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The influence of neighborhood density (and neighborhood frequency) in Spanish speech production: A follow-up report.

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ABSTRACT

Vitevitch & Stamer (2006) observed that Spanish speakers in a picture-naming task named words with dense neighborhoods more slowly than words with sparse neighborhoods; a finding that contrasts with results typically obtained in studies of speech production in English (Vitevitch, 2002b). Baus, Costa & Carreiras (2008) raised concerns about the stimuli employed in Vitevitch & Stamer (2006), and found with a different set of pictures that Spanish speakers in a picture-naming task named words with dense neighborhoods more quickly than words with sparse neighborhoods. Several supplemental analyses of the stimuli employed in Vitevitch & Stamer (2006) are reported. Furthermore, the results of a picture-naming experiment raise concerns about the stimuli used by Baus, Costa & Carreiras (2008). Finally, an analysis of naming times from an independent set of pictures (Bates et al., 2003) replicated the pattern of results initially observed in Vitevitch & Stamer (2006): phonologically similar words compete during speech production in Spanish.

Neighborhood density, or the number of words that sound similar to a given word, influences a number of spoken language processes, including word-learning (Storkel, 2004) and spoken word recognition (Vitevitch, 2002a; Vitevitch & Luce, 1998). As demonstrated in a variety of methodologies, the number of English words that sound similar to a given word also influences the process of speech production. Analyses of naturally occurring and laboratory-induced speech errors show that words with a *dense neighborhood*, or many phonological neighbors, are produced more accurately than words with a *sparse neighborhood*, or few phonological neighbors (Vitevitch, 1997; 2002b). In picture naming tasks, words with dense neighborhoods are produced more quickly than words with sparse neighborhoods (Vitevitch, 2002b). This "facilitative" influence of phonological neighbors on the production of English words has also been observed in a computational model of speech production (Gordon & Dell, 2001).

Given the fundamental assumption that cognitive models apply to all human information processors, it is perhaps not surprising that Vitevitch and Stamer (2006; henceforth V&S) found that neighborhood density also influenced speech production in Spanish. What was surprising, however, was the *way* in which neighborhood density influenced speech production in Spanish. In contrast to the pattern of results observed in English, V&S found that Spanish words with sparse neighborhoods were produced more quickly in a picture-naming task than words with dense neighborhoods. Interestingly, Vitevitch and Rodríguez (2005) also observed a "reversal" in the neighborhood density effect typically observed in spoken word recognition in English: native Spanish speakers responded more quickly and accurately in an auditory lexical decision task to Spanish words with a dense neighborhood than to Spanish words with a sparse neighborhood. Together these results suggest that different processing strategies might be employed to accomplish the same task in different languages (see also the work of Cutler, Mehler, Norris & Segui, (1983, 1986) and Mehler, Dommergues, Frauenfelder & Segui (1981) for different word segmentation strategies being used in different languages).

Alternatively, one might suggest that there was an uncontrolled variable in the Spanish stimuli used in the studies by V&S and by Vitevitch and Rodríguez (2005) that lead to the pattern of results observed in those studies. Indeed, Baus, Costa, and Carreiras (2008) expressed such concerns about the stimuli used in V&S, leading them to explore the reliability of the highly replicable result reported in Vitevitch and Stamer (2006). (The effect reported in V&S had a p_{rep} value of .97 (Killeen, 2005); the size of the effect was also large in magnitude.) In Experiment 1, Baus, Costa, and Carreiras (hereafter BCC) replicated our findings using (most of) the original stimuli from V&S and a sample of native (Peninsular) Spanish speakers (*n.b.*, the sample of native Spanish speakers in V&S predominately consisted of Spanish dialects from Central and South America).

In addition, BCC presented the same pictures to what they identified as a "control group" of speakers whose native language was German, and found a similar pattern of results as was observed in the native Spanish speakers, even though the words were reported as not being statistically different in neighborhood density in German: pictures with dense neighborhoods in Spanish were responded to more slowly than pictures with sparse neighborhoods in Spanish. BCC stated:

> *This second result is very relevant, since it suggests that the difference between the two sets of pictures observed in Spanish cannot be attributed to their different neighbourhood values*. BCC (2008; page 873).

