least two processes: the storage of units and the computations performed on those units. The role that storage and computation play in the processing of inflectional morphology is highly debated. At one end of the spectrum is the full storage model, which holds that all known words, whether morphologically complex or not, have separate entries in the mental lexicon (Jackendoff 1975, Manelis and Tharp 1977, Butterworth 1983, Bybee 1985, 1988, Rumelhart and McClelland 1986, McClelland 1988, Stemberger 1994, Rueckl, Mikolinski, Raveh, Miner, and Mars 1997). This position puts an enormous burden on memory, but entails little in the way of computation. Here computation is needed to handle only new items or those that are temporarily inaccessible from memory. At the other end of the spectrum is the full parsing model, which assumes that all complex forms are derived (Taft 1979, 1981, 1985, 1994). This model places a very minimal load on memory, but requires a great deal of computation.

Another approach, that combines both parsing and storage, is that of Schreuder and Baayen (1995). In their dual-route model, parsing and access to stored items function in parallel. That is, recognition is not uniquely a matter of full storage or full parsing, but a race between the two. If parsing is too time-consuming, access to the whole word entry will win the race. When parsing is time-efficient, access based on the constituent morphemes will take place. This model is not merely conceptual, but computational, since it involves an algorithm that is able to predict actual reaction times. In short, it is based on the idea that both full storage and parsing occur, and that for any given word, the most time-efficient method will be used.

In recent years, the tradeoff between computation and storage has focused on differences in the processing of regular versus irregular inflection. The model espoused by Pinker and his colleagues (Pinker and Prince 1988, 1994, Pinker 1991, 1997, Clahsen, Rothweiler, Woest, and Marcus 1992, Prasada and Pinker 1993, Marcus, Brinkmann, Clahsen, Wiese, Woest, and Pinker 1995, Ullman 1999) suggests that all irregularly inflected items are stored as whole units in the mental lexicon, while regular inflections have no individual representation.[1]

Instead, these are thought to be produced online via rules of morphological concatenation. According to this model, a regularly inflected word is recognized by accessing the uninflected base form from memory. Of course, Pinker's stance is not universally accepted; others maintain the view that all inflection, both regular and irregular, is the result of the same process (Rumelhart and McClelland 1986, Skousen 1989, 1992, Seidenberg and Bruck 1990, Daugherty and Seidenberg 1992, 1994, Seidenberg 1992, Elman et al. 1996, Marchman 1997, Nakisa, Plunkett, and Hahn 1998, Eddington 2000).

One way researchers have approached the storage versus parsing debate has been to look for possible processing differences between regular and irregular morphology. Our approach in the present paper, on the other hand, is to focus solely on a highly regular morphological process--Spanish noun pluralization. According to Pinker's model and the full parsing model, the production of a regular Spanish plural would result from the application of a rule that adds the correct plural morpheme to the uninflected stem (e.g. *casa* + *-s* > *casas;* 'house' > 'houses'). The recognition of a plural would entail accessing both the uninflected base form, (that is, the morpheme that underlies both the singular and plural forms), and the plural suffix. In contrast to this position, full storage suggests that both the plural and singular forms are stored as individual units in the mind and would be accessed as whole, fully inflected units. The dual-route approach would predict some words to be accessed as wholes, and others via their morphemic constituents.

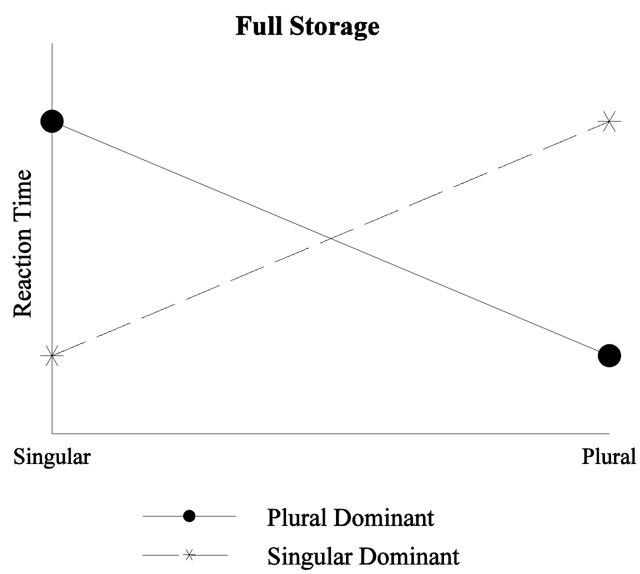
The purpose of our study is to determine whether or not Spanish noun plurals and singulars are crucially dependent on their uninflected base forms in visual word recognition. If they are, then the study would support the full parsing position and Pinker's model, since according to these, the individual plural forms are derived from their base forms and have no unique mental representation. If plurals are not dependent on the base forms, the full storage hypothesis would be supported.

