The effect of word-frequency on lexical selection in speech production: Evidence from semantic homogeneous naming contexts

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Abstract

We report an experiment exploring the extent to which the process of lexical selection in speech production is sensitive to word frequency. Participants were asked to name pictures in two sets of lists: semantic homogeneous (all pictures from the same semantic category) and semantic heterogeneous sets (pictures from various semantic categories). Naming latencies were slower for the former type of lists, replicating the semantic interference effects reported before. Importantly, the magnitude of the semantic interference effect was not modulated by the word’s frequency value. That is, the effects of a fixed semantic context were similar regardless of the picture’s name frequency. This result is interpreted as revealing that word frequency does not affect the ease with which lexical selection is achieved.

Keywords: Lexical access, word frequency, language production.

Efectos de frecuencia de palabra en la selección léxica en la producción del habla: evidencia aportada mediante una tarea de denominación en contextos semánticamente homogéneos

Resumen

En este trabajo presentamos un experimento en el que se explora hasta qué punto el proceso de selección léxica es sensible a la frecuencia de palabra. Se solicitó a los participantes que denominaran dibujos presentados en dos tipos de listas: semánticamente homogéneas (todos los dibujos pertenecían a la misma categoría semántica) y semánticamente heterogéneas (los dibujos pertenecían a diferentes categorías semánticas). Se encontraron mayores latencias de respuesta para las listas homogéneas que para las heterogéneas, replicando así los efectos de interferencia semántica reportados previamente. Sin embargo, la magnitud del efecto de interferencia semántica no resultó modulada por el valor de frecuencia de la palabra. Esto es, los efectos de un contexto semántico concreto fueron similares con independencia de la frecuencia del nombre del dibujo. Este resultado es interpretado como indicador de que la frecuencia de palabra no afecta a la facilidad con la que se realiza la selección léxica.

Palabras clave: Acceso al léxico, frecuencia de palabra, producción del lenguaje.
One crucial step in the course of language production is the selection of the lexical items corresponding to the speaker’s message. The processes by which the speaker selects words from the mental lexicon have been labelled under the term lexical selection. One important issue for models of speech production is to understand the factors affecting the efficiency and speed with which lexical selection takes place. Here we explore whether lexical selection is affected by word frequency.

Current models of speech production agree on assuming that lexical selection is driven, to some extent, by the activation-level of the target lexical node (Caramazza, 1997; Dell, 1986; Levelt, Roelofs & Meyer, 1999). On this view, the higher the activation of a target lexical node at the moment of selection, the easier its retrieval is. Given that lexical activation is, to some extent, proportional to the activation of the corresponding semantic representations, selection of the intended lexical node is usually successfully achieved. The assumption that lexical selection is sensitive to the words’ activation-levels has been implemented in various ways. For example, according to Dell’s model (1986, 1990), a lexical node is selected when the activation surpasses a given selection threshold; and words with high levels of activation would reach selection thresholds faster than words with low levels of activation. Other models assume that lexical selection is sensitive not only to the activation-levels of the target lexical node, but also to the activation-levels of other lexical nodes that act as competitors (e.g., Roelofs, 1992; Starreveld & La Heij, 1995). On this view, the ease and speed with which a lexical node is selected depends on the discrepancy between the activation-level of the target lexical node and that of all the other activated nodes. If such a discrepancy is large (e.g., the target lexical node is much more activated than other lexical items) selection is easy and quick. In contrast, if the discrepancy is small, selection is harder. Besides these specific implementations, what is important for our purposes here is that all models share the assumption that a crucial factor governing lexical selection is the activation-level of the target lexical node. Given this consensus, the question arises of which are the variables that affect the activation-levels of the representations involved during lexical selection. Here, we assess whether word frequency is one of them.

