Psicológica (2000), 21, 375-401.

Morphological processing in word recognition: A review with particular reference to Spanish data

Alberto Domínguez[*], Fernando Cuetos[**] and Juan Segui[***]

[*] University of La Laguna, Spain [**] University of Oviedo, Spain

[***] C.N.R.S. and René Descartes University, París, France

The goal of this paper is to review the main results offered by some experimental paradigms to support morphological processing of visual isolated words. Three theoretical hypotheses proposing different solutions to the role of word morphological structure in lexical access and representation are described: a) full parsing, b) full listing and c) mixed models. Data from morphologically structured nonwords, comparison between monomorphemic and polymorphemic words and between morphologically regular and irregular words, priming studies, and contrasts between superficial and cumulative frequency are examined to propose some tentative conclusions about the possibilities of the morphological processing models.

Key words: Morphology, full listing, full parging, dual route model, irregular words, gender, morphological priming, cumulative frequency.

Conventionally, and in practice, it is the word that is considered the minimal linguistic unit with meaning. When we consult a dictionary, for example, a collection of words as distinct, isolated entities is available. But, of course, the word is not the only linguistic unit with meaning. Another less visible and shorter unit is the morpheme. Words are generally morphologically articulated and structured (i.e. polymorphemic words), although, on occasion, the morpheme and

[*] Address correspondence to: Alberto Domínguez. Departamento de Psicología Cognitiva, Facultad de Psicología, Universidad de La Laguna 38205 La Laguna, Tenerife-Spain adomin@ull.es . This research was supported in part by DGE-96-PB-0545 research grant to the second author.

the word can be equivalent, as occurs in monomorphemic words. To study lexical access, therefore, it is necessary to devote some experimental effort in order to find out if the meanings of the words are indirectly reached through their morphemes (full parsing), or, conversely, attained by a direct procedure (full listing) such as that performed when we use a dictionary, that is, by acceding to their representation in memory.

The ***full parsing*** procedure requires, firstly, the isolation of the morphemes that compose the word and then, separately, the access to the meaning. For instance, if the word to recognize is *caminar (to walk),* it is necessary to separate *camin-* from *–ar*. Then, it is possible to identify the meaning of *camin-* (i.e. concerning movement on foot) and of *–ar* (infinitive verb, action). Finally, a compound meaning will be achieved: *a person going on foot*.

The segmentation and assembly operations slow down the word recognition course, but permit the access to the meanings of new words, increasing the size of the lexicon in learner readers. Also, the full parsing procedure is supported by the intuitive knowledge that readers have of the grammatical categories from the letters at the ends of the words: i.e. the suffixes. The average reader is able to classify morphologically structured pseudowords such as *cominar*, *móquina* or *sedenamente*, as verb, noun and adverb. All these advantages characterize ***full parsing*** as a convincing procedure that, in terms of processing, requires a prelexical segmentation which can be implemented as a mechanism of rules application (Taft and Forster, 1975) or as an interactive system with different processing levels (Taft, 1979, 1994).

The second possibility for acquiring the meaning of a morphologically complex word is to accede directly from a description of the input to each complete orthographic or phonological form (the whole word) stored in the lexicon. The ***full listing*** models use associative and fast procedures and consider that at the level of access, at least, morphological information is not utilized. Connectionist symbolic or sub-symbolic models such as those of Seidenberg and McClelland (1989) or McClelland and Rumelhart (1981) represent this point of view. In a more explicit way, some other authors (Butterworth, 1983; Mannelis & Tharp, 1977; Rueckl, Mikolinski, Raveh, Miner & Mars, 1997) defend a lexicon with representations for all complex items. In this light, the morphological effects would be emergent properties of the system, which, in fact, only compute the orthographic and semantic similarities of the words. This is a radical point of view that excludes a morphological treatment of the word, not only at the prelexical level, but also at the word level. A less extremist position of some full listing models is maintained by those who, assuming an explicit representation of all derived and inflected forms of the words at the lexicon, defend the idea that this lexical level is morphologically organized. The words that belong to the same morphological family (i.e. with the same root) are connected by associative links. These morphological organization should be considered as independent from the formal, orthographic or phonological similarity between words, and explain why morphologically related words produce some experimental effects such as morphological priming or cumulative frequency effects, which will be explained later (Colé, Beauvillain & Seguí, 1989; Drews & Zwitserlood, 1995; Grainger, Colé & Seguí, 1991; Seguí & Zubizarreta, 1985).

A third class of models could be defined as a combination of the full parsing and full listing models: the ***dual or mixed models***. They have emerged as a result of the incapacity of the two previous models to explain the broad and dispersed range of results in this area. The **Augmented Addressed Morphology Model** (AAM) of Caramazza, Laudanna and Romani (1988) assumes that a word activates both whole-word representations for familiar stimuli and morphemes (i.e. roots and affixes) that comprise those morphologically complex words unknown to the subject. The whole word route is faster, although both routes are activated in parallel. The velocity for the parsing route with novel or unfamiliar words increases when the constituent morphemes are common. The **Parallel Dual–Route Model** (Baayen & Schreuder, 1999; Baayen, Dijkstra & Schreuder, 1997; Schreuder & Baayen, 1995) implements an interactive architecture of three layers: form access representations for whole-word and morphemes (lexemes), integration nodes (lemmas), and semantic and syntactic representations. The direct route maps a full-form onto its associated lemma node. Also, in parallel, the segmentation route operates mapping onto the lemma nodes. The difference with the AAM model is that the lemma nodes are not sensitive to the frequency. Only the layer of formal representations is sensitive to the frequency of words and morphemes. This difference accounts for a special semantic status for some words. For instance, plural dominant items (e.g. *eyes*) commonly have a plural referent, but plural non-dominant items (e.g. *noses*) have a singular referent.

To summarize, the *full parsing* models require prelexical treatment of morphological constituents and can be implemented as a segmentation model or an activation model. However, the *full listing* hypothesis defends a non-prelexical processing of the morphological structure and a complete representation of all morphologically complex words. Moreover, the lexical level may or may not be morphologically organized. Finally, mixed models such as the AAM or the Parallel Dual-Route Model include prelexical morphological computation and lexical representation of the complex words, depending on factors such as frequency, regularity, transparency, dominance, etc.

The profusion of morphological models mirrors the need to respond to some fundamental and challenging questions: Is the morphological structure of the word relevant for the lexical processor? What is the level of the morphological computation? Is morphological processing a condition for the lexical access or, on the contrary, does it reflect a more central, lexical organization? Is it a rule-based system or an associative property?

The aim of this paper is to review some of the available data regarding the role that morphology can play in lexical access and representation, discussing different studies that use a wide range of experimental paradigms. Data are presented from non-word processing, contrast between regular and irregular verbs, priming studies and the manipulation of the superficial frequency versus the cumulative frequency. Some other papers that address this topic are the excellent reviews by Chialant, and Caramazza (1995), Clashen (1999) McQueen and Cutler (1998) and Sandra (1994).

Morphologically structured pseudowords

The research that has used pseudowords as stimuli supports the full parsing models of lexical processing. Suppose that a person has to recognize a stimulus that is a pseudoword composed of real morphemes, such as *dejuvenate*. If the prelexical unit of lexical processing is the morpheme, the reaction time to reject this stimulus as a word in a lexical decision task will be increased with respect to a pseudoword non-morphologically structured, such as *depertoire* (Taft and Forster, 1975). The problem with these results is that the similarity of *dejuvenate* to real words could be higher than the similarity of *depertoire*. Taft and Forster (1975) and Henderson, Wallis & Knight (1984), who replicated their results, do not control the N of Coltheart[1] for the different types of stimuli, although it has been proved that subject performance is affected by neighborhood size (N) (Carreiras, Perea & Grainger, 1997). However, there are other studies that control the similarity to real words across the N parameter, obtaining the same results. Pseudowords such as *cant-evi* (in Italian), composed of a real stem and a real suffix, produce lower decision times than *cant-ovi*, composed of a real stem and an invented suffix (Caramazza, Laudanna & Romani, 1988). *Cantevi,* as *cantovi,* activates the same number of lexical representations. Therefore, these results support the morpheme as a different level of activation than letters. When the naming task is used, these results are reversed with respect to lexical decision

[1] The N is the number of different words that can be obtained by changing a letter from a given word. It is an index that expresses formal similarity between words without taking into account their morphologic structure.

experiments. The morphological structure facilitates the pronunciation of *cantevi* type pseudowords. The pronunciation of morphologically structured pseudowords involves the combination of pre-assembled morphemic representations, whereas pronunciation of control pseudowords does not benefit from the availability of pre-assembled phonological representations.