Studies of the mental lexicon often entail the measurement of frequency effects. It has been shown that high frequency words are recognized and responded to more quickly than low frequency words (Scarborough, Cortese, and Scarborough 1977, Allen, McNeal, and Kvak 1992,). In addition, the frequency of the root morpheme is a factor that influences reaction times (Burani, Salmaso, and Caramazza 1984). The root morpheme frequency is the sum of the individual frequencies of all words containing the same root, which we will refer to as the cumulative frequency.

Sereno and Jongman (1997) conducted a series of experiments involving frequency effects with English plurals. In one study they matched pairs of words with similar cumulative frequencies, but with widely differing plural and singular frequencies. For example, the cumulative frequency of *river* (freq. *river* + freq. *rivers*) is almost identical to the cumulative frequency of *window*. However, the plural form *windows* is much more frequent than the plural *rivers*. In other words, *window* is plural dominant while *river* is singular dominant. In one experiment, English speakers were able to identify high frequency plurals such as *windows* more quickly that low frequency plurals such as *rivers*. This result is expected if both *rivers* and *windows* have their own entry in the mental lexicon, but would be hard to account for in a full parsing model in which plural forms must be accessed via their base forms.

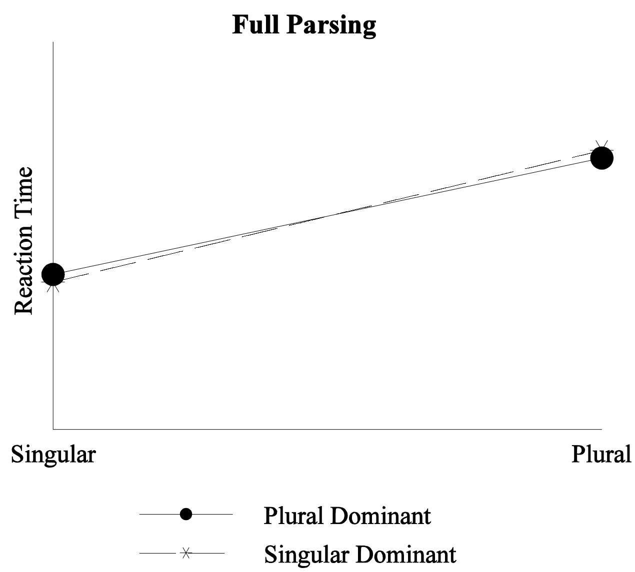
In another recognition experiment, English speakers responded to singular forms such as *river* and *window*. Here again, the individual frequency accounted for reaction times that were shorter for high frequency *river* than for low frequency *window*. Sereno and Jongman's data, therefore, characterize a model in which all inflectional variants are stored. Full storage is expected to produce frequency effects that can be schematized as shown in Figure 1.

Figure 1. Predicted Reaction Times if Inflections are Stored.



Evidence for full parsing, on the other hand, would produce frequency effects similar to those in Figure 2.

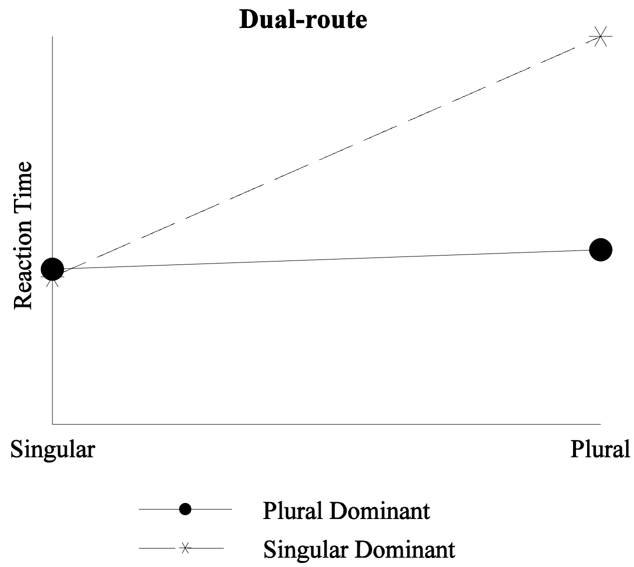
Figure 2. Predicted Reaction Times if Inflections are Parsed.