Word frequency has been shown to affect speakers’ naming performance in several contexts. For example, anomic patients fall in anomic states more often when asked to name pictures with low- than with high-frequency names (e.g., Gagnon, Schwartz, Martin, Dell & Saffran, 1997; Nickels, 1995). Along the same lines, speakers fall into tip of the tongue states more often with low- than with high-frequency words (e.g., Stemberger & MacWhinney, 1986). Also, high-frequency words seem to be less vulnerable than low-frequency words to phonological errors (Dell, 1990). Importantly for our purposes here, word frequency correlates negatively with picture naming latencies (Jescheniak & Levelt, 1994; Winfield, 1968), and with picture naming errors (Vitkovitch & Humphreys, 1991).

A common implementation of the frequency effect assumes that the resting level of activation of a given representation correlates positively with the number of times such a representation is accessed (e.g., on its frequency value; Morton, 1969). Thus, the more often a word is accessed, the higher its resting level of activation. In this scenario, if the selection of a representation is sensitive to activation-levels, those representations that have higher resting levels should be retrieved faster (and more accurately) than those with lower resting levels. The issue at stake here is whether the lexical representations upon which lexical selection acts are sensitive to word frequency, and as a consequence, such a variable affects the speed and accuracy with which lexical selection takes place.
Although many studies have assessed the effects of word frequency in speech production and the reliability of the phenomenon is undisputed, it is still under debate whether lexical selection is affected by it (Alario, Costa & Caramazza, 2002; Caramazza, Costa, Miozzo & Bi, 2001; 2004; Cutting & Ferreira, 1999; Dell, 1990; Ferreira & Griffin, 2003; Griffin & Bock, 1998; Jescheniak & Levelt, 1994; Jescheniak, Meyer & Levelt, 2003; Miozzo & Caramazza, 2003).

The most influential model of speech production assumes that lexical selection is not affected by a word’s frequency value (Levelt et al., 1999). In this model, lexical access proceeds in two discrete stages. In the first stage, where lexical selection takes place, speakers select the so-called lemma node from the lexicon. This node represents semantic and syntactic properties of the word, but not its phonological composition. The selection of the target lemma is subject to competition from other activated lemma nodes. Once a lemma is selected, activation flows to its corresponding lexeme, which stands for the morphophonological composition of the word. In this framework, word frequency is supposed to affect mainly the access to the representations at play in the second stage (e.g., morpho-phonological properties of the selected lemma), and therefore, lexical selection (selection of the target lemma) is insensitive to such variable.

There are, however, other models in which lexical selection is sensitive to words’ frequency values. For example, Dell (1990) assumes that lemmas with high-frequency values have resting levels of activation higher than lemmas with low-frequency values, and as a consequence the former lemmas reach the selection threshold faster than the later. As a consequence the speed with which lexical selection takes place depends, to some extent, on the word’s frequency value.

We assess whether an effect that is assumed to reflect the process of lexical selection is modulated by word frequency: the semantic interference effect (SIE) in the context of semantic homogeneous naming conditions. In this paradigm, participants are required to name a set of pictures in two different contexts: semantic homogeneous and semantic heterogeneous contexts. In a semantic homogeneous context, all pictures belong to one semantic category (e.g., ANIMAL; lion, tiger, zebra, etc.) while in the heterogeneous context they belong to different categories (e.g., lion, hand, apple, etc.). The SIE stands for the longer naming latencies observed in the homogeneous than in the heterogeneous contexts (e.g., Kroll & Potter, 1984). Although, in principle, the SIE could be revealing a delay in the selection of the target semantic representation, there are good reasons to believe that the effect reveals the presence for lexical competition during lexical selection (Damian, Vigliocco, & Levelt, 2001; Vigliocco, Vinson, Damian, & Levelt, 2002b). According to these authors, the SIE originates when the target lemma node is selected from the lexicon. That is, lexical selection is supposed to be harder in the homogeneous than in the heterogeneous context because semantically related lemmas act as more powerful competitors than unrelated ones.

In this study we embrace such an interpretation of the SIE and we reason as follows. If the word frequency value of a given lexical item affects the process of lexical selection (e.g., Dell, 1990), then we should expect such a value to modulate the SIE suffered by a word in a semantic homogeneous context. That is, the magnitude of the SIE should be different for high- and low-frequency words. This is because, low-frequency words are, per se, harder to select than high-frequency words and therefore a further difficulty in their selection produced by a homogeneous context would result in a much greater difficulty for the former type of words. On this view, we should expect an interaction between word-frequency and semantic context. Alternatively, if lexical selection
proceeds independently of a word’s frequency value (Levelt et al., 1999) then the magnitude of the SIE should be similar for high- and low-frequency words.

