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Processing of Spanish Preterite Regular and Irregular Verbs: The Role of Neighborhood Density

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Research into lexical processes shows that frequency and phonological similarity (neighborhood density) affect word processing and retrieval. Previous studies on inflectional morphology have examined the influence of frequency of occurrence in speech production on the inflectional verb paradigm in English. Limited work has been done to examine the influence of phonological similarity in languages with a more complex morphological system than English. The present study examined the influence of neighborhood density on the processing of Spanish Preterite regular and irregular verbs as produced by thirty native speakers of Spanish. The results of a naming task showed that regular verbs were processed faster and more accurately than irregular ones. Similar to what has been observed in English, a facilitative effect of neighborhood density for –ir verbs was observed in both regular and irregular verbs, such that –ir verbs with dense neighborhoods were produced faster and more accurately than –ir verbs with sparse neighborhoods. However, no neighborhood density effects were observed for –ar verbs (regular and irregular) in reaction times and accuracy rates. Thus, the activation of a specific –ir verb was facilitated by similar sounding verbs regardless of being regular and irregular. Implications for models of morphology language processing are discussed.
Keywords: neighborhood density, language processing, Spanish.

De acuerdo a investigación llevada a cabo en torno a procesos léxicos, la frecuencia y la similitud fonológica (vecindario de densidad) afectan al acceso y procesamiento de palabras. Estudios previos sobre morfología flexiva han examinado la influencia de la frecuencia de aparición en actos de producción de habla en el paradigma verbal flexivo del inglés. No existen muchos estudios que examinen la influencia de la similitud fonológica en lenguas con un sistema morfológico más complejo que el que presenta el inglés. En este estudio se ha examinado la influencia de la densidad de vecindario en el procesamiento de verbos regulares e irregulares del español en formas de pretérito por parte de treinta nativo hablantes del español. Los resultados en una tarea de naming mostraron que los verbos regulares se procesaron más rápida y correctamente que los irregulares. Al igual que se ha observado en el inglés, se ha encontrado un efecto facilitador de densidad de vecindario en el caso de los verbos –ir, tanto en sus formas regulares como irregulares, de tal forma que los verbos –ir pertenecientes a un vecindario denso se produjeron más rápida y correctamente que los verbos –ir en vecindarios ermitaños. No obstante, no se han observado efectos de vecindario léxico en los verbos –ar (regulares e irregulares) en cuanto a tiempos de reacción e indices de precisión. Así pues, verbos similares en pronunciación facilitaron la activación de un verbo –ir específico independientemente si el verbo era regular o irregular. Se plantean implicaciones en los modelos de procesamiento morfológico.
Palabras clave: densidad de vecindario, procesamiento del lenguaje, español.

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How do we learn and process inflectional morphology? How do we transform the phonological form of a verb into its inflected form? These questions have attracted particularly contentious consideration over the past twenty years. The controversy raised a debate that applies to many aspects of language processing but has been expressed with specific reference to past-tense English verb processing. The debate refers to the existence of two competing theories found in the literature that try to address the question of how inflected word forms are mentally represented and processed, namely, *dual-system* and *single-system* theories. From the connectionist model approach initiated by Rumelhart and McClelland (1986) followed by a critique by Pinker and Prince (1988), many articles have been published to account for regular and irregular verbs in English primarily. On the one hand, dual-system theories posit that regular and irregular forms involve two different mechanisms, i.e., both forms are produced in different systems in such a way that regular verbs are rule-driven while irregular verbs are stored in the memory (Pinker & Prince, 1991; Marcus, Brinkmann, Clahsen, Weise, & Pinker, 1995; Marcus, 1995, 1998). On the other hand, single-system theories claim that mind there is a homogeneous system when dealing with past tense formation in English, that is, both regular and irregular past forms are either governed by rules or are formed in a single given connectionist network (Marchman, 1993; Plunkett & Marchman, 1996; Rumelhart & McClelland, 1986). The issues discussed by Pinker and Ullman (2002) and McClelland and Patterson (2002b) provide a thorough summary of where each side currently stands.

Not much attention has been given to other languages that have a complex inflectional morphology system. There is some data on morphological processing in other languages such as German (Bybee 1991; Clahsen, Rothweiler, Wöst, & Marcus, 1992; Clahsen, Sonnenstuhl, & Blevins 2003; Marcus 1995) and Italian (Albright 2002; Matcovitch 2000; Orsolini, Fanari, & Bowles, 1998), also providing some evidence for and against both models. The inflectional ending patterns found in Spanish verbal morphology is more complex than the one found in English. The irregular verb system in English is simple compared to the one that the Spanish language has, where the many different kinds of irregularities that exist challenge any Spanish learner. Note that regular English verbs make up approximately 86% (type count) of verb vocabulary (Plunkett & Nakisa, 1997). The remaining 14% of verbs form their past tenses in a variety of “irregular ways” (See McClelland & Patterson, 2002a, for a discussion of the systematicity in irregular past tense formation). In Spanish, data from a subset of Spanish infinitives (n = 511) taken from a Spanish database that contains over 175,000 word types (LEXESP; Sebastián-Gallés, Martí, Carreiras, & Cuetos, 2000) revealed that 81% of the verbs were regular and 19% were irregular verbs in the Preterite.

Apart from the lack of investigation of more flexive languages such as Spanish in terms of verbal processing, researchers have been focusing their line of research on the influence of only one lexical characteristic (frequency of occurrence) in the production of irregular and regular verbs. According to dual-system theories, irregular past tense forms are retrieved from memory and are expected to be frequency sensitive, with high frequency forms being remembered better than low frequency forms. Regular past-tense forms, on the contrary, are rule driven and frequency effects are not expected once access to the stem forms is controlled for. For single-system theories, regular and irregular verb forms are memorized in associative memory with the expectation that both regular and irregular forms show word frequency effects.

However, the influence of phonological similarity, another lexical characteristic that affects word retrieval and processing, has not been thoroughly considered. Phonological similarity as a lexical characteristic that affects processing and word retrieval from memory behaves similar to word frequency. Therefore, it is important to consider phonological similarity as one of the determining factors that can explain the differences between the two theories presented here, namely, dual-system and single-system theories. By controlling frequency of occurrence, phonological similarity effects can be examined to see if they differentially affect processing of regular and irregular verbal morphology.