These results support a model of full parsing (Taft and Forster, 1975), but because it requires a morphological segmentation, the model predicts that the recognition of complex words will be more time consuming than the recognition of monomorphemic words. A prefixed word such as *re-cover* will require more time to be recognized than a monomorphemic word such as *humane*. Also pseudoprefixed words such as *regatta* (this word begins with the same letters (re), but they do not conform a prefix) will be recognized more slowly than *re-cover* because in a full parsing model RE will be detected as a candidate affix. The following search for a stem such as *gatta* will produce a garden path and a new search for the monomorphemic word *regatta* . However no reaction time differences were found between polymorphemic and monomorphemic words (Manelis & Tharp, 1977). Henderson, Wallis and Knight (1984), on the other hand, found that prefixed words (i.e. *recover*) were responded to faster than pseudoprefixed words (i.e. *regatta*) and control monomorphemic words (i.e. *humane*), but these two latter types did not differ from each other.

The lack of differences in the recognition time for monomorphemic and polymorphemic words and between psuedoprefixed and control words does not support a model of prelexical mandatory segmentation. Perhaps the effect over morphologically structured pseudowords explained earlier was due to the non-lexical status of these stimuli. Its composition from familiar roots and affixes could require a separation of the morphemes to carry out the task. To reproduce the morphological segmentation on the words, the selection of low frequency and regular items composed of roots and affixes of high frequency would be necessary. However, a direct procedure with no morphological segmentation would be more plausible.

Morphologically irregular words

Morphological regularity or transparency demands that complex forms obtained by adding affixes to a root preserve their orthographic form. The word *com-ía* (*I ate*) is, in Spanish, a regular verb form because the graphemes and phonemes of the root *com-* in the infinitive form are totally preserved in this past verb form. However, the past form *era* (*I was*) is irregular because its graphemes are very different from its corresponding infinitive form *ser (to be)*. Therefore, to recognize *era,* it is not a good strategy to use the orthographic similarity as a cue to entry into the appropriate morphological family. The best option for irregular words would be to store all the forms separately in the lexicon. Conversely, regular words could be recognized after a process of affixation by rules. This process could be the only one possible for recognizing regular forms of very low frequency of use and morphologically complex forms such as *previsualizaban (previewed)*.

An important morphological debate is centered around the differences in processing of regular and irregular verb forms. Using the priming paradigm, the results indicate that *walked*, a regular past-tense form, facilitates the processing of the stem form *walk*. However, an important reduction of the priming, and eventually non priming, is found when the prime is an irregular past tense, such as *drove,* and the target its corresponding stem *drive* (Napps, 1989; Stanners, Neiser, Hernon & Hall, 1979; for intermodal priming see Marslen Wilson, Hare & Older, 1995; see, however, Orsolini & Marslen-Wilson, 1997 for alternative results in Italian).

The debate is focused on the need for a dual system of processing and representation of the morphological information. The regular forms such as *walked* can be accessed via the stem *walk* and the application of a rule that in English involves adding the suffix *–d*. On the contrary, this procedure cannot be used for irregular forms such as *drove*, and, therefore, it is necessary for them to be represented lexically.

These differences do not present a problem for a dual model such as the AAM, but how do the full listing models explain these results? It is considered that the exposition of a connectionist system to the phonological form of the verb stems and their association with the corresponding past tense forms is enough for the learning model to produce this verbal form irrespective of the regularity of the stimuli. Also, it is expected that during the learning process the connectionist network generalizes to new irregular forms, producing any past tense form correctly. A specific purpose for implementing past tense recognition in a connectionist model is provided by the Rumelhart and McClelland network (1986), and later develops (MacWhinney & Leinbach, 1991; Plunckett & Marchman, 1993).

However, a drawback of these models is that they do not correctly mimic the learning process of irregular forms in children. The U-shaped learning curve is typical (Berko, 1958; Clashen & Rothweiler, 1993): first, children produce a reduced number of irregular forms correctly. Then, they produce a variable amount of over-regularization and finally, when their lexicon has increased sufficiently, they produce both type of verbs correctly: regular and irregular. It appears difficult to explain this particular pattern of learning from a connectionist system, which often exhibits sudden changes of tendency, produces irregularization errors (i.e. regular form produces irregular forms) and does not generalize adequately to new irregular forms.

Morphological irregularity and neurological measures

The previous considerations support a double route procedure to explain the results of the research (AAM model, Caramazza et al., 1988; Clashen, 1999). Some other converging evidence comes from some very recent studies on neuroscience. The positron emission tomographic has allowed the observation of both the areas and the amount of cortical activation produced by past tense regular verbs and past tense irregulars. Regular verbs activate left temporal inferior areas, whereas irregular verbs activate frontal superior areas (Jaeger, Lockwood, Kemmerer, Van Valin, Murphy & Khalak, 1996). Some other studies have also found different areas for these verbal forms using the Event-Related Brain Potential (ERPs) measures. Moreover, these areas are not similar in all the research (Penke, Weyerts, Gross, Zander, Münte & Clashen, 1997); Weyerts, Penke, Dohrn, Clashen & Münte, 1997). Furthermore, a reduction in the amplitude of the N400 wave has been found for regular primed verbs, but no such effect has been noted for irregular verbs.

Finally, some aphasic patients have allowed a double dissociation for the two type of verbs. One subgroup of patients showed morphological priming for regular forms, but not for irregular forms. The other subgroup showed the opposite pattern of results (Marslen-Wilson & Tyler, 1997, 1998). Moreover, in this study, DE was a patient who manifested agrammatical talk and the non-production of regular verbs, whereas the semantic dementia patient ES showed no problems with regular forms, but a poor performance regarding the production of irregular forms. Both patients showed different localization of their respective damaged areas in their MRI (Marslen-Wilson and Tyler, 1998).

These discoveries have supported the lexical access across both types of verbs via full-form representations or morphological parsing. Also, and more importantly, these two routes are qualitatively distinct and neurologically disassociable.

In summary, the differences in the amount of priming for regular and irregular verbs, the limitations of the connectionist models to adequately generalize their learning, and the dissociation of the neural circuitry for regular and irregular forms suggest the need for two different processing systems.

Morphological Priming

The priming paradigm allows the manipulation of sublexical structures such as letters, syllables or morphemes to ascertain the differences in processing that influence each of them. We have carried out some priming experiments with

Spanish nouns and adjectives with a conductual measure (lexical decision time) (Domínguez, Cuetos & Segui, 1999a) and ERP (Event Related Potential) registers (Barber, Domínguez & De Vega, 1999). The aim of the study was to test differences between pairs of words such as *loc-a/loc-o* (*crazy woman / crazy men*) that share their root and change only the gender suffix, and pairs of words such as *foc-a/foc-o* (*seal/lightbulb*) that share the orthographic description of the stem, but, in fact, remain morphologically and semantically unrelated. Pairs such as *loca/loco* could be considered regular items with respect to the gender suffixes *-a/-o*. On the other hand, for pairs such as *foca/foco,* the suffix *-a/-o* does not mark the masculine or the feminine forms, but rather distinguishes lexical items without any semantic relationship. In this respect, the *foca/foco* pairs could be considered irregular items. Laudanna, Badecker and Caramazza (1989) name them *stem homographs*. By definition, stem homographs need to be listed in the lexicon as full-forms, whereas the storage of the two gender forms of morphologically regular roots such as *loca/loco* is not necessary.