**Experiment**

In this experiment, participants were asked to name pictures in semantic homogeneous and semantic heterogeneous contexts. Crucially, each list contained pictures with high- and low-frequency names. Two main effects were expected: a) a SIE (longer naming latencies in the homogeneous than in the heterogeneous lists) and b) a word-frequency effect (longer naming latencies for low than for high-frequency words). Of special theoretical interest, however, is the assessment of the interaction between these two factors. Put it simply, would high-frequency words (e.g., “horse”) suffer less SI than low-frequency words (e.g., “wolf”)? A positive answer to that question would suggest that lexical selection is sensitive to a word’s frequency value. In contrast, an additive relationship between the two factors would suggest that the process of lexical selection is not affected by word’s frequency.

**Method**

**Participants:** Twenty native speakers of Italian and college students were paid for their participation.

**Materials:** Thirty-six pictures from six different semantic categories (see Appendix) were selected as experimental items (six pictures from each category). Half of the pictures in each category had high-frequency names (an average of 215 counts per million) and the other half low-frequency names (an average of 9.7 counts per million, *Dizionario di Frequenza della lingua Italiana*, CNR). For example, for the category animals, “cat, dog and horse” served as high-frequency elements and “sheep, tiger and giraffe” as low-frequency ones. We also selected 6 more additional pictures per semantic category that served as filler items (36 pictures in total). These filler pictures had medium-low frequency names. The inclusion of the 6 filler pictures allowed us to avoid a massive repetition of the experimental items and therefore maximize the detectability of the semantic interference and word-frequency effects.

Twelve experimental lists, of 12 pictures each, were constructed (6 Homogeneous and 6 Heterogeneous lists). All pictures appeared in both homogeneous and heterogeneous lists the same number of times. In the homogeneous lists, pictures were from the same semantic category. Heterogeneous lists were constructed by selecting two elements of each of the six semantic categories, and therefore there were two pictures per semantic category. Each list contained 3 high- and 3 low-frequency words, plus 6 filler pictures of medium frequency.

Each list consisted in 48 trials: 12 pictures (6 experimental plus 6 filler) presented 4 times each (4 blocks). That is, the whole experimental session had 12 lists of 12 pictures presented 4 times in each list. The appearance of the pictures in a given list was controlled in the following way. Pictures appeared in blocks of 12, in which all pictures inside each block were presented randomly. This design allowed us to explore the semantic effect across repetitions. Additionally, no more than three pictures of the same frequency range were presented in a row. In the heterogeneous lists, pictures of the same semantic category were separated by at least two pictures from a different category.

**Procedure:** Participants were tested individually. Before the experiment proper, participants were asked to name all the pictures once. In the experimental session, they named the pictures as fast and accurately as
possible using bare nouns. The 12 experimental lists were presented in a pseudorandom order, in which homogeneous and heterogeneous lists were interleaved, with a brief pause between lists. Half of the participants started the experiment with an homogeneous list and the other half with an heterogeneous list. Fourteen different list orders were constructed. The structure of a given trial was as follows: a) a question mark appeared on the screen until the participant press the space-bar, b) a fixation point appeared on the center of the screen for 500 ms, c) the picture appeared on the center of the screen for 700 ms, or until participants’ response. Naming latencies were measured from the target’s presentation.

**Results and Discussion**

Because the SIE is not always present in the first block of each list, we considered the first block of each list as a familiarization block, and we analyzed the responses from the three last blocks of each list (see Vigliocco, Vinson, Damian, & Levelt, 2002a for similar analyses). Responses different from the expected name, verbal dysfluencies, recording failures and outliers (i.e., responses exceeding 3 standard deviations) were excluded from the analyses (4.1%). Three main variables were analyzed: “Type of List” (Semantic Homogeneous vs. Semantic Heterogeneous), “Word-Frequency” (High frequency vs. Low-Frequency), and “Block” (2nd, 3rd and 4th).