A few studies examined differences in phonological similarity by contrasting regular and irregular past tense forms (Prasada & Pinker, 1993; Ullman, 1999). Prasada and Pinker (1993) investigated phonological similarity effects in novel verbs in a production task. According to them, the production latency of an irregular-sounding past tense form for a novel verb increases with the similarity of that verb to the prototype of an irregular neighborhood. However, if there are two systems, performance should be categorical. They found a similar distinction between acceptability ratings of irregular-sounding past tense forms of novel verbs such as *spling-splung* and –ed suffixed past tense forms of novel verbs such as plip-plipped. They concluded that there was an effect of similarity on novel irregular inflections, but no effect of similarity to known regulars for the regular inflection, supporting a dual mechanism model. However, some nonce stems, like *ploamph*, which were not similar to other regular items, were also phonologically strange. Even though participants were asked to judge the inflection and not the stem, Prasada and Pinker (1993) conceded that the judgments were affected by the phonological properties of the stem. They designed their novel verbs using informal methods, such as finding verbs that rhymed with many regulars/irregulars, or changing just one phoneme vs. multiple phonemes to obtain greater distance. There was no systematic assessment of the number of neighbors for each stimulus. The main problem with this study is that it provides no quantitative control for how many existing rhymes a novel verb has and how similar they are. It seems fair to say that Prasada and Pinker's (1993) results are open to interpretation because of the way in which novel verbs were created.

A recent study by Albright and Hayes (2003) avoided Prasada and Pinker's (1993) confound by using nonce stems of high phonological acceptability, and varied whether the item occurred in an "island of reliability" (according to the authors, over 300 verbs ending in an voiceless fricative, e.g. rush or laugh, constitute an island of reliability in that every such verb is regular). Both regular and irregular inflections received higher ratings if they came from islands of reliability. According to them, the regular past tense is sensitive to phonological attributes of the stem, violating the prediction of symbolic rule accounts (Ling & Marinov, 1993). Ullman (1999) elicited acceptability ratings for regular and irregular past tense forms and their stems in sentence contexts. Acceptability ratings of irregular past-tense verbs (such as blew) correlated with the group size of similar-sounding irregular verbs (threw, grew), but no such correlations were found for regular verbs (ratings of regular past tense forms such as walked did not correlate with measures of the number of similar sounding regular verbs, such as stalked, balked). Hence, phonological similarity was shown to influence the processing of English irregulars, but not regulars. In addition, ratings of irregular past-tense forms correlated with their frequencies, whereas ratings of regular past-tense forms did not correlate with their frequencies. Ullman interprets the results claiming that irregular past tense forms are retrieved from memory, whereas regular past tenses are produced by a suffixation rule with respect to phonological similarity and word frequency. The problem with this study is that all verbs used for acceptability ratings were existing verbs in English and received high acceptability ratings. Therefore, the means obtained for regular and irregular verbs did not differ that much, making it hard to claim support for a dual system model. Besides, the metric they used to define similarity is vague since a phonologically similar-sounding word was defined by Ullman as having a monosyllabic stem which is "phonologically similar" to another existing word. However, no additional information is given by Ullman as far as the criteria used to identify phonological similarity (e.g. similar by n features).

In contrast to the abovementioned studies, Bybee and Moder (1983) argued that their findings provide support for single-mechanism models in English and Italian respectively. Bybee and Moder investigated phonological similarity effects in novel verbs in sentence contexts. The verb stems varied in phonological proximity to the prototypical pattern which the authors defined for the i- u (e.g. string–strung) group of irregular verbs: sCCV [velar nasal]. They found an effect of similarity as a function of proximity to the prototype: the closer a real or novel verb stem was to the prototype, the more likely it is inflected similar as to the prototype form (*spling was more likely to be inflected as splung than vin as vun). They took this quasy-productivity as evidence that irregular verbs are organized into family resemblance categories. Again, this issue is not uncontroversial: the measurement of phonological similarity by means of differences by *n* number of features is unsophisticated (example of "neighbors": spring-sprang, bring-brought). Although finding words that are related to each other based on how many features are shared seems to be reliably capturing similarity, it allows such a degree of variability that many words may be similar to each other by just sharing one or two phonemes (regardless of word-length). Thus, caution should be taken when drawing conclusions from studies that fail to find effects under such a broad definition.

Accordingly, the present study employs a naming task in which thirty native speakers of Spanish produced Spanish past (Preterite) forms of Spanish infinitival verb forms. Critical variables included types of verbs (regular or irregular in the Spanish Preterite), verb-class (-ar or –ir Spanish infinitives) and words that were either phonologically related or unrelated to the target word. By examining the effects of phonological similarity, inferences can be made regarding the role that phonological similarity has as a lexical characteristic that affects language processing and, more specifically, how phonological similarity can account for the claims posited by competing theories of past tense morphological processing. In the section that follows, I discuss the phonological similarity effect (neighborhood density) that has been used in English and Spanish to test its influence on language storage and retrieval. I then present the research questions and hypotheses regarding neighborhood effects in Spanish past inflectional morphology.

Phonological Similarity: Neighborhood density

In studies of visual word recognition, neighborhood density has been traditionally assessed by means of counting the number of words that are formed by substituting of a letter into a target word. For example, the target word *cat* has neighbors such as *scat, at, pat, cut, cap* and so on. In visual word recognition this metric is usually referred to as the index *N* (Coltheart, Jonasson, & Besner, 1977). The *N* metric is based on substitution of a letter. The definition of neighborhood density proposed by Coltheart et al. (1977) seems to be too restricted and based on the orthographic similarity between a given target word and its neighbors. It has been until recent years when other parameters apart from substitution have been proposed to account for the definition of a neighbor. For example, one form of orthographic relationship that is not captured by the *N* metric is the similarity between transposition neighbors: pairs of letter strings that are identical save for the transposition of two adjacent letters, e.g. English words *trail* and *trial* (Andrews, 1996: Perea, Duñabeitia, & Carreiras, 2008; Perea & Carreiras, 2006a, 2006b, 2006c; cf. also Acha &

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Perea, 2008 in normal silect reading tasks). The role of addition and deletion neighbors in lexical decision expanded the original *N* metric and transposition neighbors to account for orthographic neighbors (Davis, Perea, & Acha, 2009).