Our objective was to test the priming effects for morphologically and orthographically related pairs (stem homographs) relative to an unrelated condition across two SOAs: a 64 ms SOA with masked prime presentation and a 250 ms. SOA with unmasked presentation. The results showed that at 64 ms. SOA the facilitation was significantly higher for morphological pairs than for stem homographs (which produce significant facilitation on the unrelated pairs), and at the 250 ms. SOA the facilitation from morphological pairs remained significant, whereas the stem homograph pairs produced a non significant tendency toward inhibition (see figure 1).

García-Albea, Sanchez-Casas and Igoa (1998), with a very similar manipulation, found a significant facilitation at 64 ms. masked priming for morphological pairs, but a non-significant facilitation for orthographically related pairs, although they did not directly compare both.

Also, we have tested priming differences with similar categories and stimuli recording the ERPs. The usual negativity effect at around 400 ms was found for targets of unrelated pairs. The waveforms for orthographic (*foca-foco*) and morphologically (*loca-loco*) related conditions showed a significant reduction of this negativity, but started to differ at 350 ms. Orthographically related pairs showed a broad negativity, with a peak latency at 550-650 ms. ERP of morphologically related pairs did not show that negativity (Barber, Domínguez & De Vega, 1999).

As in the case of the past-tense research, our results could be used in support of the dual route models, because irregular pairs, or stem homographs, which need to be listed in the lexicon, produced a different priming pattern than morphologically related pairs. But the question is whether a non-dual connectionist model is capable of explaining these differences between the processing of regular and irregular words based only on the computation of semantic and orthographic features.

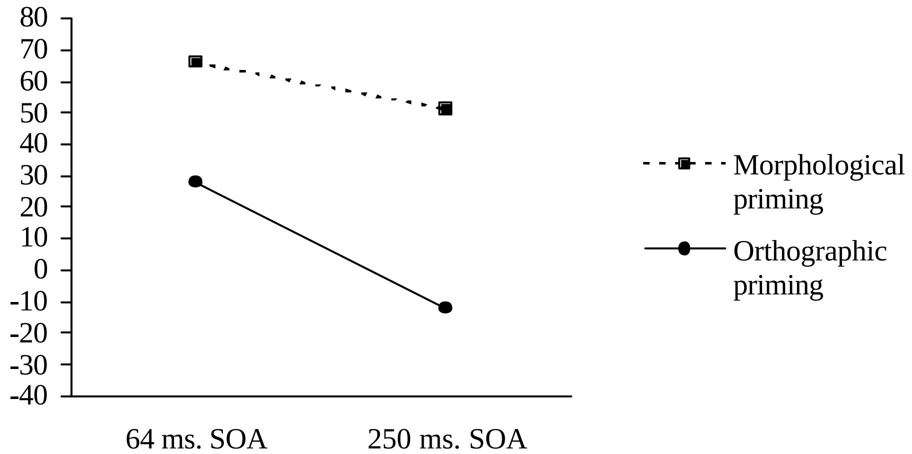


Figure 1. Facilitation for morphologically related pairs (*loco*-*loca*) and stem homograph pairs (*foco*-*foca*) at 64 and 250 ms SOAs in a lexical decision task. A higher and more sustained facilitation is observed for morphological pairs than for stem homographs, which at the longer SOA tended to inhibition.

The response has to be affirmative for the past tense studies. The orthographic overlap between *walk* and *walked* is greater than that between *drive* and *drove.* Perhaps the reduction of the priming for irregularly inflected words was due to this overlapping difference. Moreover, the orthographic overlapping of our stimuli was similar in the morphological category (*loco/ loca*) to that in the stem homograph category (*foco*/*foca*). The prime and the target shared the same number of letters in the two experimental conditions, but the semantic information that incorporates the specific orthographic description of the prime was only useful for the access to the target meaning in the morphological pairs, and promoted a "garden path" in the stem homograph target. *Loco* provides a secure piece of information to reach the meaning of *loca,* but *foco* is a non-reliable cue to arrive at the meaning of *foca*..

Some other studies have dedicated their efforts to solving this alternative explanation. Laudana, Badecker and Caramazza (1989) reported slower lexical decision times for a pair of stem homographs such as *portare/porte* (*to carry/door*) than for pairs of words with similar orthographic overlapping, but different stem descriptions such as *coll-o* (neck)/*colp-o* (blow). Similar results were obtained in Spanish by Allen and Badecker (1999). The inhibition obtained for *mor-ía/mor-os* (the prime is the first and third person singular imperfect form of the verb *mor-ir* "*to die*"; the target means *arabic*) was higher than the inhibition for *moral/mor-os (morality/ arabic)*. This result points, first, to an orthographic activation of the stem *mor-*, and, second, to a competition between the two morphemes and meanings (*death* and *race*) that activates the orthographic description of the root *mor-*. The homographic stem inhibition is not explicable in terms of letter overlap, but only in terms of morphological parsing.

The nature, orthographic, morphological or semantic, of the underlying process that explains these inhibitory results is not so clear. The study of Laudanna et al. (1989) in Italian and of Allen and Bakecker (1999) in Spanish have assumed the AAM model (Caramazza, Miceli, Silveri & Laudana, 1985; Caramazza, Laudana & Romani, 1988) was the best frame to explain their results. In this model, the entries are stored in an Input Orthographic Lexicon as a structured sequence whose first element is the orthographic form of the stem and all the grammatical features associated with this form. The entries for *moría* and *moros* have the same orthographic form; they are stem homographs. As a consequence, the competition or inhibition at the moment of lexical selection is produced.

However, the study of Allen and Badecker (1999) attempts to find out whether the nature of the lexical representations is orthographic or, on the contrary, it is necessary to assume another abstract level (not formal) of representation of morphological order (M-level). This level allows the discrimination between homographic stems and, equally important, permits the use of the same entry to different orthographic representations of the same stem, such as irregular forms in the case of the English irregular past tense. To test this hypothesis the aforementioned authors presented a prime such as *huele* (third person singular present form of the verb *ol-er* [*to smell*]) and a stem allomorph target such as *ol-as*(*waves*). An allomorph is a flexion whose phonological and orthographic aspect has changed from the base form (*ol-er [to smell]*). *Huele* is an allomorphic form of the stem of the noun *ol-as*. If the inhibition obtained for the stem homographs *mor-ía/mor-os* was abstract and located at the M level, it is hoped that *huele* inhibits *ol-as*, but *duele* (third person singular present form of the verb *doler [to hurt]*) does not. *Huele* and *duele* have the same orthographic similarity with *olas*; however, only *huele* has some capacity of inhibition on this target because of its morphological relationship. It is supposed that if the orthographic lexical forms similar to *huele* were first activated (i.e., neighbors) at the orthographic input lexicon (i.e., *huelen, huelo, huero, hueco, huevo*), and then at the M level (the so-called morpho-syntactic-semantic level of Allen and Badecker, 1999), the forms that share the stem (stem homographs also) will be activated, irrespective of their superficial aspect (i.e., *huel-en, ol-er, ol-ían, huel-o, olor, ol-as, etc.*). This explanation provides a framework to explain the effects. The inhibition of *mor-ía* on the target *mor-os* would be located at the abstract M level and not at the orthographic level as expected by the AAM model. However, the orthographic inhibition of *moral* on the target *mor-os* would be situated at the orthographic level (in this case the stems have a different orthographic representation, although the orthographic overlapping is similar). In the same vein, *huelen* will activate the abstract representation of the verb *ol-er* at the M level and will inhibit the representation of *ol-as,* which will be retarded with respect to a control situation where it appears as a target.

