LANGUAGE AND COGNITIVE PROCESSES
2006, 21 (6), 760–770

Psychology Press
Taylor & Francis Group

The curious case of competition in Spanish speech production

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In previous studies in English examining the influence of phonological neighbourhood density in spoken word production, words with many similar sounding words, or a dense neighbourhood, were produced more quickly and accurately than words with few similar sounding words, or a sparse neighbourhood. The influence of phonological neighbourhood density on the process of spoken word production in Spanish was examined with a picture-naming task. The results showed that pictures with Spanish names from sparse neighbourhoods were named more quickly than pictures with Spanish names from dense neighbourhoods. The present pattern of results is the opposite of what has been previously found in speech production in English. We hypothesise that differences in the morphology of Spanish and English and/or the location in the word where phonological neighbours tend to occur may contribute to the processing differences observed in the two languages.

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This research was supported in part by grants from the National Institutes of Health to the University of Kansas through the Schiefelbusch Institute for Life Span Studies (National Institute on Deafness and Other Communication Disorders (NIDCD) R01 DC 006472), the Mental Retardation and Developmental Disabilities Research Center (National Institute of Child Health and Human Development P30 HD002528), and the Center for Biobehavioral Neurosciences in Communication Disorders (NIDCD P30 DC005803).

We would like to thank Allard Jongman, Joan Sereno, Holly Storkel, Jie Zhang, and the members of the Spoken Language Laboratory for helpful comments, suggestions, and discussions.

http://psypress.com/lcp DOI: 10.1080/01690960500287196

Neighbourhood density refers to the number of lexical representations that sound like a given word. A word with few similar sounding words, or neighbours, like *pig* (*fig, wig, big, pin, pitch*), is said to have a *sparse* neighbourhood, whereas a word with many similar sounding neighbours, like *cat* (*hat, fat, rat, mat, sat, cut, kit, cot, can, cap, calf*), is said to have a *dense* neighbourhood. Note that each word has more words as neighbours, but only a few items were listed for illustrative purposes. Luce and Pisoni (1998; see also Vitevitch & Luce 1998, 1999) demonstrated in several laboratory-based spoken word recognition tasks that English words with sparse neighbourhoods were responded to more quickly and accurately than words with dense neighbourhoods, suggesting that multiple word-forms are activated and compete with each other during spoken word recognition (see Vitevitch, 2002a, for a similar pattern of results obtained from an analysis of a corpus containing speech perception errors known as ‘‘slips of the ear’’). Indeed, all current models of spoken word recognition account for competition among word-forms one way or another (e.g., Luce & Pisoni, 1998; McClelland & Elman, 1986; Norris, McQueen & Cutler, 2000).

Previous work employing a variety of tasks—including analyses of naturally occurring speech errors (Vitevitch, 1997), elicited speech errors and picture naming (Vitevitch, 2002b), and a tip-of-the-tongue elicitation task (Vitevitch & Sommers, 2003)—has also demonstrated that neighbourhood density influences the production of spoken words in English. The influence of neighbourhood density in spoken word production in English, however, was the opposite of its influence in spoken word recognition in English. Specifically, words with dense neighbourhoods were produced more quickly and accurately than words with sparse neighbourhoods (see also Gordon & Dell, 2001 for similar results with aphasic patients). These results suggest that during speech production, similar sounding words facilitate lexical retrieval rather than ‘‘block’’ or compete with each other. Several current models of speech production can also account for the facilitative influences of neighbourhood density observed in speech production in English (e.g., Burke, MacKay, Worthley, & Wade, 1991; Dell, 1986).