The definition attested for orthographic neighbors is similar to the definition of a word neighbor in auditory word recognition. In auditory word recognition, neighborhood density refers to the number of lexical representations that phonologically resemble a target word (Goldinger, Luce, & Pisoni, 1989; Luce & Pisoni 1998; Vitevitch & Luce 1998, 1999). Similarity is operationally defined by an "add, subtract or change" rule (one-phoneme metric), in which a lexical entry counts as similar to another if it can be changed into the other by adding, subtracting or changing one phoneme (See James & Burke, 2000 and Luce & Pisoni, 1998 for other ways to define similarity). Thus, when a word has many similar representations in the lexicon, it is said to come from a *dense* neighborhood. On the contrary, a word that has few similar representations in the lexicon is said to come from a *sparse* neighborhood. In the present study, I will define neighborhood as consisting of all the words (verbs included but not limited) that may be generated by the addition, deletion or substitution of a single phoneme.

Neighborhood density has shown to have measurable effects on processing, including accuracy scores and reaction times in English and in Spanish. Similarity neighborhoods have been shown to influence lexical access in word perception. Perception of spoken words in English involves two processes: activation and competition (See Luce & Pisoni, 1998; Marslen-Wilson, 1989; McClelland & Elman, 1986). Thus, the input activates a set of candidates in memory and the candidates compete for selection (competition slows responses). Evidence for competition among lexical representations activated in memory is found in a variety of experiments.

Luce and Pisoni (1998) have shown that similarity neighborhood density and frequency, both indices of lexical competition, have demonstrable effects on processing time and accuracy in auditory lexical decision and perceptual identification: words with dense neighborhoods being responded slower and less accurately than words with sparse neighborhoods (See also Vitevitch & Luce, 1998; 1999). The role of competition has been a primary focus of research on spoken word recognition in English (e.g. Cluff & Luce 1990; Goldinger et al., 1989; Norris, McQueen, & Cutler, 2000; Vitevitch & Luce 1998, 1999). These results suggest that multiple words get activated and compete with each other during spoken word recognition. As a matter of fact, current models of spoken word recognition can account for competitive effects among words in English (Luce & Pisoni, 1998; McClelland & Elman, 1986; Norris et al., 2000).

Contrary to the competitive effect of phonological neighborhood density typically found in English, data from Spanish suggest that facilitation is shown in Spanish word perception. Facilitative effects have been obtained in an auditory lexical decision task (Vitevitch & Rodríguez, 2005). In this experiment, Vitevitch and Rodríguez (2005) observed that word frequency and neighborhood density influenced spoken word recognition in Spanish. For Reaction times, high frequency words (M = 932ms) were responded more quickly than low frequency words (M = 979ms). Words with dense neighborhoods (M = 945ms) were responded to more quickly than words with sparse neighborhoods (M = 966ms). For the accuracy rates, high frequency words (M = 94%) were responded to more accurately than low frequency words (M = 87%). Words with dense neighborhoods (M = 93%) were responded to more accurately than words with sparse neighborhoods (M = 88%). These results then suggest that dense neighborhoods facilitate processing, opposite of what has been observed in English (Luce & Pisoni, 1998). The authors attribute opposite findings obtained in Spanish and English to the specific characteristics of words in both languages, suggesting that cross-linguistic differences may account for some differences observed in segmentation strategies (in a stress-timed language like English and in a syllable-time language as Spanish), and different orthography systems (the deep orthography observed in English compared to the shallow orthography in Spanish may account for the differences in reading performance in English and Spanish).

As far as speech production is concerned, previous studies examining phonological neighborhood density on speech production have found facilitation effects in English (Harley & Brown, 1998; Vitevitch 1997, 2002). Vitevitch (2002) studied the influence of phonological similarity neighborhoods on the speed and accuracy of speech production. In speech-error elicitation tasks, more errors were elicited for words with sparse neighborhoods than for words with dense neighborhoods. In a picture-naming task, words with sparse neighborhoods were named slower than words with dense neighborhoods. In another study by Vitevitch (1997), errors were examined in malapropisms (whole word substitutions that are only phonologically related): more errors were found with sparse neighborhoods than with dense neighborhoods. These studies have demonstrated that neighborhood density influences the production of spoken words in English.

Contrary to the facilitative effect of phonological neighborhood density that was found in English production tasks, a study using a picture-naming task conducted by Vitevitch & Stamer (2006) found that pictures with Spanish names from sparse neighborhoods were produced more quickly than pictures with Spanish words from dense neighborhoods. The authors attribute the contrastive effects found for English and Spanish to the difference regarding the complexity of the morphological system (Spanish being a higher flexive language than English). However, the results obtained in a recent study conducted by Baus, Costa, and Carreiras (2008) showed a facilitatory effect of neighborhood density and neighborhood frequency in speech production in

Spanish. More specifically, in Experiment 1 the authors replicated the study conducted by Vitevitch and Stamer by adding a control group with speakers of German. An inhibitory effect of neighborhood density was found in Baus et al´s study. However, speakers of German showed the same difference between the two sets of pictures as Spanish speakers did in a picture naming task, which suggested that any explanation of neighborhood density effect may not depend on language-specific properties. In Experiment 2 and 3, Baus et al´s data showed a facilitatory effect of neighborhood density and neighborhood frequency. The results in Experiment 2 and 3 from Baus et al´s study are aligned with the facilitatory effect found by Vitevitch and Sommers (2003) and are explained by interactive models of lexical access. In interactive models, lexical selection is subject to both semantic and phonological factors (Dell 1986; Harley, 1993; Rapp & Goldrick, 2000). According to these models, semantic representations activate a lexical node that contains similar semantic representations. Sublexical representations of the target lexical node (phonemes) and all its similar lexical representations containing such phonemes are also activated. Both the activation and the retrieval of the phonological features of the target lexical node are expected to be higher in the case of words that constitute a dense neighborhood since there will be more words that activate common sublexical representations in dense neighborhoods.

Other variables related to neighborhood density that influence processing are word-frequency and word-length. Landauer & Streeter (1973) and Pisoni, Nusbaum, Luce, & Slowiacek (1985) have found that words vary substantially not only in the number of words to which they are similar but also in the frequencies of these similar words. Landauer and Streeter observed that common words have more neighbors in English, that is, frequency of occurrence and neighborhood density are positively correlated (Frauenfelder, Baayen, Hellwig, & Schreuder, 1993). Additionally, Pisoni et al. (1985) found that there is a negative correlation between word length and neighborhood density in English. Shorter words have many neighbors, whereas longer words have fewer neighbors.