Some other studies provide experimental evidence favoring the differences between the processes that involve orthographic or morphological treatment. Drews and Zwitserlood (1995), using masked and unmasked primes in lexical decision and naming tasks in Dutch and German, obtained facilitation for the morphologically related pairs (*kersen-KERS [cherries-cherry]*), whereas the orthographically related pairs (*kerst-KERS [christmas-cherry]*) yielded inhibition on lexical decision time and facilitation on naming time. These results are in agreement with those of Segui and Grainger (1990), who obtained inhibition from an orthographically related masked prime.

Also, when the orthographic overlapping between prime and target is avoided by the use of two alphabets, as is possible in Serbo-Croatian, a similar facilitation is obtained for morphological and identity priming as for pairs written with the same alphabet. (Feldman & Moskovljevic, 1987).

In summary, the data coming from the use of the priming paradigm supports a procedure of the lexical access based on the morphological structures of the words. Furthermore, the effects are not an emergent property of a system with only a direct route of processing that computes only orthographic features of the words.

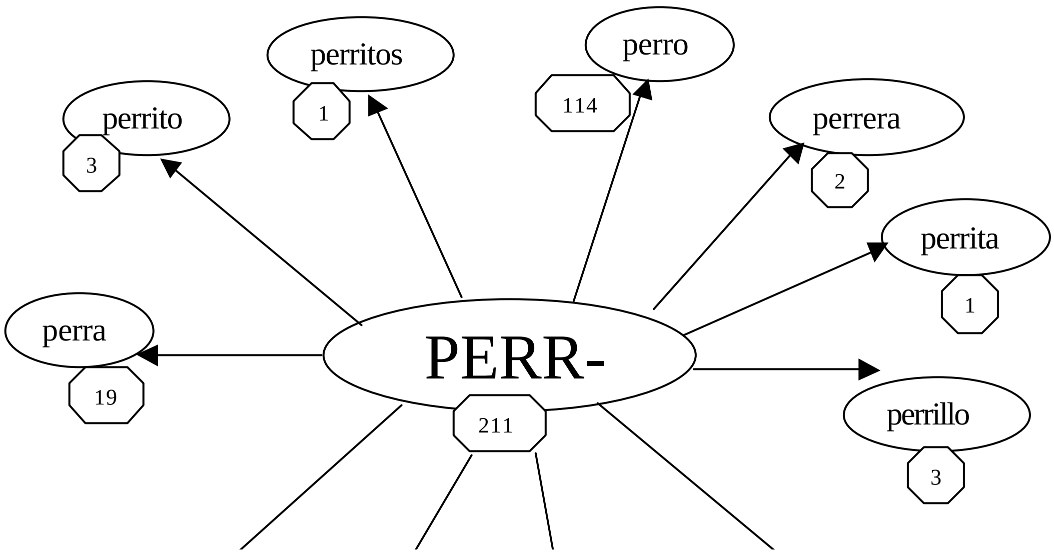
Superficial and cumulative frequency

One of the most consistent effects in visual word recognition is the lexical frequency: words that appear frequently in the texts are recognized faster than low frequency words. This effect, reported by Howes and Solomon (1951), has been repeatedly replicated using different paradigms and experimental tasks.

However, this is not a unitary effect. In fact, this effect has been systematically confused with the neighborhood frequency effect (Segui & Grainger, 1990): a low-frequency word will generally tend to have neighbors of higher frequency than itself, whereas a high frequency word will tend to have lower frequency neighbors (Landauer & Streeter, 1973).

Also, the contrast between stem frequency (cumulative frequency) and superficial frequency (see figure 2) could be a new source of confusion: a low frequency word will have morphological relatives of higher frequency, whereas a high frequency word will have morphological relatives of lower frequency. Therefore, the access to a particular lexical form could be determined not only by its own frequency, but also by the frequency of the morphemes that make up the input.

The contrast between these two frequency indexes has been used to determine whether the lexical access is achieved by employing a morphological code, the stem, or, in contrast, via whole-word representation. For full parsing models, because the lexical access is achieved across the stem, it is to be expected that the access be more sensitive to the cumulative frequency. Unlike for the full listing hypothesis, because the lexical access is accomplished by contacting the input with a whole-word representation, a greater influence of the superficial frequency on the reaction times is predicted. The comparison between words such as *shoe* and *fork* may be of interest. Both words have similar superficial frequency but different cumulative frequency. The singular form of *shoe* is less frequent than the plural form *shoes*. On the other hand, the singular form of *fork* is more frequent that the plural form *forks*. Taft (1979) demonstrated that lexical decision times are shorter for *shoe* than for *fork*. However, Taft also reported significant differences when the opposite manipulation was carried out: At the same cumulative frequency, the stimulus with a higher superficial frequency is recognized sooner (Taft, 1979; Burani, Salmaso & Carammazza, 1984 in Italian). Both results seem contradictory, unless one supposes the subject's performance was the consequence of two points of influence of the frequency, prelexical for cumulative frequency and lexical for superficial frequency; or a dual system model was operating (Caramazza, Laudanna & Romani, 1988; Schreuder & Baayen, 1995; Taft, 1994).



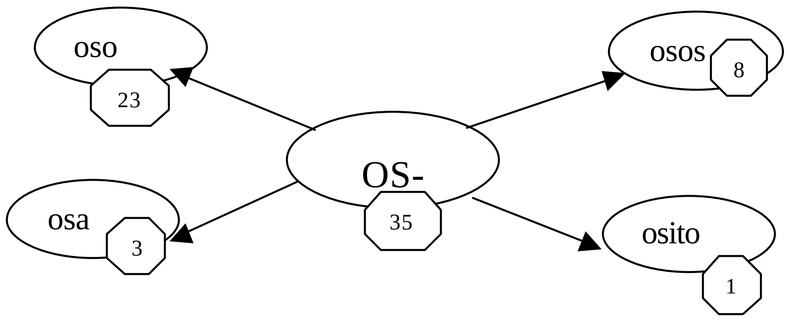


Figure 2. Lexical representations for two different stems with a high (top) and a low (down) cumulative frequency (from Alameda & Cuetos dictionary). The superficial frequency for *perra (female dog)* (19) and *oso (male bear)* (23) is similar but the recognition of these words depends, according to some theoretical accounts, on the frequency of the stem, 211 for *perra* and 35 for *oso*.

Some other very recent results contrast both types of frequencies and thereby increase the problems of interpretation of the existing data. Sereno and Jongman (1997) compared English noun stimuli with different inflectional structures (inflected plural nouns or uninflected singular nouns). Nouns were presented in homogeneous lists of singular or plural forms in a series of lexical decision experiments. The results indicated that the frequency of the presented form (singular or plural) was the essential determinant of RTs. When nouns were presented in the singular form, high-base/low-plural frequency items were responded to faster than low-base/high-plural items. In contrast, when the same nouns were presented in the plural form, high-base/low-plural items were responded to more slowly than low-base/high-plural items. Sereno and Jongman have also studied the eventual contribution of the root frequency by comparing two sets of nouns equated in terms of frequency of uninflected words but contrasting in terms of cumulative frequency. The main result was that total or cumulative frequency contributes little to response time in uninflected or inflected nouns. This result confirms the substantial contribution of surface frequency in the determination of lexical decision response times.

On the other hand, Bayeen et al. (1997) support the claim that response latencies to singular words in Dutch are determined by the frequency of the stem whereas the latencies to plural words are only determined by their superficial frequency. The suffix *–en,* in Dutch has two different roles: as a plural suffix or as a verbal suffix. It is possible that this subcategorization ambiguity leads to a full listing of plural forms in the lexicon. Perhaps the use of another more common suffix in Dutch would produce results in favor of the stem frequency. In this respect, Clahsen et al. (1999) contrasted the effects produced by the superficial frequency on two groups of plural German words. One of them forms the plural using a very common and regular suffix, *-s*, whereas the other admits only an infrequent suffix, *-er*. Regular –s plurals produced similar decision times, irrespective of whether they were low or high frequency words. Irregular (or infrequent) *–er* plurals, however, produced significant differences between high and low frequency words.