Although much work has examined the influence of neighbourhood density on various spoken language processes in English (see also for example Storkel, 2004, for effects of neighbourhood density on the acquisition of words; Gierut, Morrisette, & Champion, 1999, for effects of neighbourhood density on the acquisition of sounds), there has been relatively little work examining the influence of neighbourhood density on various spoken language processes in other languages. The importance of examining spoken language processes in other languages is highlighted by research that examined the process of segmenting spoken words from the stream of continuous speech (cf., Cutler, Mehler, Norris, & Segui, 1983, 1986; Mehler, Dommergues, Frauenfelder, & Segui, 1981). In studies investigating word segmentation in English, a stress-timed language, Cutler et al. (1983, 1986; see also Cutler & Norris, 1988) found evidence to support a metrical segmentation strategy, which relies on a pattern of strongly stressed and weakly stressed syllables to segment spoken words from the stream of continuous speech. In contrast, in studies investigating word segmentation in French, a syllable-timed language, Mehler et al. (1981) found evidence to support a model of word segmentation that was sensitive to syllable boundaries. This set of results suggests that different strategies may be employed to perform the same task (e.g., word segmentation) in different languages.

Given the possibility for differences in processing to exist across languages, Vitevitch and Rodríguez (2005) examined the influence of neighbourhood density in spoken word recognition in Spanish by having listeners whose native language was Spanish perform an auditory lexical decision task. In an auditory lexical decision task the listener must indicate as quickly and as accurately as possible whether the item they heard over a set of headphones was a real word or a made-up, nonsense word. The Spanish words that the listeners heard varied in neighbourhood density (as well as the frequency of the neighbours, and the frequency of the target word).

Vitevitch and Rodríguez predicted that they would find Spanish words with sparse neighbourhoods being responded to more quickly and accurately than Spanish words with dense neighbourhoods—as is typically found in English (e.g., Luce & Pisoni, 1998). However, they instead found exactly the opposite: Spanish words with dense neighbourhoods were responded to more quickly and accurately than Spanish words with sparse neighbourhoods. These results suggest that similar-sounding Spanish words facilitate each other rather than compete among each other during spoken word recognition. Most current models of spoken word recognition can account for the competitive effects of phonological neighbours observed in English (e.g., Luce & Pisoni, 1998; McClelland & Elman, 1986; Norris, McQueen, & Cutler, 2000), but it is not clear if those same models can account for the influence of neighbourhood density in Spanish observed by Vitevitch and Rodríguez (2005).

Although differences were observed across languages for the processes of word segmentation (cf., Cutler et al., 1983, 1986; Mehler et al., 1981) and spoken word recognition (cf., Luce & Pisoni, 1998; Vitevitch & Rodríguez, 2005), it is not clear if different processing strategies are used in different languages during *speech production*. To examine this question, native Spanish speakers participated in a picture-naming task (Oldfield & Wingfield, 1965) in which the Spanish words illustrated in the pictures varied in phonological neighbourhood density. If pictures with Spanish names from dense neighbourhoods are named more quickly than pictures with Spanish names from sparse neighbourhoods—as is the pattern observed in the production of English words—then a general model of speech production might account for the processes involved in speech production across all languages. Conversely, if pictures with Spanish names from sparse neighbourhoods are named more quickly than pictures with Spanish words from dense neighbourhoods—the opposite of what is observed in the production of English words—then the various differences that exist across languages might need to be taken into account when developing models of speech production.

METHOD

Participants

Twenty-four adult native Spanish-speakers were recruited from the University of Kansas community. All of the participants were native speakers of Spanish, were raised in a Spanish speaking environment, and all but one received their secondary education at institutions in which Spanish was the language of instruction. None of the participants reported a history of speech or hearing disorders, and all received $10 for their participation. Note that all communication with the participants (e.g., recruitment flyers, consent forms, instructions, etc.) was conducted in Spanish by the second author. A technical problem resulted in the loss of data from four participants.