Given full parsing, reaction times to all inflectional forms would depend on cumulative frequency. In this case, reaction times would vary little, except that a certain amount of time would be required to access the plural suffix in addition to that required to access the base morpheme. Given full storage, reaction times would vary according to the frequency of the individual plural or singular form.

Baayen, Dijkstra and Schreuder (1997) and Baayen, Burani, and Schreuder (1996) studied plurals and singulars in Dutch and Italian respectively. In both languages they made the same observations; the individual frequency of the plural forms accounted for the observed reaction times, while the individual frequency of the singular forms had no effect on reaction times (Figure 3). Instead, reaction times to singulars were dependent on cumulative frequency. These finding support a dual-route race model in which parsing wins for singulars, but the whole word route wins in the case of plurals.

Figure 3. Reaction Times in a Dual-route Model.



Given these data, it appears that the full storage hypothesis holds for English pluralization, while the dual-route model holds for Dutch and Italian. The question we ask is how Spanish plurals and singulars are processed. Dutch, English, and Spanish plurals are formed with simple suffixes. Italian, in contrast, does not pluralize by the addition of a plural suffix, but indicates plurality by modifying the quality of the word-final vowel. However, Spanish and Italian differ from English and Dutch in the complexity of their inflectional morphology. Spanish and Italian pluralize both nouns and adjectives, in contrast to Dutch and English that mark plural only on nouns. Moreover, Spanish and Italian adjectives must agree in gender with the noun they modify. In verbal morphology, English verbs have four or five possible inflectional variants (e.g. *eat, eats, eating, ate, eaten*), and Dutch verbs six or seven (e.g. *werk, werkt , werken, werkte, werkten, gewerkt, werkende*). Spanish and Italian, on the other hand, have about 35 to 40 inflectional variants, depending on the dialect. It is highly plausible that in a language with a simple morphology, all known inflectional variants may be stored. However, in languages with complex morphology, full storage processing becomes less likely. For example, Finnish, which has an extremely intricate morphology, appears to be processed in accordance with the full parsing model (Bertram, Laine, and Karvinen 1999, Laine, Vainio, and Hyönä 1999).

Domínguez, Cuetos, and Segui (1999) designed an experiment similar to Sereno and Jongman's English study, but with Spanish noun plurals and singulars. They used pairs of words with similar cumulative frequencies but varying plural and singular frequencies. Reaction times to singular words were dependent on the individual frequency of the singular form, not on the cumulative frequency. This leads to the conclusion that singular nouns in Spanish have unique lexical entries in the mental lexicon. The reaction times to plural forms depended on the cumulative frequency rather than on the frequency of the individual plural word. This suggests that the recognition of a Spanish plural is carried out via the root morpheme. In other words, Spanish plurals appear to be parsed, while English plurals are stored.

On the one hand, the differential processing of Spanish and English plurals could be explained by the fact that Spanish has a more complex morphology, and as a result, full storage would be less likely than in a morphologically simple language such as English. Although differences in morphological complexity between English and Spanish could account for the differing test results, the data from the Italian and Dutch experiments cast doubt on this assumption. Italian is a much more morphologically complex language than Dutch, yet plural processing in both languages follows the same route (Figure 3) in contrast to both Spanish and English.

There are two reasons we have chosen to examine further the processing of Spanish plurals. First, although Domínguez et al. have already provided some evidence regarding plural processing, it is unwise to draw conclusions based on the outcome of one study. Therefore, we designed the present experiments in order to broaden the evidential base. Second, we were concerned about a possible flaw in the data analysis used by Domínguez et al. In a study of this nature, it is standard procedure to eliminate extreme response times, as well as data resulting from erroneous responses. However, a crucial element in their study was that it revolved around pairs of words that were matched in terms of number of letters and cumulative frequency. In this way, the unwanted effects of word length and cumulative frequency were controlled. The possible confound in their study was that once test items with errors and extreme response times were removed, the characteristics of the resulting high and low frequency groups may have been inadvertently mismatched, thus tainting the results.

2.0. Experiment 1.

We designed a test to determine the amount of time required to recognize plural nouns in Spanish. To this end, we utilized a lexical decision task.