In Spanish, Vitevitch & Rodríguez (2005) examined frequency of occurrence, number of neighbors and length in a Spanish database (Sebastián-Gallés et al., 2000), which sampled over five million words from various written sources (Spanish language novels, essays, weekly news magazines, and newspapers between the years of 1978 and 1995). The same metric used in English (one-phoneme) has proven to have measurable results in Spanish, with a similar relationship among variables being observed. In Spanish, like in English, high frequency words are found in dense neighborhoods and low frequency words tend to occur in sparse neighborhoods. The results obtained by Vitevitch and Rodríguez in an analysis of nouns from a Spanish database resemble the results obtained in English, namely, common words have more neighbors than rare words (positive correlation, $r = .09$) shorter words have more neighbors than longer words in Spanish (negative correlation, $r = .47$).

The present study

The experiment conducted in the present study was based on previous work on processing of inflectional morphology and research into lexical processes. Extensions were made to investigate if phonological similarity (*neighborhood density*) of a target lexical entry has strong effects on access. Previous studies on inflectional morphology have examined the influence of frequency of occurrence in speech production on the inflectional verb paradigm. The experimental method employed in the present study allows adding neighborhood density to the previous line of research examining morphological processing since the data in the present study manipulated phonological similarity and held frequency of occurrence constant. Thus, the present study aims to examine the influence of neighborhood density on the processing of Spanish Preterite regular and irregular verbs during speech production. The method will borrow from previous work on orthographic and phonological neighborhood effects in word recognition and elicitation tasks (Luce & Pisoni, 1998; Vitevitch & Luce, 1999). At the same time, the present study will be substantially different from prior work on processing of regular and irregular verbal morphology. First, it will examine the verbal morphology of a language (Spanish) that has a more complex morphology system and, second, a more systematic neighborhood metric (one phoneme) will be used to assess phonological similarity. When answering the research questions proposed here, neighborhood density of infinitival forms (all the words generated by the addition, deletion or substitution of a single phoneme) will be manipulated to determine whether neighborhood effects in regular and irregular verbs can be observed. The predicted asymmetry in frequency effects is expected with the other lexical characteristic, namely, phonological similarity.

Based on the claims posited by the two main theories of morphological processing, dual and single-system theories, if neighborhood density influences reaction times for irregular verbs, but does not affect regular verbs, dual-system models will be supported. Thus, if dual-system models are correct, I will predict effects of neighborhood density for irregular verbs. Dense irregulars will pattern differently than sparse irregulars. Additionally, no neighborhood effects should be found for regular verbs (no significant differences between sparse and dense regular verbs). On the contrary, if neighborhood density influences reaction times for both regular and irregular verbs, single-system models will be supported, with a facilitative effect of neighborhood density (similar to the one observed in Baus et al. 2008's study for speech production tasks in Spanish) for both dense regular and dense irregular verbs as compared to sparse regular and irregular verbs.

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Method

Participants

Thirty right-handed Spanish-speaking students (both male and female students) were recruited by word of mouth. All of them were native speakers of Spanish, with no reported history of speech or hearing disorders. When participants arrived at the laboratory, they signed a consent form informing them of their rights, completed a brief questionnaire, and then performed the task. Recruitment, consent forms and task instructions were given in Spanish.

Materials

Forty eight Spanish inflected verb forms (Spanish Preterite) containing two syllables (measure of word length in the present study) and forty eight bisyllabic nonwords were used as stimuli. All Spanish infinitives were taken from a Spanish database (Sebastián-Gallés et al., 2000) that contains over 175,000 word types and provides information about frequency counts of words. Out of 511 infinitival forms that were found in the database, a subset of words was selected. Sixteen conditions, were formed combining two levels of neighborhood density (sparse and dense), verb-type (regular and irregular), verb-class (-ar and –ir such as Spanish *cantar* ´to sing´and Spanish *pedir* ´to ask for´ respectively) and two levels of subject pronoun (*yo*, 1st person singular, and *él*, 3rd person singular). For each condition, three verbs were used. Thus, twelve regular sparse verbs (3 –ar 1st person, 3 –ar 3rd person, 3 –ir 1st person, 3 –ir 3rd person), twelve regular dense verbs (3 –ar 1st person, 3 –ar 3rd person, 3 –ir 1st person, 3 –ir 3rd person), twelve irregular sparse verbs (3 –ar 1st person, 3 –ar 3rd person, 3 –ir 1st person, 3 –ir 3rd person) and twelve irregular dense verbs were used (3 –ar 1st person, 3 –ar 3rd person, 3 –ir 1st person, 3 –ir 3rd person). Neighborhood density in Spanish was determined as it is assessed in English, that is, by means of substituting, adding or deleting a single-phoneme in the target word to form a neighbor (Landauer & Streeter, 1973; Luce & Pisoni, 1998). Phonological density was varied but the words were presented visually. Since Spanish has a shallow orthography (there is close to a one-to-one correspondence between orthography and phonology) the number of letters and phonemes in a word are very similar in Spanish. In order to determine infinitival forms with a dense and a sparse neighborhood, a median split was used. Half of the infinitives (24) had a sparse number of neighbors (M = 3.91 neighbors, SD =1.13) and the other half of infinitives (24) had a dense number of neighbors (M = 8.70 neighbors, SD = 2.78). Neighborhood density counts were based on the data contained in Sebastián-Gallés et al. (2000). As mentioned earlier, Spanish Preterite has three main types of regular verbs in which infinitival forms end with –ar, -er or –ir. -er verbs were excluded in the present study because no words were found under the –er sparse irregular verb category.

The stimuli used in the present study did not differ in their frequency of occurrence (word frequency) and word length (only bisyllabic words were used). Regular verbs with a sparse neighborhood had a mean frequency value of 104 occurrences per million (SD = 39). Regular verbs with a dense neighborhood had a mean frequency value of 103 occurrences per million (SD = 39) [$F(1, 44) = .012$, $p = .913$]. Irregular verbs with a sparse neighborhood had a mean frequency value of 106 occurrences per million (SD = 39) and irregular verbs with a dense neighborhood had a mean frequency value of 114 occurrences per million (SD = 39). Frequency values were based on the data contained in Sebastián-Gallés et al. (2000).