Materials

The stimuli consisted of line drawings (either from Snodgrass & Vanderwart, 1980, or of a similar style) of 48 bisyllabic Spanish nouns, and are available from the authors upon request. Neighbourhood density in Spanish was evaluated as it is typically evaluated in English, with a single-phoneme substitution, addition or deletion in the target word to form a neighbour (e.g., Landauer & Streeter, 1973; Luce & Pisoni, 1998; see also Luce & Pisoni, 1998 for an alternative but comparable similarity metric based on phoneme confusion matrices). A median split was used to categorise half of the items as words with a dense neighbourhood: mean = 27.1 neighbours, $SD = 7.6$, and the other half as words with a sparse neighbourhood: mean = 10.8 neighbours, $SD = 3.5$; $F(1, 46) = 89.99$, $p < .0001$. The number of neighbours in each category is comparable with the number of neighbours in each category in previous studies (e.g., Vitevitch & Rodríguez, 2005; Vitevitch & Sommers, 2003).

Although the words differed significantly in neighbourhood density, the items did not differ in their frequency of occurrence (i.e., *word frequency*), nor in the mean frequency of the neighbours, i.e., *neighbourhood frequency*: all Fs(1, 46) $<$ 1. Words with a dense neighbourhood had a mean frequency value of 26 occurrences per million ($SD = 49$) and a mean neighbourhood frequency value of 11 occurrences per million ($SD = 6$). Words with a sparse neighbourhood had a mean frequency value of 26 occurrences per million ($SD = 47$) and a mean neighbourhood frequency value of 11 occurrences per million ($SD = 10$). Frequency values and neighbourhood density counts were based on the data contained in Sebastián Gallés, Martí Antonín, Carreiras Valiña, and Cuetos Vega (2000). Furthermore, an equal number of consonant onsets occurred in each condition: three words in each condition started with /b, k, l, p, r, t/, and two words in each condition started with /g, m, s/.

Procedure

To minimise recency effects, which are differences in the ability to retrieve a word-form from the lexicon as a function of the last time it was retrieved (Burke et al., 1991), participants reviewed a booklet that, on each page, contained the stimulus picture and the Spanish word that identified that picture. Thus, gross differences in the recency of usage of these lexical items among participants entering the laboratory—which might influence responses in the picture-naming task—were attenuated because all participants saw each stimulus item in the booklet just prior to the picture-naming task. Participants were then seated in front of an iMac running PsyScope 1.2.2 (Cohen, MacWhinney, Flatt, & Provost, 1993), which controlled stimulus randomisation and presentation, and collection of response latencies. A headphone-mounted microphone (Beyer-Dynamic DT109) was interfaced to a PsyScope button box that acted as a voice-key with millisecond accuracy.

A typical trial proceeded as follows: The word "LISTO" (READY) appeared in the centre of the monitor for 500 ms. One of the 48 randomly selected stimulus pictures was then presented and remained visible until a verbal response was initiated. Response latency, measured from the onset of the stimulus, was triggered by the onset of the participant's verbal response. Another trial began 1 s after a response was made. Responses were also recorded on high quality audio-tape for later accuracy analyses. No picture was presented more than once. Prior to the trials used in the experiment, the participants received three practice trials. These trials were used to familiarise the participant with the task, and none of the responses from the practice trials were included in the final analysis.

RESULTS AND DISCUSSION

Analysis of variance was used to examine each dependent measure (response latency and accuracy rates) with participants (F_1) and stimulus items (F_2) treated as random variables. A trained speech scientist used linguistic conventions to score the tape-recorded responses of each participant for accuracy. A response was considered correct if it matched a phonological transcription of the stimulus word. Only accurate responses were included in the analysis of response latency. Responses due to the improper triggering of the voice-key (e.g., cough, ‘‘uh’’, etc.), which accounted for about 3% of the total responses, were also excluded from the analyses.