In summary, Sereno and Jongman (1997) defend separate representations for all of the gender and number flexion of English words. However, Baayen et al. (1997) support only the representation of high frequency plurals in German. And finally, Clahsen (1999) demonstrates that the distribution properties of affixes is one of the parameters that influences morphological processing in the experiments: the less frequent a suffix is in a complex word, the higher the probability of this word's representation in the lexicon.

Some other data increase the interpretation problems for the frequency variable. Kelliher & Henderson (1990) found, unlike in Clashen´s (1999) data, an influence of the cumulative frequency (with superficial frequency equated) on the reaction times of irregular past tense forms: *bought* produced faster reaction times than *shook* because the infinitive form *buy* is more frequent than *shake.* Because irregular past tense forms need, by definition, to be represented as independent forms in memory, this effect has to be the consequence of a lexicon morphologically organized and cannot be interpreted as the result of a common entry for related forms. Even the priming effect with allomorphs in Spanish (Allen & Badecker, 1999), explained by the authors as a product of a common abstract morphological code, admits an interpretation in terms of a central organization.

Gender frequency in Spanish

Gender has not received the same amount of experimental attention as number. This is a particular consequence of the problem that the majority of psycholinguistic research relies on English, a language that some authors consider atypical (Cutler, 1997). English does not have gender suffixes and represents sexual differences with separate lexical entries. Spanish, on the contrary, merges masculine and feminine gender suffixes with a bound stem. Gender (and number) is expressed in Spanish at three levels of representation: morphological, syntactic and semantic. Morphological gender value depends on the phonological end of a stem and is reflected by a suffix. In general, the suffix "-a" gives the feminine value to a word and the suffix "-*o*" gives its masculine value (vg. *loc-a* [*crazy woman*] and *loc-o* [*crazy man*]).

The aim of our study was to manipulate the superficial and the root morpheme frequency of feminine and masculine words to find out some clues about the morphological processing of these words. It is anticipated that the gender suffixes used in our stimuli (i.e. a/o) are very regular in Spanish, and, therefore, we expected a greater influence of the cumulative frequency on lexical decision times. A feminine or a masculine regular word could be decoded by the application of a simple rule of segmentation and addition of suffixes. This is, in fact, the expected route of processing for these type of words by both the dual and full parsing models.

Our initial approach to the gender processing (Dominguez, Cuetos & Segui, 1998) was to take a set of words in their four possible gender (and number) forms and carry out a lexical decision task (e.g. masculine singular: *loco*; feminine singular: *loca*; masculine plural: *locos* and feminine plural: *locas*). The next step was to correlate the frequency for each individual form with their reaction times. The aim was to discover the best predictor for the reaction times of a particular form: its own frequency or, on the contrary, the frequency of the other gender or number form. In particular, in Spanish, the masculine is the non-marked form. For example the form *"el perro" (male dog)* , the masculine form, is used to refer to *perros (male dogs*) and *perras (female dogs)* in a generic context *"el perro es el mejor amigo del hombre" "the dog is man´s best friend"*. Perhaps the frequency of the masculine version of the words better predicts the reaction times of the feminine words than their own frequency. The results showed a better correlation of reaction times in a lexical decision task for masculine and feminine forms with their respective logarithmic frequency than with the frequency of the other gender form (see table 1, all indexes of correlation are statistically significant).

Table 1. Correlation between reaction times and frequency of masculine and feminine forms in a lexical decision task. Each gender correlates better with their own frequency than with the frequency of the opposed gender.

	REACTION TIMES			
	SINGULAR		PLURAL	
FREQUENCY	MASCULINE	FEMININE	MASCULINE	FEMININE
MASCULINE	.72	.52	.60	.40
FEMININE	.42	.58	.33	.49

The first conclusion drawn is that the superficial frequency is the strongest predictor of gender. However, this is a tentative conclusion because of the correlational method used. A new experiment tried to test this prediction with a more suitable methodology (Domínguez, Cuetos and Segui, 1999b). Our intention was to compare the lexical decision times for pairs of words that share the same root, but differ in the frequency of the masculine form and feminine form. The pair *viuda/viudo* is feminine dominant because *viuda* is more frequent than *viudo*. On the other hand, the pair *ciego/ciega* is masculine dominant because *ciego* is more frequent than *ciega*. Again the subjects performed a lexical decision task on these words. The results showed faster reaction times for *viuda* than for *viudo* and for *ciego* than for *ciega* (see figure 3), although the differences were more substantial for masculine dominant stimuli.

The superficial frequency was the best predictor of RTs, irrespective of the gender of the word. It seems that the two gender forms of a stem are stored separately in the lexicon. However, a new test could be carried out manipulating the cumulative frequency in pairs of words equated in their superficial frequency. We want to know whether the reaction time for *calvo (bald man)*, will be similar to the reaction time for *guapo (handsome)*. Both words have a similar superficial frequency, but a different cumulative frequency, because the frequency of *calva* (*bald woman*) is lower than its masculine form, whereas the frequency of *guapa (pretty)* is higher than the frequency of *guapo* (see figure 4). The results of this manipulation showed identical decision times for *calvo* and *guapo* .

It has been demonstrated by these two reversed procedures that the only predictor of reaction times for masculine words is their own reaction time, as suggested by the correlational study. But what is the case for feminine words? The same manipulation was carried out recently in our laboratory. The results are as yet preliminary and non-conclusive, but it seems that lexical decision times for feminine forms are significantly different for high and low cumulative frequency forms, in contrast with the results obtained for masculine words. Remember that the differences in reaction times for masculine and feminine forms of the same stem when the feminine is the dominant form was less than in the case where the masculine was the dominant form.

The variability of the results could be due to the influence of another factor that has not been take into account: the cumulative frequency could be affected differentially by high and low frequency words. The dual models predict a direct access for high frequency words because firm lexical representations have to be made, whereas low frequency words will be accessed through their stem.

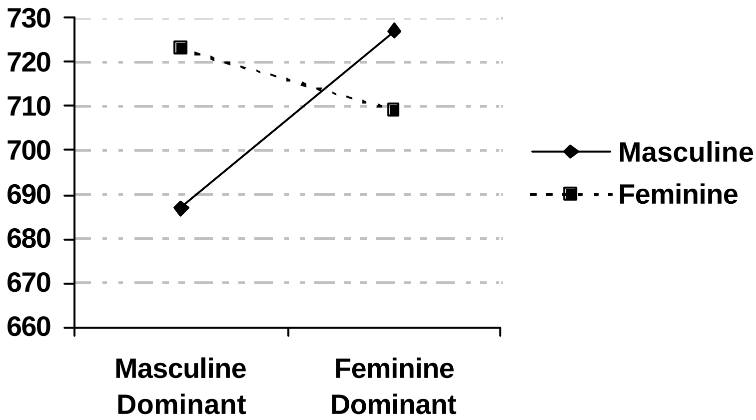


Figure 3. Lexical decision Times for masculine and feminine forms of the same stem in two categories: masculine dominant and feminine dominant. The differences in each category reveal the superficial frequency as the best predictor for reaction times.