Even though Spanish has five standardized subject pronouns, only the first person singular (*yo* form) and the third person singular (*él*) were used to control for a number of factors. For the Preterite, the second person singular (*tú* form) and the first person plural (*nosotros*, English "we") contain three syllables (word length was controlled in the present study and only two syllable words were considered). The third person plural form (*ellos,* English "they") is identical to the third person singular in Spanish Preterite. Therefore, since similar effects should be observed in the third person singular or plural, only singular bisyllabic forms were considered. Furthermore, the motivation for such a choice of verb forms (1st, and 3rd) is that 1st and 3rd person singular forms show many irregularity patterns when forming the Spanish Preterite (e.g. there are irregular past tense forms that are only irregular in 1st or 3rd person subject forms). Within each category of six inflected forms (e.g. regular sparse –ar), three inflected verb forms were used in the first person singular and the other three in the third person singular, that is, only one form, either yo or él, was used per verb so that there would be no repetition of verb stems within the experiment.

Design and Procedure

Participants were instructed to respond as quickly and as accurately as possible to the words presented on the computer screen. They had to generate the inflected past tense forms (e.g. *yo- bailar*, English "I-to sing", correct response: *bailé*). All participants were tested individually. The task was conducted with *Superlab* software. It controlled stimulus randomization, presentation and the collection of response latencies. A headphone-mounted microphone was interfaced to the computer. The experiment was controlled by the DMDX software (Forster & Forster, 2003). All instructions were presented in Spanish. A typical trial proceeded as follows: one of the subject pronouns (*yo* *or él*) appeared in the center of the monitor for 1500 milliseconds. One of the forty eight randomly selected stimulus item (existing infinitival forms in Spanish) was then presented and remained visible on the screen until participants initiated a verbal response which was registered by the computer (voice-activated response). Immediately following the response, the target stimulus was erased from the computer screen. The Inter-Stimulus Interval duration was 2000 milliseconds. This pattern was followed for each stimulus item. Responses were also recorded (using a high quality audiotape), for accuracy rates. No infinitive was presented more than once. Response times were measured from the onset of the stimulus presentation until the onset of the participant's verbal response. The entire experiment lasted approximately fifteen minutes. Prior to the experimental trials, each participant received ten practice trials. None of the items used in the trials were used in the experiment. Those trials were used to familiarize the participants with the task and were not included in the data analysis. Participants were given explicit instructions not to include in their response the subject pronoun, just the Preterite form.

Results

Analyses of variance (Repeated Measures ANOVAs) were conducted to examine each dependent measure (reaction time and accuracy rates) for participants (F_1) and items (F_2) as random factors. As in Experiment 2, Reaction times greater than 2 SD from each participant's mean were excluded in the present study (2.23% of all the data). The responses from the tape-recorder were scored for each participant for accuracy rates. A response was considered correct if it matched a phonological transcription of the stimulus item. When participants accidentally triggered the voice-key by means of coughing or false starts such as "uh", these responses (2.03% of the total responses) were excluded from the final data analysis. Only accurate responses were included in the analysis of Reaction times.

In the analysis of response latencies, regular verbs (M = 1444 ms, SD = 67) were responded to more quickly than irregular verbs (M = 1506 ms, SD = 70) [$F_1(1, 29) = 10.042, p = .004$; $F_2(1, 32) = 6.042, p = .020$]. The results obtained here are similar to the ones obtained in Experiment 2 and other experiments in the related literature in the sense that they confirm that regular verbs are produced faster than irregular ones. Another effect of verb-class revealed significant differences: –ar verbs (M = 1430 ms, SD = 68) were significantly faster than those to –ir verbs (M = 1520 ms, SD = 69) [$F_1(1, 29) = 42.223, p = .000$; $F_2(1, 32) = 18.555, p = .000$].

The results obtained for the production data revealed significant differences between verbs with a sparse neighborhood (M = 1489 ms, SD = 386) and verbs with a dense neighborhood (M = 1449 ms, SD = 373). Verbs with dense neighborhoods were responded to more quickly than verbs with sparse neighborhoods [$F_1(1, 29) = 9.690, p = .004$; $F_2(1, 32) = 5.546, p = .025$], suggesting a facilitation effect among verbs. As far as subject pronoun is concerned, an analysis of subject pronoun (*yo* vs. *él*) revealed no significant differences between the two categories (Fs < 1).

In the two-way interaction (Verb-Type and Neighborhood Density) significant differences were found between regular and irregular verbs with regards to neighborhood density. However, the two-way interaction was significant in the subject analysis [$F_1(1, 29) = 4.288, p = .047$] but not significant in the item analysis [$F_2(1, 32) = 1.414, p = .243$]. Other two-way interactions (Verb Type X Subject Pronoun, Verb Type X Verb Class, Verb Class X Subject Pronoun, and Neighborhood density X Subject Pronoun) revealed no significant differences. No significant differences were found in any of the three-way interactions or the four-way interaction.

Two one-way ANOVAs were then conducted to analyze neighborhood density effects in regular and irregular verbs separately (See Figure 1). Among regular verbs, a one-way ANOVA revealed that there was no difference between words with a sparse neighborhood and words with a dense neighborhood [$F_1(1, 29) = .389, p = .538$; $F_2(1, 22) = .776, p = .338$]. Among irregular verbs, the data showed significant differences between words with a sparse neighborhood and words with a dense neighborhood [$F_1(1, 29) = 16.317, p = .000$; [$F_2(1, 22) = 2.842, p = .106$], with a significant difference observed in the subject analysis and a strong trend observed in the item analysis. As shown in Figure 1, for irregular verbs dense neighborhoods were responded to faster (M = 1463 ms, SD = 379) than sparse neighborhoods (M = 1529 ms, SD = 390). These data seem to suggest that there are neighborhood density effects in irregular verbs but not in regular verbs.