In the analysis of response latency, words with sparse neighbourhoods: mean = 875 ms, $SD = 230$, were responded to more quickly than words with dense neighbourhoods: mean = 917 ms, $SD = 230$; $F_1(1, 19) = 8.55$, $p = .008$; $F_2(1, 46) = 4.32$, $p = .04$. The proportion of variance in the dependent variable accounted for by the independent variable, or *PV*—a measure of effect size—was .31 in the present experiment (based on information from the F_1 analysis). For reference, $PV = .01$ is considered a small effect, $PV = .10$ is considered a medium effect, and $PV = .25$ is considered a large effect (Murphy & Myors, 1998). Although the present effect is considered a large effect, given the uniqueness of the present finding, we calculated, p_{rep} (for the F_1 analysis), the probability that a replication will obtain a mean difference in the same direction as the present experiment (Killeen, 2005). Note that p_{rep} only predicts the probability of obtaining a result in the same direction, not that the replication will obtain a statistically significant difference. Using the formula provided in the appendix of Killeen (2005) to compute p_{rep} as a function of the obtained *p*-value (keeping in mind that ANOVA is a non-directional test, so the obtained *p*-value was halved in the calculation of p_{rep}), the probability of replicating the present result was .97, suggesting that an exact replication is quite likely to obtain the same result as that obtained in the present experiment. No significant difference was found with regards to accuracy rates, $F_1(1, 19) = 1.30$, $p = .27$; $F_2(1, 46) < 1$, suggesting that participants did not trade-off between speed and accuracy in their responses. Words with dense neighbourhoods were correctly responded to 87% of the time ($SD = 9$), and words with sparse neighbourhoods were correctly responded to 84% of the time (*SD* = 11).[1]

The results of the present experiment showed that pictures with Spanish names from sparse neighbourhoods were produced more quickly than pictures with Spanish words from dense neighbourhoods. The pattern of results obtained in the present experiment contrasts with the pattern of results that is typically observed in speech production in English. In English, words with dense neighbourhoods are produced more quickly than English words with sparse neighbourhoods (e.g., Vitevitch, 1997, 2002b).

It is not clear at present why neighbourhood density produces opposite effects in spoken word production in Spanish and English as observed in the present results (or in spoken word recognition, as in Vitevitch & Rodríguez, 2005), however, we hypothesise that the difference in the amount of morphological inflection in Spanish and English may be a contributing factor. Note that the Spanish language is more inflected than the English language (Mencken, 1921), meaning that affixes indicating gender and number in nouns, and tense in verbs are used to a greater extent in Spanish than in English. In Spanish, therefore, it might be more likely that two word-forms that are phonologically similar to each other might also be morphologically and semantically similar to each other than two word-forms in English. Consider the Spanish nouns *niño* (a male child) and *niña* (a female child). Both words sound similar to each other, and have similar meanings (both refer to a child, but differ in the gender of the child). Now consider the English nouns *cat* and *can*. Both words sound similar to each other, but they are not morphologically or semantically similar to each other (with the exception that *cats* and *cans* often sit on high shelves).

In the case of spoken word recognition, the additional morphological and semantic similarity for words that are phonologically similar in Spanish might account for the facilitative effect of neighbourhood density observed in Vitevitch and Rodríguez (2005). Consider the work of Rastle,

[1] Although the accuracy rates in the present experiment may appear to be low (i.e., less than 90%), they are, in fact, comparable to the results from other picture naming studies (e.g., Experiments 3 and 4 in Vitevitch, Armbrüster & Chu, 2004). It should also be noted that in the present experiment one of the dense words was *tarta* and one of the sparse words was *torta*. In Castilian Spanish *tarta* means "cake" and *torta* means "pie." However, in many Central and South American dialects of Spanish, the meanings of *tarta* and *torta* are reversed. Due to the different meanings across dialects, responses to these items from some participants were scored as "incorrect" as per Castilian Spanish, which was used to generate the stimulus items and score the items for accuracy. The results of all statistical analyses with those items excluded from all participants did not substantively change the present findings.

Davis, Marslen-Wilson, and Tyler (2000) who found that, even in the relatively less inflected language of English, morphologically related words (e.g., departure-DEPART) primed or facilitated processing of each other in a visual word recognition task. Therefore, in a language like Spanish, which is even more inflected than English, facilitation rather than competition among phonologically similar words (which are also likely to be morphologically similar) may be the norm for spoken word recognition. Spanish words with many phonologically (and morphologically) similar word-forms (i.e., a dense neighbourhood) will therefore facilitate spoken word recognition more than Spanish words with few phonologically (and morphologically) similar word-forms (i.e., a sparse neighbourhood), as observed in Vitevitch and Rodríguez (2005).