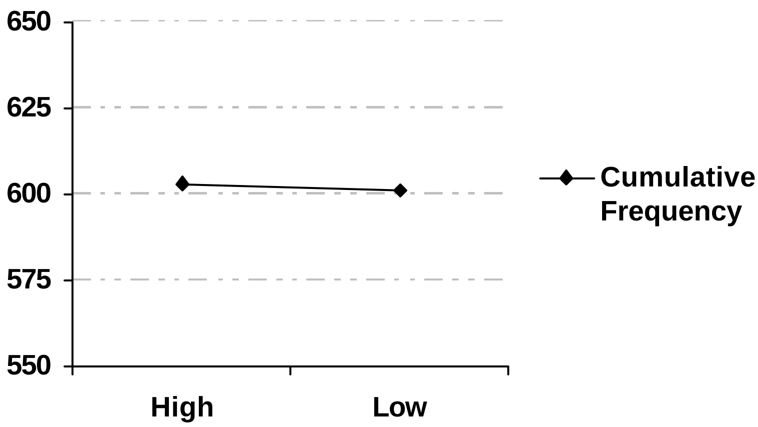


Figure 4. Lexical Decision Times for masculine words of high cumulative frequency (*guapo [handsome]*) and low cumulative frequency (*calvo [bald man]*). The superficial frequency for both words was equated. No effect of the cumulative frequency was observed.

Number frequency in Spanish

Morphological number is expressed, in Spanish, by default (*-0*) in the singular value and by the suffix "*-s*" (or *-es* when the word ends in a consonant) in the plural value (i.e. *loc-a [crazy woman]* and *loc-a-s [crazy women] or árbol [tree] and árbol-es*). This is an inflectional category in English, German or Dutch, and very recent studies have been carried out in these languages which allow an interesting comparison to be made.

A difference with respect to gender is the lexical status of the base form to which the suffix of number is added. Inflected masculine and feminine words are obtained by adding *–o* or *–a* to a root morpheme that is a bound stem, not a word. Number, on the contrary, is composed of a base morpheme that is a word with, generally, a suffix of gender incorporated (i.e.*loc-a-s [crazy women]*). *Loc-*, a base morpheme that admits gender suffixes is not a word in Spanish, but *loca-* or *loco-*, the base morphemes that are made plural by adding the –s suffix, are two lexical entries in the dictionary. Perhaps this important point will produce some differences in the processing of plural words.

As in the case of the gender experiments, a similar correlational study was completed. The correlated factors were the reaction times in a lexical decision task on singular and plural words (the same base morphemes which were used for gender) and the logarithmic superficial frequency of each form. Table 2 shows the significant correlation. The remarkable result was that RTs for singular forms correlated better with the singular frequency, whereas the RTs for plural forms correlated a little better with the frequency of the singular forms than with their own frequency.

Table 2. Correlation between reaction times and frequency of singular and plural forms in a lexical decision task. Singular forms correlate better with singular frequency, but plural forms correlate better with the frequency of the singular forms.

	REACTION TIMES			
	MASCULINE		FEMININE	
FREQUENCY	SINGULAR	PLURAL	SINGULAR	PLURAL
SINGULAR	.72	.61	.68	.50
PLURAL	.68	.60	.49	.49

Number seems to behave differently from gender. These preliminary data indicate that the plural forms could be acceded from the singular forms. This is not such a strange conclusion because, in fact, gender and number can be distinguished in Spanish in the way they are obtained, as has been indicated before. The asymmetry between the results of the experiments of gender and number was investigated (Domínguez, Cuetos and Segui, 1999b) with a more suitable design: manipulating the superficial frequency of two lists of words. The first included singular dominant words with a higher frequency of the singular form with respect to the plural form (*cielo [sky]*). In the second list, plural dominant, the frequency for plurals was higher than for singulars (*brazo [arm]*). The cumulative frequency for number (singular plus plural form frequency of the same stem morpheme) was equated. On a lexical decision task, singular forms were responded to faster than plural forms in the list of singular dominant stems. However, no differences between singular and plural items were obtained when the more frequent form of a stem was the plural (see figure 5). The variation in the superficial frequency affects the results only when the dominant form is singular, and not when it is plural.

Two new experiments were run. The first employed pairs of singular words, such as *dama* and *dedo*, equated in their superficial frequency, but differing in their cumulative frequency (the frequency of *damas* was lower than the frequency of *dama*, whereas the frequency of *dedos* was higher than the frequency of *dedo*) . The lexical decision times (see figure 6) in a lexical decision task were significantly shorter for *dedo* (with a high cumulative frequency) than for *dama* (low cumulative frequency). The second experiment included pairs of plural words, such as *botas* and *ratos*, equated in their superficial frequency, but differing in their cumulative frequency (the frequency of *bota* was lower than the frequency of *botas*, whereas the frequency of *rato* was higher than the frequency of *ratos*). *Botas* was recognized more slowly than *ratos* (see figure 7). Again the cumulative frequency created differences in the reaction times: the higher the cumulative frequency, the lower the lexical decision times.

In summary, it seems that the superficial frequency influences the reaction times for singular words but not for plural words. On the other hand, the cumulative frequency (singular plus plural frequency) induced important differences in the singular words as well as the plural words. These results seem to be inconsistent because superficial frequency like cumulative frequency produces significant differences, but this pattern of results is not so atypical. Taft (1979) obtained significant differences for both variables. Moreover, the interactive models that represent morphology as connections at the lexical level (Drews & Zwitserlood, 1995; Grainger et al., 1991) can simultaneously assume both types of results: cumulative frequency could be the result of a summed activation of members of a morphological family, and superficial frequency could determine the resting activation of a particular node. These results could also be predicted by a dual model such as the AAM: the segmentation route would be sensitive to the cumulative frequency because it computes the stem at a prelexical level, whereas the superficial frequency would be the product of the recognition of those words which are represented in their complex form at the lexical level.

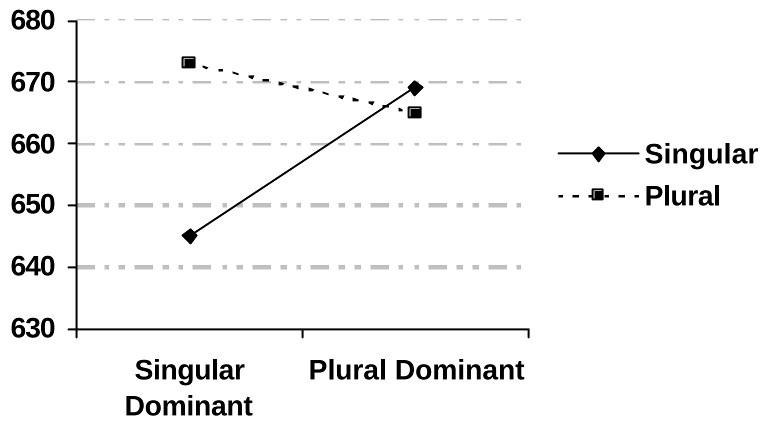


Figure 5. Lexical Decision Times for singular and plural words of the same stem in two categories: singular dominant and plural dominant. The differences in each category reveal the superficial frequency as the best predictor for singulars but not for plurals.

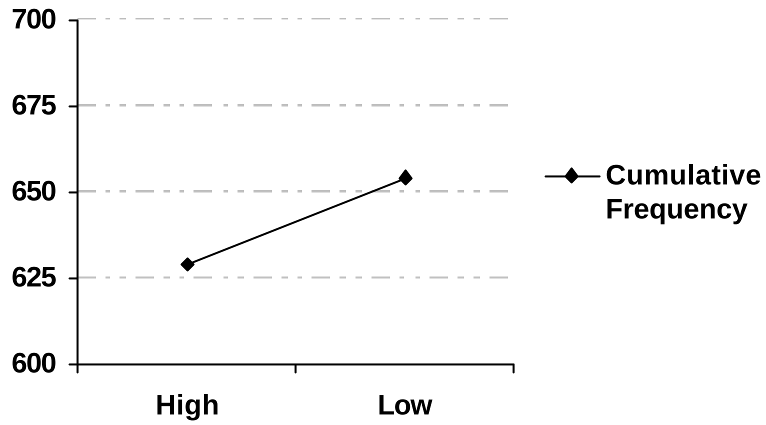


Figure 6. Lexical decision Times for singular words of high cumulative frequency (*dedo*) and low cumulative frequency (*dama*). The superficial frequency for both words was equated.