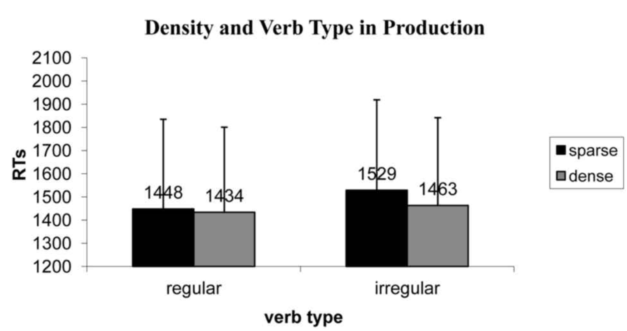

Figure 1. Mean reaction times and Standard Deviations for the naming task (comparison between neighborhood density and verb type). Results for regular verbs are on the left and for irregular verbs on the right. Sparse neighborhood density is indicated by solid bars and dense neighborhood density by striped bars. Means for each condition are shown above each bar.

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The overall existence of neighborhood density effects in the naming task presented here and the lack of a robust effect in the analyses (subject vs. by-item) in the two-way interaction (Neighborhood density X Verb Type) motivated a further investigation of potential differences between sparse and dense neighborhoods in –ar and –ir verbs. The significant difference between sparse and dense neighborhoods in irregular verbs may have been carried by differences between –ar and –ir verbs or *yo* and *él* pronoun forms rather than differences between regular/irregular and sparse/dense *per se*. This seems to be the case since a two-way interaction between neighborhood density and verb class also yielded significance: [$F_1(1, 29) = 7.263$, $p = .012$; $F_2(1, 32) = 3.182$, $p = .084$], such that participants responded to verbs with dense neighborhoods faster than to verbs with sparse neighborhoods in the case of –ir verbs.

To further examine the verb class effect, 4 one-way ANOVAs were conducted to separately examine –ar and –ir verbs in terms of neighborhood density. Among regular verbs, 1 one-way ANOVA revealed only one main effect of neighborhood density: –ir verbs with a dense neighborhood (M = 1444 ms, SD = 359) were responded to more quickly than –ir verbs in a sparse neighborhood (M = 1503 ms, SD = 397) [$F_1(1, 29) = 4.692$, $p = .039$; $F_2(1, 22) = 6.741$, $p = .016$]. No significant differences were found in the case of regular –ar verbs in terms of neighborhood density [$F_1(1, 29) = .077$, $p = .783$; $F_2(1, 22) = .145$, $p = .707$]. The results illustrated in Figure 2 suggest that regular –ir verbs are subject to neighborhood density (facilitative effects) when regular –ar verbs are not.

The same procedure was followed to investigate the existence of neighborhood density effects in irregular verbs in terms of verb-class. A one-way ANOVA revealed a main effect of neighborhood density in –ir verbs. As shown in Figure 3, -ir verbs with a dense neighborhood (M = 1519 ms, SD = 418) were responded more quickly than –ir verbs with a sparse neighborhood (M = 1601 ms, SD = 412 [$F_1(1, 29) = 6.826$, $p = .014$], with significance observed in the subject analysis and a strong trend in the item analysis [$F_2(1, 10) = 3.869$, $p = .078$]. For –ar verbs, no main effect was found of neighborhood density [$F_1(1, 29) = 3.198$, $p = .065$; $F_2(1, 10) = .619$, $p = .450$].

Interestingly, –ir verbs (both regular and irregular ones) are the only class of verbs that are subject to significant differences of neighborhood density in the present study. More precisely, -ir verbs with dense neighborhoods were produced faster than –ir verbs from sparse neighborhoods. Most importantly here, though, are the implications that these results have within the framework of the two competing theories contrasted in the present study. Overall, the naming task revealed an interaction of neighborhood density and verb type, showing that neighborhood density effects were observed in irregular verbs but not in regular ones. Separate analyses showed that neighborhood density effects were observed in –ir verbs in both regular and irregular verbs. Further research should explore the interaction effect between frequency and neighborhood density by means of manipulating frequency as well as neighborhood density (low frequency and high frequency –ar and –ir Spanish infinitival verbs should be included as stimuli to slow participants down and make them less efficient processors of regular verbs).

For the accuracy rates, both subject and item analyses were also conducted for the error data. Accuracy rates were above 84% performance in all conditions. The results for accuracy rates are very similar to the ones obtained for Reaction times, suggesting that participants did not trade-off between speed and accuracy in their responses. Regular verbs were responded to more correctly (M = 98%) than irregular verbs (M = 96%) [$F_1(1, 29) = 20.670$, $p = .000$; $F_2(1, 32) = 28.252$, $p = .000$]. Repeated measures ANOVA also showed a significant main effect of verb-class [F_1(1,

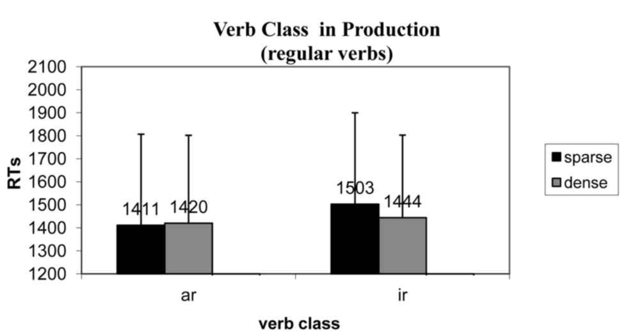

Figure 2. Mean reaction times and Standard Deviations for the naming task (comparison between neighborhood density and verb class in regular verbs). Results for –ar verbs are on the left and for –ir verbs on the right. Sparse neighborhood density is indicated by solid bars and dense neighborhood density by striped bars. Means for each condition are shown above each bar.

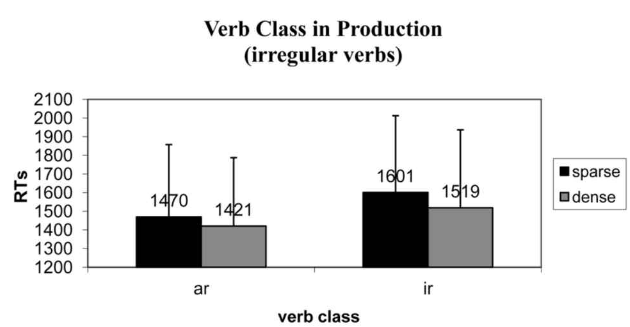

Figure 3. Mean reaction times and Standard Deviations for the naming task (comparison between neighborhood density and verb class in irregular verbs). Results for –ar verbs are on the left and for –ir verbs on the right. Sparse neighborhood density is indicated by solid bars and dense neighborhood density by striped bars. Means for each condition are shown above each bar.