2.1. Procedure.

A lexical decision task requires that the subject choose between lexical items presented. In this lexical decision task, native Spanish speakers were asked to determine whether or not a string of letters that appeared on a computer screen represented a Spanish word. They were instructed first orally by the investigator, and then by written on-screen instructions to indicate their choice by pressing one key for 'word' and another for 'non-word'. Both speed and accuracy were emphasized. The program was designed so that half of the strings were legitimate words and the other half non-words. In this way, subject response times could be measured discretely. The first ten responses were practice items and did not include test words. These items allowed the participants to become familiar with the task required.

2.2. Subjects.

The study included 43 native speakers of Spanish from twelve Hispanic countries. Twenty women and 24 men participated. Most were attending the university or preparing to enter; the other few were well-educated professionals. Ages ranged from 19 to 69 with a mean of 32. Subject participation in each experiment was determined randomly so that no person was involved in both experiments. Twenty-one participated in the first experiment.

2.3. Stimulus Materials.

The test items used as stimuli consisted of 44 test words, all of which were nouns ending in a vowel plus plural morpheme -*s*. Care was taken not to include words that have both nominal and verbal readings (e.g. *cuentas* 'bills' or 'you count'). Also included were 44 non-words that ended in a vowel plus -*s*. These were devised by changing one or more letters in existing Spanish words in such a way that the word still had a legitimate phonotactic shape. In addition, there were 36 distractor items consisting of 18 inflected verbs and 18 inflected non-verbs. These were provided in order to avoid a 'noun mindset' in the subjects during the experiment.

The test nouns were grouped in pairs with closely matched cumulative frequencies but differing individual frequencies. All word frequencies were taken from a word count of a corpus of five million Spanish words (Alameda and Cuetos 1995). The pairs were also matched identically in number of letters per word. Only vowel final words were included, thus controlling for variations in plural allomorphy. The complete list of test words and individual frequencies appears in the Appendix.

Table 1. Individual and Cumulative Frequencies for Two Test Items.

Test Word	Singular Freq.	Plural Freq.	Cumulative Freq.
labio(s)	24	322	346
miedo(s)	338	25	363

An example of a pair of test words appears in Table 1. The cumulative frequencies of *miedo* and *labio* are quite similar, but the plural *labios* is much more frequent than the plural *miedos*. If *miedos* and *labios* have individual representation in the lexicon apart from their respective base forms, then *labios* should elicit a faster reaction than its low frequency counterpart *miedos*. In addition, plural *labios* and singular *miedo* would result in similar reaction times given their similar frequencies. In other words, we would expect reaction times similar to those in Figure 1.

However, if the individual inflected forms are not stored, and recognition of a plural is carried out by accessing the plural's base form instead of a fully formed plural, there should be no differential frequency effects between the words *miedos* and *labios*. Reaction times would reflect the amount of time required to access the base from memory plus the amount of time needed to recognize the plural morpheme. In this case, we would expect reaction times to be similar to those in Figure 2.

2.4. Results.

Incorrect responses to non-words resulted in a 6.5% error rate. The error rate on the test words was 2.8%, which not only includes incorrect responses, but also response times of over 2000 ms at which the timeout was set. The test items consisted of pairs of high and low frequency items that were closely matched in terms of word length and cumulative frequency. In order not to skew the characteristics of the high and low frequency groups, as may have occurred in the study by Domínguez et al. (1999), if an error occurred on one member of a pair, the reaction time for the other member was deleted as well, resulting in 5.6% of the data being eliminated.

Once errors were deleted, the remaining data were subjected to statistical analyses (Table 2). The difference between the mean reaction time to high and low frequency plurals was 110 ms, which ANOVA shows to be highly significant (F (1) = 22.86, $p < .005$).

Table 2. Outcome of Experiment 1.

	Mean	**Stan. Dev.**
High Freq.	864.82 ms	299.97
Low Freq.	974.99 ms	376.87

2.5. Discussion.

By closely matching pairs of words on cumulative frequency, we were able to control for cumulative frequency as a confounding factor. Since high frequency plurals required 110 ms less time to be recognized than their low frequency counterparts, the frequency of the individual plural forms themselves must be responsible for the reaction times. It would be difficult to account for such results if plurals were not uniquely represented in the mental lexicon. Therefore, this outcome provides strong evidence that the subjects accessed the plural forms presented to them instead of accessing the base form of each plural. It also demonstrates that completely regular, morphologically complex inflections need not be parsed into constituent morphemes in order to be recognized. These data are incompatible with the full parsing model, but corroborate both the dual-route and full storage models. However, the results of the singular experiment described in the next section are needed in order to differentiate between the adequacy of the full storage and dual-route models.