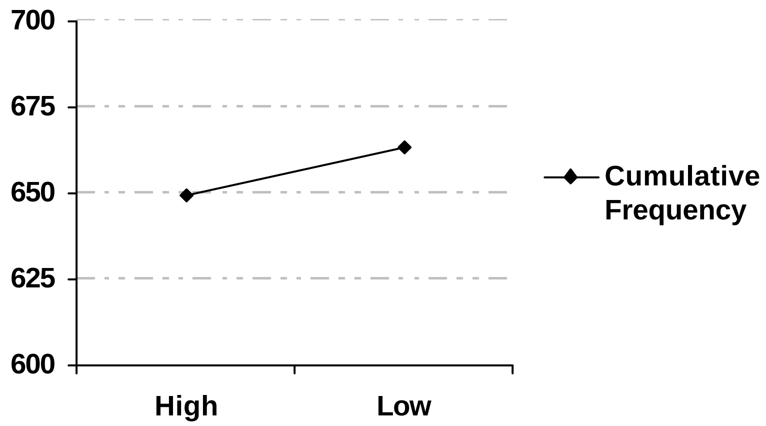


Figure 7. Lexical decision times for plural words of high cumulative frequency (*ratos*) and low cumulative frequency (*botas*). The superficial frequency for both words was equated.

In short, our results concerning the plural flexion differ from those of Sereno and Jongman (1997) where a common representation for singulars and plurals is proposed. They also differ from the Baayen et al. (1997) results that propose an independent representation only for plurals. According to our data, the recognition time of a singular word is influenced as much as by the frequency of the root as by the frequency of the particular form. However, plural word recognition depends on the frequency of the root. Singular words could be represented in the lexicon, whereas plurals would be recognized from a previous access to the singular form. These results are compatible with those of Taft (1979) and Burani, Salmaso & Carammazza (1984). They also could be interpreted from different theoretical frameworks, because the dual and the interactive models, with adequate morphological restrictions, could adequately fit the results. In order to decide between them, it would be necessary to collect new data, which, for the moment, are unavailable.

The results for gender processing are quite different from those obtained for number processing. The contrast between superficial and cumulative frequency for words with gender suffixes supports the superficial frequency as the best predictor of reaction times. Perhaps the differences with number processing are caused by the lexical or non-lexical condition of the base morpheme to which the suffixes are attached: a bound

CONCLUSIONS

Some questions have been raised at the beginning of this article about the processing of word morphological structure. Our first aim was to clarify whether morphological processing is really necessary or, on the contrary, it responds only to a linguistic analysis of the stimulus without psychological entity. The application of a wide variety of experimental and methodological approaches demonstrates the existence, in a word recognition system, of a morphological processing that takes into account the morphemes and affixes which compose the word as processing units, or, at least, computes the special relations between words of the same morphological family.

Two words with the same root morpheme also share a chain of letters or sounds and some semantic features. However, the formal overlapping does not explain the morphological priming effects when this overlapping is avoided by the use of primes and targets of different alphabets (Felmand & Moskovljevic, 1987), or stem allomorphs (Allen & Badecker, 2000; Laudana et al. 1989). Moreover, the effects of morphological priming usually show a stable facilitation, whereas orthographic priming with neighbor words (Drews & Zwitserlood, 1995; Grainger et al. 1991) and semantic priming (Napps, 1989) are variable and depend on some restrictions (e.g., SOAs).

However, not all morphologically related words show a facilitation effect. The irregular forms of the verbs produced a morphological priming significantly shorter than that obtained for regular forms (Stanners, Neiser, Hernon & Hall, 1979). According to the AAM model, this result supports a dual processing of stimuli. Irregular words are directly reached and represented in the lexicon and, therefore, do not receive priming because their roots do not become active when the morphologically related prime is presented (see, however the results of Allen and Badecker, 1999 with allomorphs). An interactive non-dual model (Drews & Zwitserlood, 1995; Grainger et al. 1991), on the contrary, represents all complex forms in the lexicon and has serious limitations for explaining why regular forms (*andar-andaba* [*walk-walked*]) have facilitatory connections and irregular forms (*ser-era* [*be-was*]) do not. At the morphological level, there is no reason to suppose that irregular forms, because they have a low orthographic similarity, produce a low facilitation.

A new source of evidence that supports the dual procedure of access for complex words is the contrast between superficial and root or cumulative frequency. In many cases, both variables produce significant differences with the same task and language (Taft, 1979; Burani, Salmaso & Carammazza, 1984). The contrast between languages offers contradictory results, as in the case of number processing in Dutch (Bayeen et al., 1997), German (Clashen, 1999), English (Sereno and Jongman, 1997) or Spanish (Domínguez et al., 1999b). This inconsistency precludes the conclusions concerning the locus, prelexical or lexical, of morphological processing. The results seem highly dependent on stimuli attributes such as orthographic transparency between the root and its flexion or derivation, semantic transparency, and dominance of the superficial frequency relative to the cumulative frequency. It is in this context where the dual route models (Caramazza et al., 1988; Baayen & Schreuder, 1999; Baayen, Dijkstra & Schreuder, 1997; Schreuder & Baayen, 1995) have proved successful, because they specify the attributes of the stimulus that increases the probability of being processed by a segmentation route or by a direct procedure.

Recent studies in neuro-imaging have supported the notion that stimuli derived by rules (regulars) use a different neural substrate than that used by irregular stimuli (Clahsen, 1999). This neural dissociation upholds a dual interpretation of the system.

On the contrary, it does not seem that the mandatory segmentation models or morphological mandatory prelexical processing (Taft, 1994) could be maintained. Also, extremist positions of connectionist models that reject morphological specifications in their architectures could prove to be unsupported (Butterworth, 1983; Mannelis & Tharp, 1977; McClelland and Rumelhart, 1981; Rueckl, Mikolinski, Raveh, Miner & Mars, 1997; Seidenberg and McClelland, 1989).

What is known for certain is that the morphological structure is computed at some moment in word processing, but the question continues to be whether the morphology acts at the prelexical or only the lexical level. The results obtained with the morphologically structured pseudowords support the prelexical processing of the roots. Nevertheless, the fact that this operation is one that requires no effort, as has been demonstrated with the contrast between monomorphemic and polymorphemic words, advises against supporting such models. In conclusion, we are in agreement about the need to uphold a model of word recognition that includes, at some level, operations on the morphological structure of the words. However, experimental findings up to the present have not been sufficiently resolved and delimited so as to permit the discernment between dual models with a prelexical morphological computation and those of an interactive processing that solely represent the morphology at a lexical level. For the moment, the dual models are the most effective and comprehensive because they include all the processing possibilities. Nevertheless, it is certain that such models emerge when the dispersion of the results increases, as occurred with the dual model of Coltheart (1978) for phonologically mediated and direct lexical access.

RESUMEN

Procesamiento morfológico en el reconocimiento de palabras: una revisión con especial referencia a los datos en español. El objetivo de este artículo es presentar de forma organizada los resultados que apoyan el procesamiento de las unidades morfológicas de palabras aisladas desde distintos paradigmas experimentales. Para ello se han revisado tres hipótesis que proponen distintas soluciones al problema del papel de la morfología en el acceso al léxico: a) segmentación obligatoria, b) listado exhaustivo y c) hipótesis mixta. Se barajan los problemas y ventajas de cada una de ellas, y de los modelos que representan, a la luz de los datos que provienen de las siguientes manipulaciones experimentales: pseudopalabras estructuradas morfológicamente, palabras monomorfémicas versus palabras polimorfémicas, estudios de priming morfológico y comparación entre frecuencia acumulada y frecuencia superficial.

Palabras clave: Morfología, listado exhaustivo, segmentación obligatoria, modelo de doble ruta, palabras irregulares, género, priming morfológico, frecuencia acumulada

REFERENCES

Allen, M. & Badecker, W. (in press) Stem homograph inhibition and stem allomorphy: representing and processing inflected forms in a multi-level lexical system. *Journal of Memory and Language*.