Homogeneous lists led to more errors than heterogeneous lists ($F_1 (1, 19) = 12.15, MSE = .42; p < .01; F_2 (1, 34) = 6.93; MSE = .81; p < .02). Participants produced slightly fewer errors when naming high- than low-frequency words ($F_1 (1, 19) = 4.10, MSE = 1.70; p < .05; F_2 (1, 34) < 1). The main effect of “Block” was marginally significant in the subject analysis ($F_1 (2, 38) = 2.65, MSE = .26; p = .08; F_2 (2, 68) = 1.60; MSE = .48; p > .20). None of the interactions reached significant values (all $p$s > .19) (see Table I).

In the analyses of naming latencies, the main effect of “Type of List” was significant ($F_1 (1, 19) = 106.25, MSE = 1083.72; p < .01; F_2 (1, 34) = 39.37; MSE = 2653.1; p < .01), revealing faster latencies in the heterogeneous than in the homogeneous lists (44 ms). The main effect of “Word-Frequency” was significant only in the subject analyses ($F_1 (1, 19) = 17.99; MSE = 1312.35; p < .01; F_2 (1, 34) = 1.87; MSE = 15943.56; p = .18), indicating faster latencies for high- than for low-frequency words (23 ms). The main effect of “Block” was significant ($F_1 (2, 38) = 8.13; MSE = 636.97; p < .01; F_2 (2, 68) = 7.13; MSE = 825.06; p < .01). None of the interactions were significant (all $p$s > .15).

<table>
<thead>
<tr>
<th></th>
<th>High-Frequency</th>
<th></th>
<th></th>
<th>Low-Frequency</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>E%</td>
<td>Mean</td>
<td>SD</td>
<td>E%</td>
</tr>
<tr>
<td>Semantic Homogeneous</td>
<td>673</td>
<td>63</td>
<td>4.0</td>
<td>698</td>
<td>61</td>
<td>5.9</td>
</tr>
<tr>
<td>Semantic Heterogeneous</td>
<td>630</td>
<td>31</td>
<td>2.4</td>
<td>652</td>
<td>58</td>
<td>4.3</td>
</tr>
</tbody>
</table>

**Table I**

*Naming latencies (Mean), error rates (E%) and standard deviations (SD) for semantic homogeneous and semantic heterogeneous sets in Experiment 1 collapsed by block and broken by word frequency*

*Latencias de respuesta (Mean), porcentajes de error (E%) y desviaciones estándar (SD) de las listas semánticamente homogéneas y semánticamente heterogéneas del Experimento 1 colapsados por bloque y divididos por frecuencia de palabra*
Crucially, the interaction between “Word-Frequency” and “Type of List” was far from significance (both \( F_s < 1 \)).

The SIE for low- and high-frequency words was virtually identical (43 and 45 ms, respectively), indicating that the magnitude of the SIE is independent of the picture’s name frequency value. Further support for such a conclusion can be found when considering the filler pictures that had low/medium frequency, and for which the SIE was of a similar magnitude (40 ms) as well.

**General Discussion**

This study addressed whether word-frequency affects the process of lexical selection. We used the SIE produced by a semantic homogeneous context as a signature effect of the process involved in lexical selection, and we assessed whether it is modulated by the word-frequency of the target pictures.

Four main results were observed. First, participants were slower in the homogeneous than in the heterogeneous lists. Second, responses were faster for high- than for low-frequency words. Third, responses decreased across repetitions. Fourth, none of the interactions were significant. Importantly for the aims of our study is the lack of an interaction between the factors “Type of List” and “Word-Frequency”. This observation reveals that a semantic homogeneous context delays the production of a high-frequency word (e.g., “horse”) as much as that of a low-frequency word (e.g., “wolf”).