29) = 31.506, p = .000; F_2(1, 32) = 20.878, p = .000], such that participants responded more accurately to –ar verbs (M = 99%) than –ir verbs (M = 96%). However, there was no difference in error rates between *yo* and *él* forms [F_1(1, 29) = 1.470, p = .234; F_2(1, 32) = 2.513, p = .123].

With regards to neighborhood density, there was also a significant difference in accuracy rates between sparse and dense neighborhoods [F_1(1, 29) = 58.674, p = .000; F_2(1, 32) = 4.600, p = .040], such that participants responded more accurately to dense neighborhoods (M = 97%) than sparse neighborhoods (M = 91%). The facilitation effect was consistent with earlier results for Reaction times.

When evaluating potential two-way, three way and four-way interactions, no significant differences were found for the following two-way interactions: Verb Type X Subject Pronoun, Verb Type X Verb Class, Neighborhood Density and Subject Pronoun, Verb Class X Subject Pronoun). None of the three-way interactions (Verb Type X Neighborhood Density X Verb Class, Verb Type X Neighborhood Density X Subject Pronoun, Neighborhood Density X Verb Class and Subject Pronoun) and the four-way interaction (Verb Type X Verb Class X Neighborhood Density X Subject Pronoun) revealed significant differences.

However, a strong trend of significance was observed when comparing neighborhood density with verb type [F_1(1, 29) = 3.890, p = .058; F_2(1, 32) = 3.139, p = .086]. In order to verify predictions regarding neighborhood density, separate analyses were then conducted for the regular and irregular verbs separately. Among regular verbs, 1-way ANOVA with repeated measures revealed no significant differences of neighborhood density [F_1(1, 29) = 1.198, p = .283; F_2(1, 22) = .142, p = .710]. Among irregular verbs, however, a main effect was found for neighborhood density only in the subject analysis [F_1(1, 29) = 5.449, p = .027; F_2(1, 22) = 1.932, p = .178], suggesting that dense neighborhoods (M = 97%) were responded to more correctly than sparse neighborhoods (M = 89%). These data seem to suggest that neighborhood density effects are observed in irregular verbs but not in regular verbs.

A two-way interaction between verb class and neighborhood density was found to be significant [F_1(1, 29) = 55.365, p = .000; F_2(1, 32) = .704, p = .408], with a significant difference observed in the subject analysis but not in the item analysis. Four one-way ANOVAs were conducted for regular (both –ar and –ir verbs) and irregular verbs (both –ar and –ir) separately. Among regular verbs (see Figure 14 below), a one-way ANOVA with repeated measures did not reveal a main effect of neighborhood density for –ar verbs [F_1(1, 29) = .108, p = .745; F_2(1, 10) = .154, p = .703]. However, significant differences were observed for -ir verbs in the subject analysis [F_1(1, 29) = 16.523, p = .000; F_2(1, 10) = .000, p = 1.000], such that participants responded to dense –ir neighborhoods (M = 98 %) more accurately than to sparse –ir neighborhoods (M = 90%).

Among irregular verbs, a main effect of neighborhood density in a one-way ANOVA was not found for –ar verbs in the subject analysis [F_1(1, 29) = .685, p = .415, with a significance difference observed in the item analysis [F_2(1, 10) = 10.000, p = .010]. The other class of verbs, -ir verbs, showed a main effect of neighborhood density in the subject analysis [F_1(1, 29) = 32.431, p = .000; F_2(1, 10) = .450, p = .518], suggesting that –ir dense verbs (M = 96%) were responded to more correctly than –ir sparse verbs (M = 85 %).

Discussion

The question addressed by the present study was whether phonological similarity effects (measured by neighborhood density) were observed in Spanish regular and irregular verbal morphology in speech production. The results obtained in the present study showed systematic differences between the speed and accuracy rates of regular and irregular verbs in a naming task, such that participants responded to regular verbs faster and more accurately than to irregular ones. Additionally, significant differences were observed between –ar and –ir verbs, with –ar verbs being responded to faster and more accurately than to –ir verbs.

As an attempt to investigate the influence of neighborhood density as a lexical characteristic that affects word processing, the results of the present naming study show that verbs from dense neighborhoods are produced more quickly and accurately than words from sparse neighborhoods, indicating that multiple words become activated in memory at the same time and influence the speed and the accuracy of speech production by means of facilitative effects. Overall, neighborhood density effects were observed in irregular verbs. However, localization of the source of neighborhood density effects in the speech production process was only found in –ir verbs. Those facilitative effects found for both –ir regular and irregular verbs were evident in both the reaction times and accuracy rates.

This facilitative pattern is similar to what is typically observed in speech production in English (Vitevitch, 2002). The results obtained in the present study for neighborhood density in Spanish correlate with those obtained in English (Gordon 2000, 2002; Harley & Bown 1998; Vitevitch 1997, 2002), further attesting to the potential universal nature of word processing. The facilitative neighborhood density effects found in the present study are aligned with the recent facilitative effects found for Spanish in production tasks (Baus et al., 2008) and are explained by interactive models of lexical access where words in a dense neighborhood are expected to have a processing advantage compared with those in sparse neighborhoods.

In terms of morphological processing, analogy approaches (Skousen, 1989) within single-system theories exploit the idea that morphologically complex words are

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stored as wholes (this concept has also support within psycholinguistic research analyses: Baayen, Schreuder, De Jong, & Krott, 2002; Sereno & Jongman, 1997). The repetitive calculation of an analogical set (in Spanish, verbal forms have more morphological inflectional units than nouns) allows the set to be stored as lexical units in memory thus eliminating the need to perform a full search each time. Thus, facilitative effects are better understood for more complex morphological units such as verbs rather than nouns. This might explain why facilitative effects were observed in the present study as compared to the competition observed for neighborhood density in Spanish nouns (Vitevitch & Rodríguez, 2005).