Baayen, H. & Schreuder, R. (1999) War and peace: Morphemes and full forms in a Noninteractive Activation Parallel Dual-Route Model. *Brain and Language, 68*, 27-32.

Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997) Singulars and plurals in Dutch: evidence for a parallel dual-route model. *Journal of Memory and Language, 37*, 94-117.

Barber, H, Domínguez, A. & De Vega (1999) Morphological and orthographic priming in Spanish: Evidence from event-related potentials. *Proceedings of the 39th Meeting of the Society for Psychophysiological Research. In Psycholphysiology, 36*, supplement 1, p. 30.

Berko, J. (1958) The child's learning of English morphology. *Word*, *14*, 150-177.

Burani, C., Salmaso, D. & Caramazza, A. (1984) Morphological structure and lexical access. *Visible Language, 4*, 348-358.

Butterworth, B. (1983) Lexical representation. In B. Butterworth (De.). *Language production* (Vol.2, pp.257-294). London: Academic Press.

Caramazza, A., Laudanna, A. & Romani, C. (1988) Lexical access and inflectional morphology. *Cognition*, *28*, 297-332.

Caramazza, A., Miceli, G., Silveri, C. & Laudanna, A. (1985). Reading mechanisms and the organization of the lexicon: evidence from acquired dyslexia. *Cognitive Neuropsychology, 2*, 81-114.

Carreiras, M., Perea, M. & Grainger, J. (1997) Effects of orthographic neighborhood in visual word recognition: Cross-task comparisons. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *23*, 857-871.

Coltheart, M. (1978) Lexical access in simple reading tasks. In G. Underwood (Ed.) *Strategies in information processing*. New York: Academic Press.

Chialant, , D. & Caramazza, A. (1995) Where is morphology and how is it processed? The case of written word recognition. In L. B. Feldman (De.), Morphological aspects of language processing (pp. 55-78) Hillsdale, N.J. Erlbaum.

Clashen, H. & Rothweiler, M. (1993) Inflectional rules in children´s grammars: evidence from the development of participles in German. Yearbook of Morphology 1992, 1-34.

Clashen, H. (1999) Lexical entries and rules of language: A multidisciplinary study of German inflection. *Behavioral and Brain Sciences, 22*, 991-1060.

Colé, P., Beauvillain, C. & Segui, J. (1989) On the representation and processing of prefixed and suffixed derived words: A differential frequency effect. Journal of *Memory and language*, *28*, 1-13.

Cutler, A. (1997) The comparative perspective: on spoken language processing. *Speech communication*, *21,* 3-15.

Domínguez, A., Cuetos, F. & Segui, J. (1999a) Gender and number processing in Spanish. Presented at the *Workshop of Processing of Grammatical gender*. Leippzig, July 24-25.

Domínguez, A., Cuetos, F. & Segui, J. (1999b) The processing of grammatical gender and number in Spanish. *Journal of Psycholinguistic Research, 28,* (5), 485-498.

Drews, E., & Zwitserlood, P. (1995) Morphological and orthographic similarity in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 5, 1098-1116.

Feldman, L.B. & Moskovljevic, J. (1987) Repetition priming is not purely episodic in origin. *Journal of Experimental Psychology: Learning, Memory and Cognition, 13,* 573-581.

García-Albea, J.E., Sanchez-Casas, R. and Igoa, J.M. (1998) The contribution of word form and meaning to language processing in Spanish: Some evidence from monolingual and bilingual studies. *Sentence processing: a cross-linguistic approach*. In D. Hilbert (Ed.) Academic Press.

Grainger, J., Colé, P., and Segui, J. (1991) Masked priming in visual word recognition. *Journal of Memory and Language, 30*, 370-384.

Henderson, L., Wallis, J., & Knight, D. (1984) Morphemic structure and lexical access. In H. Bouma & D.G. Bowhuis (Eds.), *Attention and performance X* (pp.211-226). London: Erlbaum.

Howes, D. H., & Solomon, R.L. (1951) Visual duration threshold as a function of word probability. *Journal of Experimental Psychology, 41*, 401-410.

Jaeger, J.J., Lockwood, A.H., Kemmerer, D.L., Van Valin, R.D., Murphy, B.W. & Khalak, H.G. (1996) A positron emission tomographic study of regular and irregular verb morphology in English. *Language, 22*, 3, 451-497.

Kelliher, S. & Henderson, L. (1990) Morphologically based frequency effects in the recognition of irregularly inflected verbs. *British Journal of Psychology, 81*, 527-539.

Landauer, T.K., Streeter, L.A. (1973) Structural differences between common and rare words: Failure of equivalence assumptions for theories of word recognition. *Journal of Verbal Learning and Verbal Behavior, 12*, 119-131.

Laudanna, A., Badecker, W. & Caramazza, A. (1989) Priming homographic stems. *Journal of Memory and Language, 28*, 531-546.

MacWhinney, B. & Leinbach, J. (1991). Implementations are not conceptualizations: Revising the verb learning model. *Cognition, 40*, 121-157.

Mannelis, L. & Tharp, D. (1977) The processing of affixed words. Memory and *Cognition, 5*, 690-695.

Marslen-Wilson, W.D. & Tyler, L.K. (1997) Dissociating types of mental computation. *Nature*, *387*, 592-594.

Marslen-Wilson, W.D. & Tyler, L.K. (1998) Rules, representations, and the English past tense. *Trends in Cognitive Sciences, 2,* 428-435.

Marslen-Wilson, W.D., Hare, M., & Older, L. (1995). Priming and blocking in the mental lexicon: The English past-tense. Paper presented at *the Meeting of the Experimental Psychology Society*, London.

McClelland, J.L. & Rumelhart, D.E.(1981) An interactive activation model of context effects in letter perception. Part I. An account of basic findings. *Psychological Review, 88*, 375-405.

McQueen, J.M. and Cutler A. (1998) Morphology in word recognition. In A. Spencer and A.M. Zwicky (Eds.) *The handbook of morphology*. Oxford. Blackwell Publishers.

.

Sandra, D. (1994) The morphology of the mental lexicon: Internal word structure viewed from a psycholinguistic perspective. *Language and Cognitive Processes, 9 (3)* 327-269)

Schreuder, R. & Baayen, H. (1995) Modeli morphological processing. In L.B. Feldman (Ed.). *Morphological aspects of language processing* (pp.131-154). Hillsdale, NJ: Erlbaum.Segui, J. & Zubizarreta, M.L. (1985) Mental representation of morphologically complex words and lexical access. *Linguistics, 23*, 757-767.

Segui, J. & Grainger, J. (1990) Priming word recognition with orthographic neighbors: effects of relative prime-target frequency. *Journal of Experimental Psychology: Human Perception and Performance, 16,* (1), 65-76.

Seidenberg, M.S. & McClelland, J. L. (1989) A distributed, developmental model of word recognition and naming. *Psychological Review, 96*, 523-568.

Sereno, J. & Jongman, A. (1997) Processing of English inflectional morphology. *Memory and Cognition, 25*, (4), 425-437.

Stanners, R., Neiser, J., Hernon, W. & Hall, R. (1979) Memory representation for morphologically related words. *Journal of Verbal Learning and Verbal Behavior, 18*, 399-412.

Taft, M. & Forster, K.I. (1975) Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior, 14*, 638-647.

Taft, M. (1979) Recognition of affixed words and the word-frequency effect. *Memory and Cognition, 7*, 263-272.

Taft, M. (1994) Interactive activation as a framework for understanding morphological processing. *Language and Cognitive Processes, 9*, 271-294.

Weyerts, H., Penke, M., Dohrn, U., Clashen, H. & Münte, T.F.(1997) Brain potentials indicate differences between regular and irregular German plurals. *Neuroreport, 8,* 957-962.