3.0. Experiment 2.

In Experiment 1, the frequency of the individual plural form was shown to predict reaction times. In Experiment 2, our goal was to determine if the frequency of individual singular forms predicts reaction times in like manner.

3.1. Procedure.

Same as in Experiment 1.

3.2. Subjects.

Twenty-two subjects were drawn from the same pool of subjects as in Experiment 1 in such a way that no subject participated in both experiments.

3.3 Stimulus Materials.

The same test words were used, but this time in the singular form instead of the plural. The practice items were also made singular.

3.4. Results and Discussion.

The data from two subjects were eliminated; one because of a computer error, and the other because of an extremely high error rate (23.4% of the non-words were misidentified). The average error rate on the non-words was 7.6%. Only 1.5% of the test words elicited errors. As in the previous experiment, an error on any one member of a pair resulted in the elimination of both members, with the result that 3.0% of the test word data was eliminated.

Table 3. Outcome of Experiment 2.

	Mean	Stan. Dev.
High Freq.	861.85	273.11
Low Freq.	874.45	285.71

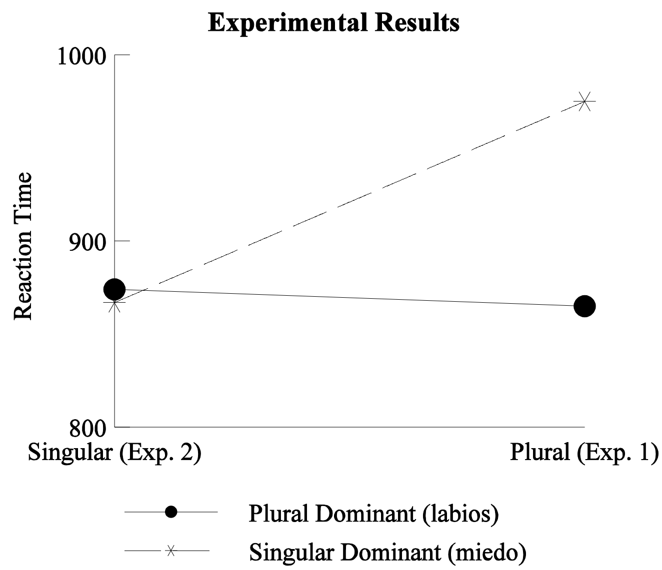
As Table 3 demonstrates, the response to high frequency singulars was about 12 ms faster than to low frequency singulars. However, this small difference was not significant (F (1) = .434, p < .510). In spite of the fact that the individual frequency of these singular test items varied a great deal, no significant differences in response times were found. This indicates that the reaction times were influenced by cumulative frequency instead of the frequency of the individual singular test item.

4. General Discussion.

Our findings directly contradict those of Domínguez et al. (1999). While they reported frequency effects for singulars and no frequency effects for plurals, we found just the opposite. The possible confound produced by not equating high and low frequency groups in terms of word length and cumulative frequency, once errors were removed, may have been responsible for their findings. Such an error was avoided in our study by eliminating both members of a pair of test words if either member was incorrectly identified as a non-word.

Figure 4 summarizes the mean reaction times in Experiments 1 and 2. What we observe is that frequency effects exist for plurals, indicating that recognition of these items involves accessing them as preinflected wholes; they are not parsed into constituent morphemes and recognized on the basis of their parts. Recognition of singulars, conversely, is carried out via access to the base form. In one regard, this is an unexpected outcome since it suggests that recognition of a singular noun activates not only the singular noun, but the plural form as well. On the other hand, the surface form of the singular is identical to the base form from which the effects of the base frequency may derive.

Figure 4. Outcome of Experiments 1 and 2.



In any event, the frequency effects we obtained do not correspond either to the full storage model (Figure 1) or the full parsing model (Figure 2). Instead, they support the dual-route model (Figure 3) that has been demonstrated for Italian and Dutch. In the case of singulars, activation of the stored item appeared to be extremely slow, which explains why the parsing route wins the race. However, the parsing route for plurals requires a more time-consuming segmentation into constituents. For this reason, access to the plural form in storage wins the race, which explains the influence of the individual frequency of plural forms.