Unfortunately, BCC fail to state what this pattern of results *can* be attributed to. That is, they do not explicitly identify any potentially confounding variables. Furthermore, BCC do not state how speakers of another language "…serve as a baseline against which to compare the results of the Spanish group…" (BCC, 2008 page 870). However, Caramazza, Costa, Miozzo, and Bi (2001) suggest that using speakers of another language can be used to examine the possibility that certain pictures are "…particularly difficult to recognize…" (Caramazza et al. 2001; page 1436, e.g., English and Italian speakers in Experiments 1A and 1B). If some pictures are more difficult to *visually* recognize than other pictures, perhaps that difference in the stimuli rather than the difference in neighborhood density in the stimuli might account for the results observed in the picture-naming task in V&S. Using speakers of another language is an intriguing method to use to test for the influence of some visual characteristic that might make some pictures more difficult to recognize than others. It is, however, an *indirect* way to assess visual characteristics of the pictures that one uses as stimuli.

Supplemental Analysis of V&S stimuli

To more *directly* evaluate the visual characteristics of the pictures that were employed as stimuli in V&S (2006) and in Experiment 1 of BCC (2008), we evaluated the complexity of the stimuli using an objective measure of picture complexity, namely the size (in kilobytes) of the picture files saved in PICT file format. Data stored in PICT file format are stored in a vector format, which is essentially a collection of instructions (stored as vectors) of how to draw an object. Unlike other file formats, these instructions are invariant with regards to the resolution or size of the object when displayed on a computer screen, making the size of the file (in kilobytes) the same regardless of how the image is rendered on the computer screen. However, a more complex picture will require a more complex set of instructions to draw the picture, and will therefore require more kilobytes than a less complex picture to store that information, enabling us to use the size of the file as an objective measure of image complexity.

To objectively evaluate the complexity of the pictures used in V&S, we compared the size of the files in the two stimulus conditions. Pictures of words with dense neighborhoods had a mean file size of 19.0 kilobytes (sd = 6.38), and pictures of words with sparse neighborhoods had a mean file size of 20.5 kilobytes (sd = 7.11). This difference was not statistically significant (t (46) = -.77, p = .45), suggesting that the pictures in each condition were of comparable complexity. This result also casts doubt on the hypothesis that the pictures employed as stimuli in V&S (2006) and in Experiment 1 of BCC (2008) differed in some visual characteristic, and that the difference in that visual characteristic—not the difference in neighborhood density—was responsible for the effect observed in V&S.

Object Decision Experiment

Despite the comparable amounts of objective complexity in the images, the objects depicted might still differ in some other psychologically relevant way. To test for some psychologically relevant difference in the stimuli used in V&S (2006) and in Experiment 1 of BCC (2008) that is related to visual perception or visual recognition, we conducted an object-decision task in which participants were asked to identify the image on the screen as a real object (i.e., one of the stimuli from V&S) or a nonsense object (one of the images from Kroll & Potter, 1984). An example of one of the nonobject stimuli from Kroll and Potter (1984) is presented in Figure 1.

Method

Participants: Forty native English speakers from General Psychology classes at the University of Kansas took part in the experiment. All reported normal or corrected-to-normal vision.

Materials: The stimuli consisted of the 48 real objects used in V&S, and 48 nonobject images that were randomly selected from the collection in Kroll and Potter (1984).

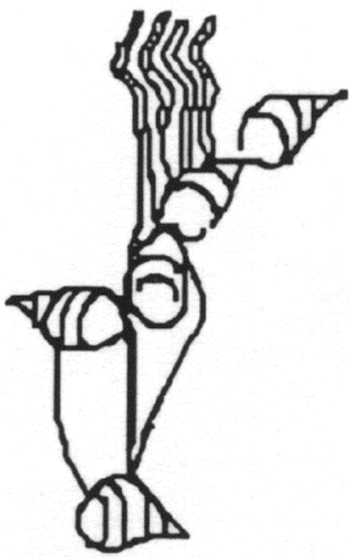

Figure 1. An example of a nonobject used in the object-decision task.