Before interpreting the theoretical implications of our results, it is important to discuss their reliability. It is always controversial to derive theoretical implications from the lack of a significant effect, in this case, the lack of an interaction between the word-frequency effect and the SIE. However, confidence when interpreting this observation is increased by the fact that we were able to observe all of the other predicted effects. We obtained the SIE, the word-frequency effect and the Block repetition effect (see Figure 1). Also the fact that neither of the effects interacted with each other is predicted on the basis of previous results. For example, previous research has already established that both the SIE and the word-frequency effects are quite stable across repetitions (Jescheniak & Levelt, 1994). Also, both the SIE and the word-frequency effect were large enough to have enough room to detect an interaction between the two factors if that were to exist. In sum, the pattern of results observed in our experiment conforms those observed already in other studies, which allows us to be more confident when interpreting the lack of interaction between word-frequency and semantic context.

The additive nature of semantic context and word-frequency has theoretical implications for: a) the variables that are supposed to affect the process of lexical selection and, b) the processing dynamics of the language production system. We will discuss them in turn.

The results are consistent with the assumption that lexical selection is not affected by a word’s frequency value. One model holding such an assumption is that proposed by Levelt et al. (1999; see also Jescheniak & Levelt, 1994; but see Jescheniak et al., 2003; and Caramazza et al., 2001, 2004) in which lexical selection operates at a level of representation (lemma level) where word-frequency does not play a role, and therefore, such a process is assumed to be unaffected by that variable. In this model, word-frequency is supposed to affect later stages of processing such as the retrieval of morphophonological properties of the selected lemma. The results are also consistent with other proposals about how word-frequency affects the production system. For example, the results are consistent with the notion
that frequency is not a property of discrete lexical nodes, but rather a property of the connections between different levels of representation (e.g., Vitkovitch & Humphreys, 1991). For example, frequency may exert its effects by affecting the speed and reliability with which information is passed from one level into the other (from the semantic level to the lexical level, or from the lexical level to the phonological level) (see note 1).

However, the additive nature of the SIE and the word-frequency effect can be used to reject some claims about the relationship between lexical selection and word-frequency. For example, in Dell’s model (1990) word frequency does modulate the availability of lexical nodes at the level at which lexical selection operates. According to this model, a high-frequency word is selected faster because its resting level of activation is higher than that of a low-frequency word. In this framework, and to the extent to which the SIE reflects the processes involved in lexical selection, high-frequency words should have suffered less interference than low-frequency words. A prediction at odds with our observations.

These results also have implications for the dynamics of lexical access in speech production. In particular, they are inconsistent with the notion of interactivity across levels of representation. According to some models, activation flows across the different levels of representation bidirectionally (Dell, 1986; 1990, etc.). That is, activation from the lexical level spreads to the phonological level and vice versa. In such a framework, and if frequency exerts its effects, say, at the phonological level, one should expect such a variable to affect also the representations located at the lexical level, and hence affect how fast they are selected. This is because, the activation sent back from the phonological representations to their corresponding lexical nodes would be higher for high-frequency words than for low-frequency words. In other words, models holding the interactivity assumption would predict lexical selection to be affected by word frequency.
Before concluding, it is important to recall that our rationale is based on the assumption that the SIE reflects the processes engaged in lexical selection. Although, there are good reasons to embrace such an assumption, it is possible that future experimentation determines that the SIE originates at a different level of processing in the course of lexicalization. If it turns out that this is the case, and that the SIE reveals processes related to say visual/conceptual processing, then we should put in hold the conclusion that lexical selection is not affected by word-frequency (see similar argument in the context of the picture-word interference paradigm by Costa, Mahon, Savova, & Caramazza, 2003).

To conclude, the results reported in this article reveal that the SIE produced by a homogeneous semantic context is not modulated by the target’s word frequency. To the extent that the SIE is revealing the process of lexical selection these results suggest that word frequency is not one of the major determinants affecting such process.

Notes

1 Note, that the goal of the study is not to determine the precise level(s) at which word-frequency exerts its effects, but rather to explore whether lexical selection is affected by such a variable. Therefore, our results should be interpreted with caution when used to determine the precise locus of the word-frequency effect.