Attempts to explain plural processing in each language by considering morphological differences or similarities between the languages is not fruitful. Spanish, English, and Dutch form plurals by suffixation in contrast to Italian. On the other hand, Spanish and Italian have a fairly complex morphology in contrast to English and Dutch, yet neither of these groupings accounts for the differences in the processing of plurals observed in the studies. The processing of Spanish, Dutch, and Italian plurals follows the dual-route model in contrast to English, which follows the full storage model. Only further inquiry into the subject will reveal why these differences exist.

5. Conclusions.

We have presented the results of two experiments dealing with visual recognition of singulars and plurals in Spanish. The individual frequency of the plural forms influenced the subjects' reaction times. This indicates that recognition of plurals is carried out by accessing the preinflected plural from memory. The recognition of singular forms, in contrast, was not influenced by the individual frequency of the singulars, but by the cumulative frequency of the root. Given the fact that results similar to ours were found in Dutch and Italian, we conclude that the dual-route model, which account for the Dutch and Italian data, is applicable to Spanish plurals as well. The model is essentially a race model in which parsing and access to stored lexical items takes place in a parallel fashion. Parsing wins the race for singular items, while access to stored items wins for plurals.

Notes

1. Pinker and Prince have backed away from the strong version of their model, and admit that it is possible that some high frequency regular items have individual representation in memory (1994:331).

Appendix

Pair #	Test Word	Singular Frequency	Plural Frequency	Cumulative Frequency
1	labio(s)	24	322	346
	miedo(s)	338	25	363
2	pierna(s)	77	245	322
	asunto(s)	243	88	331
3	minuto(s)	68	209	277
	verano(s)	256	23	279
4	página(s)	62	188	250
	espejo(s)	207	44	251
5	pájaro(s)	69	98	160
	tamaño(s)	145	15	160
6	hueso(s)	44	91	15
	prisa(s)	103	27	130
7	rodilla(s)	21	107	128
	miseria(s)	93	2	119
8	recurso(s)	41	76	117
	dominio(s)	83	30	113

9	colega(s) sábado(s)	38 69	5 23	94 92
10	muslo(s) drama(s)	21 75	69 14	90 89
11	acontecimiento(s) funcionamiento(s)	28 87	61 2	89 89
12	defecto(s) orgullo(s)	29 82	53 1	82 83
13	órgano(s) vidrio(s)	25 72	4 8	79 80
14	sábana(s) fiebre(s)	23 69	55 9	78 78
15	tejado(s) exceso(s)	30 63	48 16	78 79
16	párpado(s) permiso(s)	5 62	59 2	64 64
17	turista(s) corbata(s)	12 51	51 12	63 63
18	pino(s) lana(s)	19 46	32 5	51 51
19	tiniebla(s) pretexto(s)	9 41	41 10	50 51
20	tonelada(s) urgencia(s)	3 44	48 9	51 53
21	zapatilla(s) dictadura(s)	2 34	37 5	39 39
22	terrorista(s) delicadeza(s)	5 26	25 4	30 30

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David Eddington and Patricia Lestrade

Abstract

The role that lexical storage and computation play in the processing of morphologically complex words is highly debated. Thus far, studies that contrast these processes have yielded widely varying results. At present, three viewpoints predominate: (1) the full storage model, in which all known words are stored separately in the mental lexicon, (2) the full parsing model, in which all complex forms are parsed into constituent morphemes, and (3) the dual-route model, in which some words are parsed while others are accessed as wholes.

In two experiments utilizing a lexical decision task, the influence of cumulative and individual frequency on Spanish noun plurals and singulars was tested. In each experiment, native Spanish speakers were asked to identify visually presented words and non-words. The first experiment involved discriminating between plural nouns and plural non-words. The second experiment replicated the first except that singular forms were used.

The results were compared to findings of previous studies of plurals in English, Dutch, Italian, and Spanish. Contrary to an earlier study of Spanish, The present study supports a dual-route race model in which direct access wins the race for plurals. Reaction times to singulars, on the other hand, were influenced by cumulative frequency, indicating that both the singular and plural forms are activated during recognition of singulars.

Biographical notes

David Eddington teaches at the University of New Mexico. He is interested in psychologically plausible theories of phonology and morphology and experimental approaches to linguistics. His most recent research involves exemplar-based models of language that account for rule-like behavior without assuming the existence of rules or constraints.

Patricia M. Lestrade is an Assistant Professor at Mississippi State University. Her primary research interests are in issues of language contact and bilingualism within a sociolinguistic framework. She has worked with the Isleños of Louisiana, with Spanish immigrants in Toulouse, France, and, most recently, with Mexican workers in Mississippi.