Procedure: Participants were seated in front of an iMac running PsyScope 1.2.2 (Cohen, MacWhinney, Flatt, & Provost, 1993) interfaced to a New Micros button box. PsyScope controlled stimulus randomization and presentation, and collection of response latencies (with millisecond accuracy).

A typical trial proceeded as follows: The word READY appeared in the center of the monitor for 500ms. One of the 96 randomly selected images was then presented and remained visible until a button press response was initiated. Response latency was measured from the onset of the stimulus to the onset of the manual response. Another trial began 1s after a response was made. No picture was presented more than once. Participants were asked to indicate by pressing the appropriately labeled button (YES or NO) whether the image presented on the computer screen was a real object.

Results and Discussion

A significant effect was found (F (2, 78) = 46.34, $p < .0001$), and post-hoc analyses using Scheffe's test confirmed that participants responded more slowly to the nonobjects (*mean* = 712 ms, *sd* = 158) than to either the dense objects (*mean* = 573 ms, *sd* = 95) or the sparse objects (*mean* = 598 ms, *sd* = 100). Importantly, however, the difference between dense and sparse objects was not statistically significant (p = .66). Like the analysis of the size of the picture files, the results of the object-decision experiment failed to find evidence for any sort of visual characteristic that might better account for the pattern of results that were observed in V&S (2006) and replicated in BCC (2008).

Although BCC failed to identify (or even speculate on) the nature of the other potentially confounding variable that might better account for the picture-naming results, the results of the supplemental analysis and the object-decision experiment cast doubt on the idea that some sort of visual characteristic associated with the pictures themselves led to the results originally observed in V&S (2006). Furthermore, Vitevitch and Rodríguez (2005) observed a "reversal" in the neighborhood density effect typically observed in spoken word recognition in English: native Spanish speakers responded more quickly and accurately in an auditory lexical decision task to words with a dense neighborhood than to words with a sparse neighborhood. It is unclear how a variable related to visual processing could *also* account for the reversal of neighborhood density effects observed in native speakers of Spanish by Vitevitch and Rodríguez (2005) in a spoken word recognition experiment.

Picture Naming Experiment Using Stimuli from BCC

Although it is unclear what using speakers of a different language in a picture-naming experiment reveals about the stimuli employed, we grant BCC that a significant difference in such a task with such speakers should raise some concern. To evaluate whether BCC should be concerned about their stimuli, we asked native speakers of English to name the pictures they selected as stimuli in Experiment 2 of BCC (2008; see their Appendix B). In that experiment BCC found that native Spanish speakers named words with dense neighborhoods more quickly and accurately than words with sparse neighborhoods.

Method

Participants: Thirty-two adult native English-speakers were recruited from General Psychology classes at the University of Kansas. None of the participants reported a history of speech or hearing disorders.

Materials: The stimuli consisted of the set of pictures that were selected by BCC and tested in Experiment 2 of BCC (2008; see their Appendix B). Note that we omitted two of the 46 words in BCC (*glass* and *roller skate*) because two Spanish words (*copa* and *vaso*) translated into English as *glass*; *roller skate* was omitted because the English equivalent consisted of two words. Furthermore, dialectal differences resulted in us translating *trolley*, *handbag*, and *cock* as *cart*, *purse*, and *rooster*, respectively.

Procedure: To minimize 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 English 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 randomization 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 READY appeared in the center of the monitor for 500ms. One of the 44 pictures was randomly selected and presented on the screen, remaining visible until a verbal response was initiated. Response latency was measured from the onset of the stimulus to the onset of the participant's verbal response. Another trial began 1s 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 familiarize the participant with the task, and none of the responses from the practice trials were included in the final analysis.