In the case of spoken word production, the location of the morphological inflections found in Spanish might also contribute to the competitive effect of neighbourhood density observed in the present study. Consider that several models of spoken word production propose that the phonemes that comprise a word-form are entered sequentially into a part of the speech production plan referred to as a phonological frame (Sevald & Dell, 1994). If several word-forms are activated at the same time, any overlapping phonemes will facilitate the retrieval and entry of those segments into the phonological frame. However, different phonemes (from different word-forms) that occur in the same position in a syllable frame will compete with each other for that location. In a word naming task, O'Seaghdha and Marin (2000; see also Sevald & Dell, 1994) found that greater amounts of competition were observed when there was significant overlap in the beginning of the word, but different phonemes near the end of the word in the prime-target pairs (e.g., storage-story) than when there was a different phoneme in the beginning of the word, but significant overlap near the end of the word in the prime-target pairs (e.g., glory-story).

In Spanish, morphological inflections typically affect the end of the word-form. Thus, during spoken word production, there will be several words activated with phonological overlap in the beginning of the word-forms, but competing segments at the end of the word (e.g., *niño* vs. *niña*). Spanish words with many phonologically (and morphologically) similar word-forms (i.e., a dense neighbourhood) will therefore have more segments competing for the same position near the end of the phonological frame than Spanish words with few phonologically (and morphologically) similar word-forms (i.e., a sparse neighbourhood), producing the competitive effects of neighbourhood density in spoken word production observed in the present experiment.

As a preliminary examination of this hypothesis we selected 90 highly familiar English words that contained two syllables with four phonemes (i.e., stimuli from another experiment currently underway in our lab) and compared those items to the 18 Spanish words from the present set of stimuli that also contained two-syllables with four phonemes (the remaining Spanish items contained five phonemes). For each word we counted the proportion of neighbours formed by a phoneme substitution in the first and second positions of the word (i.e., the first half of the word), and the proportion of neighbours formed by a phoneme substitution in the third and fourth positions of the word (i.e., the second half of the word). A statistical analysis using a mixed-model ANOVA found a significant interaction between language and the proportion of neighbours in the first half versus the second half of the word, $F(1, 106) = 14.18$, $p < .001$. English words had a larger proportion of neighbours in the first half of the word (mean = 0.51, $SD = 0.26$) than in the second half of the word (mean = 0.20, $SD = 0.19$), whereas Spanish words had a larger proportion of neighbours in the second half of the word (mean = 0.48, $SD = 0.12$) than in the first half of the word (mean = 0.39, $SD = 0.09$). (The proportion of neighbours in each language does not total 1 because of neighbours formed by phoneme additions and deletions, which were not included in this preliminary assessment.) The result of this additional analysis suggests that the location in the word where phonological neighbours tend to occur may also contribute to the processing differences observed between Spanish and English.

The result of the present experiment presents a challenge to current models of speech production. Although the influence of neighbourhood density in spoken word production in English can be accounted for by some current models of speech production (e.g., Burke et al., 1991; Dell, 1986; cf., Levelt, Roelofs, & Meyer, 1999), it is not clear if the same models of speech production can also account for the results of the present experiment, in which neighbourhood density had the opposite influence on the production of words in Spanish. Computational simulations are required to verify that current models of speech production can account for the influence of neighbourhood density in spoken word production in Spanish as well as in English (e.g., Gordon & Dell, 2001). The result of the present experiment also highlights the importance of cross-linguistic research. Additional studies of spoken word production in other languages (e.g., those that vary in morphological inflection and the location in the word where phonological neighbours tend to occur) would provide important insight into the general and language-specific constraints that govern processing and enable crucial tests of models of speech production.

Manuscript received June 2005
Revised manuscript received July 2005
First published online March 2006

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