Besides, the existence of predictable phonological contexts in which a particular morpho-phonological change works well in the existing lexicon may facilitate word processing (see Albright's *islands of reliability*, 2002). Consider the Spanish irregular verbs *concluir* "to conclude" and *confluir* "to converge". Both of them are irregular –ir verbs, are phonologically similar to each other (neighbors) in their infinitival forms and their inflected Preterite forms are also neighbors: first person singular, *concluí* and *confluí* ("I concluded, I converged" respectively; See also *incluir* "to include" and *influir*, "to influence"). The same "reliable/productive" observation can be applied to regular –ir verbs such as *cundir* "to expand/spread", *fundir* "to melt" and *hundir* "to sink/plunge". This powerful phonological similarity (and also phonotactic probability) is often observed in this kind of verb in Spanish and is not often observed in Spanish nouns, due to the fact that nouns have fewer possible forms. Another factor that may explain the special phonological similarity properties primarily observed in –ir verbs could be found in the influence of other languages into the creation of new words in Spanish. The new vocabulary that is borrowed from other languages and adopted into the Spanish language may have different phonotactic properties. When creating a new word in Spanish, it is likely to be the case that it be an –ar verb or a noun. It is not common to find new words in Spanish that follow –er and –ir verb paradigms. In the case of lexical borrowings, the new –ar Spanish verbs may have different phonotactic properties that resemble the original language where the loan word is coming from. Therefore, the predictability of phonotactic similarity among –ar verbs would be expected to be lower when compared to –ir verbs.

The results of this experiment have revealed a new avenue of results when supporting the two main competing theories of verb processing, namely, the dual and single-system theories. Although neighborhood density effects were not observed in –ar verbs in the present experiment, the facilitative effect found in –ir verbs for both regular and irregular verbs supports the claim that regular and irregular verbs do not qualitatively differ in terms of processing. However, further research should be conducted in –ar verbs before drawing final conclusions that neighborhood density does not influence –ar verbs. The results of the present study are consistent with previous studies of English Past tense processing, where a difference in speed and accuracy between regular and irregular verbs is often observed. Recall that dual-system mechanisms considered this difference as evidence to support the fact that regular and irregular verbs do involve two different mechanisms, where regular verbs are rule-driven while irregular verbs are stored in the memory. Differences in reaction times and accuracy rates do not necessarily imply that regular and irregular verbs are stored and processed differently. The differences in response latencies and accuracy rates between regular and irregular verbs should not then have to rely on qualitatively different mechanisms. Instead, Spanish offers a much less clear-cut distinction between regular and irregular verbs than English, which at the end should not be promoting the existence of two different mechanisms, one for regular and another one for irregulars. In fact, it is quite frequent that Spanish irregular verbs combine the regular and irregular forms within the same paradigm. Take, for instance, the Spanish verb *probar* ("to try"): its Preterite and imperfect forms are fully regular, and the present indicative forms include both regular and irregular forms (irregular stem found for all singular forms and third person plural {prueb-}, regular stem for first person plural, {prob-}). For the Spanish verb *gozar* ("to enjoy"), while Present Indicative and Imperfect forms are fully regular, Preterite first person singular form is irregular ({goc-}). The same given verb in Spanish can be, then, regular or irregular depending whether we are dealing with Present or Past tense. Therefore, the dichotomy between regular and irregular verbs in Spanish should be carefully considered since it is not as clear-cut as in English, where there are not verbs that follow regular patterns in the Past and irregular ones in the Present. In Spanish, however, verbs such as *pensar* "to think" are regular in the Past (Preterite) {pens-} but irregular in Present Indicative {piens-}.

The irregular verb system in English does not have such morph-phonological complexity. Forms such as *break* and *took* cannot be decomposed in smaller phonological units consisting of a stem and an inflectional suffix. However, they have to be learned and stored as whole forms. In Spanish and other languages such as French and Italian, almost all verbs combine a stem with at least a suffix marking person, number and tense. This pattern is applied equally to words that have a regular stem and an irregular one. An irregular Spanish verb like *vestir* ("to dress"), has an irregular stem in the third person singular and plural forms {vist-}, but it has the same Preterite suffixes attached its stem as the ones found for regular verbs. Even though the stems alternate between regular and irregular forms, the inflectional suffixes remain constant. Therefore, this complexity and the absence of a qualitative distinction between the regular and irregular domains (sometimes within the same verb as in *probar* and *gozar)* may support a single system representational framework. The similar decomposition effects observed for both, regular and irregular verbs in Spanish should then contradict the dichotomy predicted by dual-system theories.

The differences in reaction times and accuracy rates between regular and irregular verbs in the present study were due to neighborhood density effects found in –ir verbs (regular and irregular) suggesting that regular -ir forms behave similarly to irregular –ir forms. Thus, neighborhood density is relevant in the processing of regular and irregular –ir verbs. The facilitative effects found in the present study with regards to neighborhood density may be related to the efficiency in storage capacity where regular and irregular stems are driven by the same mechanism. The same associative factors are present to account for regular and irregular verbs in Spanish but to different degrees (regulars produced faster and more accurately than irregulars).

Since the neighborhood density effects found for regular verbs in the naming task described above did not differ from the ones found for irregular verbs (both conjugational classes, -ar and –ir), these findings seem consistent with the predictions of the single mechanism account hypotheses for the processing behavior of inflected regular and irregular Preterite forms in the naming task.

In summary, the naming study presented here shows that Spanish irregular –ir verb forms are processed and are subject to neighborhood density effects similarly to regular –ir forms. The activation of a specific verb is facilitated by other similar sounding verbs regardless of being regular and irregular. The interpretation of these results may posit supporting arguments or problems for the classic dual and single system theories. However, more work needs to be done to account for the facilitative effects observed for –ir verbs and the lack of neighborhood effects in –ar verbs in naming tasks such as the one presented in the present study. Further research should address this question. Additional research must examine whether neighborhood density effects are observed in other kinds of perceptual identification tasks, namely, auditory lexical decision tasks to see if there is any difference with regards to neighborhood density in the speed and accuracy of responses in stimuli presented auditory and visually.

Although there are questions to address in future research, the results of the present study highlight the importance of cross-linguistic research and make a contribution to the on-going debate on the acquisition and processing of verbal morphology when examining data from Spanish, a higher flexive language than English. The present study has examined a lexical characteristic that affects word processing that has not been widely considered and carefully defined in the morphology literature, namely, neighborhood density. Indeed, neighborhood density can be used as a tool for revealing the underlying nature of processing of morphology.

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