Results and Discussion

Significant differences were observed in response latency and accuracy when native English speakers named the set of pictures that were selected by BCC and tested in Experiment 2 of BCC (2008). For response latency, native English speakers named the English equivalents of the dense Spanish words more quickly (*mean* = 773 ms, *sd* = 106) than the sparse Spanish words (*mean* = 794 ms, *sd* = 104; t (31) = 2.341, $p < .05$). For accuracy rates, native English speakers named the English equivalents of the dense Spanish words more accurately (*mean* = 94%, *sd* = 8.5) than the sparse Spanish words (*mean* = 89%, *sd* = 7.7; t (31) = 3.136, $p < .01$).

The differences in response latency and accuracy rates were observed even though the English translations did not differ with regard to familiarity, word frequency, neighborhood density, and neighborhood frequency in English (all $p > .10$). Our finding of native English speakers producing statistically significant results *in the same direction* as the native Spanish speakers in Experiment 2 of BCC suggests that the unidentified variable that they were concerned about in our materials may also have affected their materials.

Analysis of Naming Times from an Independent Set of Pictures

The present situation—evidence for a competitive influence (V&S 2006) and for a facilitative influence (BCC 2008) of neighborhood density in speech production in Spanish—is indeed curious. What could possibly lead to such contradictory outcomes? Unfortunately, BCC did not identify or even speculate on the nature of the variable that they alluded to observing, making it difficult to resolve this issue unequivocally.

One might argue that syllable or segment frequency rather than neighborhood density might have produced the results observed in V&S. Note, however, that there is a positive correlation between neighborhood density and both segment and syllable frequency. If segment or syllable frequency were responsible for the results observed in V&S, then one would predict that words with dense neighborhoods (which tend to be comprised of common segments and syllables) would be produced more quickly than words with sparse neighborhoods (which tend to be comprised of less common segments and syllables). The pattern of results predicted by the frequency of the syllables or segments is exactly the opposite of what was observed in Spanish by V&S, raising further doubts that such sub-lexical accounts underlie the effect of neighborhood density in speech production observed in Spanish by V&S.

Although the evidence we have presented so far raises doubts about visual or sub-lexical characteristics accounting for the result observed in Spanish by V&S, it is possible that a *lexical* variable might be responsible for the contradictory outcomes observed by V&S and BCC, namely *neighborhood frequency*. Whereas neighborhood density refers to the number of words that sound similar to a given word, neighborhood frequency refers to the mean frequency of occurrence in the language of those similar sounding words.

Vitevitch and Sommers (2003; Experiment 3) demonstrated in a picture-naming task that neighborhood frequency influences speech production in English. Similarly, BCC demonstrated that neighborhood frequency influences speech production in Spanish, such that words with high neighborhood frequency were named more quickly than words with low neighborhood frequency (see their Experiment 3). The careful reader of BCC would have observed that the mean of the reported neighborhood frequency values for the dense and sparse words in Experiment 1 (i.e., the stimuli from V&S) was 11 occurrences per million, whereas the mean of the reported neighborhood frequency values for the dense and sparse words in Experiment 2 (i.e., the new stimuli selected by BCC) was 26 occurrences per million, over two times the neighborhood frequency values of the items used in V&S. Furthermore, Vitevitch (1997) found that neighborhood frequency can indeed interact with other variables to influence speech production (see also Vitevitch & Sommers, 2003). Thus, the possibility exists that differences in neighborhood frequency might underlie the antagonistic interaction observed when comparing the results of V&S and the results of Experiment 2 in BCC.

To evaluate the possibility that neighborhood frequency might underlie the difference in the results of V&S (2006) and BCC (2008) we examined an independent set of pictures and their accompanying response times (Bates et al. 2003). Of the 520 pictures used in the study by Bates et al. (2003), information regarding (phonological) neighborhood density and (phonological) neighborhood frequency was obtained from BuscaPalabras (Davis & Perea, 2005; the same lexical database employed in BCC) for 448 of the Spanish words. The items that were not analyzed included: 8 words that were longer than 12 characters in length (a restriction of BuscaPalabras), 9 objects that were named with a phrase (e.g., *trashcan* in Spanish is *bote de basura*), and 55 other words that simply were not among the items in BuscaPalabras. Based on the information obtained from BuscaPalabras, a median split was used to classify the 448 words as having dense or sparse neighborhoods, and high or low neighborhood frequency. Crucially, the words with high neighborhood frequency were within the range of neighborhood frequency observed in BCC, and the words with low neighborhood frequency were within the range of neighborhood frequency observed in V&S (see Table 1).