2 Convergent evidence supporting the notion that word frequency does not modulate the magnitude of semantic interference comes from some results obtained with the picture-word interference paradigm. In this paradigm participants had to name a picture while ignoring a distractor word. Participants responses are slower when the distractor word and the picture belong to the same semantic category (when they are coordinates), than when they belong to two different categories. Interestingly, however, the magnitude of semantic interference is not modulated by the word frequency of the picture’s name (Miozzo & Caramazza, 2003).

3 It is always difficult to derive predictions from interactive models without simulating the possible outcomes. For example, the effects of word frequency on lexical selection via the interaction between phonological and lexical levels might be undetectable if one assumes a quite reduced level of interactivity (See for example Goldrick & Rapp, 2002; Rapp & Goldrick, 2000)

References


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Appendix

Experimental pictures used in the experiment are presented in the table with their correspondent frequency values, whereas filler pictures are listed below

<table>
<thead>
<tr>
<th>ANIMALS</th>
<th>VEHICLES</th>
<th>FURNITURE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Noun</strong></td>
<td><strong>Freq</strong></td>
<td><strong>Noun</strong></td>
</tr>
<tr>
<td>High</td>
<td>Frequency</td>
<td>High</td>
</tr>
<tr>
<td>Gatto (cat)</td>
<td>111</td>
<td>Machina (car)</td>
</tr>
<tr>
<td>Cane (dog)</td>
<td>148</td>
<td>Treno (train)</td>
</tr>
<tr>
<td>Cavallo (horse)</td>
<td>124</td>
<td>Moto (motorcycle)</td>
</tr>
<tr>
<td>Low</td>
<td>Frequency</td>
<td>Low</td>
</tr>
<tr>
<td>Giraffa (giraffe)</td>
<td>3</td>
<td>Trattore (tractor)</td>
</tr>
<tr>
<td>Pecora (sheep)</td>
<td>1</td>
<td>Furgone (truck)</td>
</tr>
<tr>
<td>Tigre (tiger)</td>
<td>7</td>
<td>Autobus (bus)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CLOTHING</th>
<th>BUILDINGS</th>
<th>BODY PARTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Noun</strong></td>
<td><strong>Freq</strong></td>
<td><strong>Noun</strong></td>
</tr>
<tr>
<td>High</td>
<td>Frequency</td>
<td>High</td>
</tr>
<tr>
<td>Cappello (hat)</td>
<td>33</td>
<td>Casa (house)</td>
</tr>
<tr>
<td>Camici (shirt)</td>
<td>75</td>
<td>Pallazzo (edifice)</td>
</tr>
<tr>
<td>Giacca (jacket)</td>
<td>52</td>
<td>Chiesa (church)</td>
</tr>
</tbody>
</table>

Low  | Frequency | Low  | Frequency |
| Maggiore (jersey) | 6 | Igloo (igloo) | 1 | Pugno (fist) | 36 |
| Guanto (glove) | 4 | Mulino (mill) | 8 | Pollice (thumb) | 10 |
| Cappotto (coat) | 8 | Tenda (tent) | 19 | Baffi (moustache) | 17 |

Fillers:

**ANIMALS:** Topo (mouse), Mucca (cow), Pingüino (penguin), Leone (lion), Scimmia (monkey), Elefante (elephant).

**VEHICLES:** Elicottero (helicopter), Gondola (gondola), Aereo (airplane), Bicicletta (bicycle), Nave (ship), Dirigibile (airship).

**FURNITURE:** Porta (door), Comodino (bedside table), Vasca (bathtub), Divano (sofa), Sgabello (stool), Scrivania (desk).
CLOTHING: Stivale (boat); Vestito (dress); Pantaloni (trousers); Gonna (skirt); Mutande (pants); Sciarpa (scarf).

BUILDINGS: Torre (tower); Stadio (stadium); Castello (castle); Fabbrica (factory); Faro (lighthouse); Piramide (pyramid).

BODY PARTS: Schiena (back); Naso (nose); Occhio (eye); Braccio (arm); Gamba (leg); Orecchia (ear).