Table 1. Spanish Lexical Characteristics of Pictures from Bates et al (2003)

	Density Value	**NHF Value**
Sparse/Low NHF	.528	.4
Dense/Low NHF	4	1.4
Sparse/High NHF	1.5	34.0
Dense/High NHF	11	49.2

Note: **NHF** = Neighborhood Frequency; occurrence per million.

Analysis of variance of the naming times in Spanish (the measure identified as **srttar** in the Bates et al. (2003) database) revealed a number of interesting results; see Figure 2. First, there was no interaction between neighborhood density and neighborhood frequency (F (1, 444) < 1), failing to support our hypothesis that neighborhood frequency might account for the contradictory pattern of results obtained in V&S and in BCC. However, a statistically significant main effect was observed for neighborhood frequency (F (1, 444) = 5.14, p < .05), such that Spanish words with high neighborhood frequency (*mean* = 1099 ms, *sd* = 264) were named significantly more quickly than Spanish words with low neighborhood frequency (*mean* = 1143 ms, *sd* = 250). This finding provides an independent replication of the results obtained in Experiment 3 of BCC regarding the influence of neighborhood frequency on speech production in Spanish.

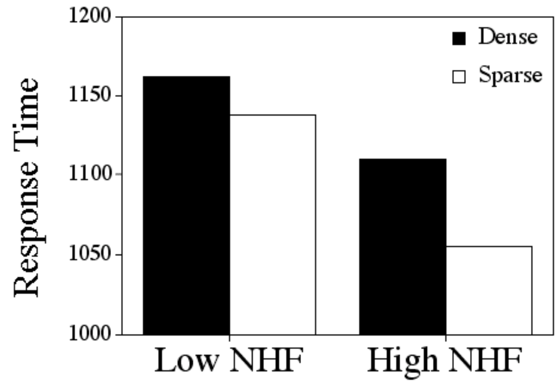

Figure 2. Naming times for 448 Spanish words obtained from the Bates et al. (2003) picture database.

More important, however, is the pattern of results for neighborhood density. Although the main effect only approaches statistical significance (F (1, 444) = 1.76, p = .18; note the large standard deviations), the pattern of results—as expected by the p_{rep} value of .97 reported in V&S—for words with low (**dense** *mean* = 1162 ms, *sd* = 255; **sparse** *mean* = 1138 ms, *sd* = 248) and with high neighborhood frequency (**dense** *mean* = 1110 ms, *sd* = 273; **sparse** *mean* = 1055 ms, *sd* = 219) indicate that words with dense neighborhoods tend to be named more slowly than words with sparse neighborhoods.

Although our hypothesis regarding the role of neighborhood frequency in the contradictory results reported by V&S and BCC was not supported, the evidence obtained from an independent set of pictures and response latencies suggests that BCC and V&S are both (at least partially) correct: Spanish words with high neighborhood frequency are named more quickly than words with low neighborhood frequency, and Spanish words with sparse neighborhoods are named more quickly than words with dense neighborhoods. The cross-linguistic difference (relative to English) in the influence of neighborhood density on speech production in Spanish that was originally reported in V&S (2006), that was replicated in Experiment 1 of BCC, and that was replicated again using an independent set of pictures in the present analysis may, as we initially discussed in V&S,

"…provide important insight into the general and language-specific constraints that govern processing and enable crucial tests of models of speech production" (V&S, 2006, page 768). Only by understanding how cognitive processes, such as lexical retrieval, adapt to different environments shaped by the specific characteristics of each language can we develop better models of language processing.

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