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The specific-word frequency effect in speech production: Evidence from Spanish and French

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The role of word frequency in lexical access during the production of homophones remains unresolved. In the current study, we address whether specific-word (the frequency of occurrence of the word "*nun*") or homophone frequency (the summed frequency of words with the pronunciation /nΛn/) determines the production latencies of homophones. In Experiments 1a, 2a, and 3a, participants named pictures of high-frequency (e.g., "*banco*"–a bank: financial institution) and low-frequency (e.g., "*banco*"–park bench) Spanish (Experiments 1a and 2a) or French (Experiment 3a) homophones and control pictures of nonhomophone words matched in frequency with each of the two uses of the homophones. The naming latencies for low-frequency homophones were longer than those for high-frequency homophones. Furthermore, the naming latencies for homophones were indistinguishable from those for nonhomophone controls matched in specific-word frequency. In Experiments 1b, 2b, and 3b, the participants performed either object decision or picture–word matching tasks with the stimuli used in the corresponding Experiments 1a, 2a, and 3a. There were no reliable differences between high- and low-frequency homophones. The findings support the hypothesis that specific-word and not homophone frequency determines lexical access in speech production.

Keywords: Lexical access; Picture naming; Homophones.

The influence of homophones on word production was investigated for the first time by Dell (1990). Using an error induction technique, Dell showed that the phonological errors produced by the participants were determined not by the specific frequency of the target word, but rather by the combined frequency of the word and its homophones. Several years later, in an influential

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article, Jescheniak and Levelt (1994), operating with a model of lexical access that assumes that there are two lexical layers between a word's meaning and its phonological content (i.e., the lemma and the lexeme levels, respectively), made two important assertions. First, homophones (words that have the same pronunciation but different meanings) share a lexical representation at the lexeme level (morphemic). Second, the word frequency effect in speech production is located at the level of the shared lexeme representation. These two assertions were based primarily on the findings of an experiment in which Dutch–English bilingual participants had to translate English words into Dutch. The experiment focused on the translation times for the homophones, which, because Dutch has a transparent orthography, were also homographs (e.g., the Dutch word "*bos*", which has the meanings "bunch" and "forest"). There were three experimental conditions: (a) a condition in which the words were low-frequency homophones (e.g., the bunch sense of bos) with high-frequency homophone equivalents (e.g., the forest sense of bos); (b) nonhomophonous words of the same frequency as the low-frequency homophone (in this case, similar in frequency to the bunch sense of bos); and (c) nonhomophonous words similar in frequency to the total frequency of the homophone (the sum of the frequencies of the bunch and forest senses of bos). The authors found that the translation times for the homophones were shorter than those for controls of the same specific-word frequency and similar to those for the homophone frequency controls. Jescheniak and Levelt interpreted these findings as suggesting that homophones share a lexeme representation and that the frequency effect is located at the level of the lexeme. In other words, given the assumption that homophones share a lexeme representation, it follows that low-frequency homophones should inherit the frequency of their homophone mates (see Figure 1).

Somewhat similar results were obtained by Jescheniak, Meyer, and Levelt (2003) in a number of experiments using the same task and procedure but involving different languages. In one experiment, the participants had to translate words from English to Dutch and in another experiment from English to German.

Using a different methodology, Ferreira and Griffin (2003) also obtained evidence that appeared to support the hypothesis that homophones have a common lexical representation. The technique these researchers used was the rapid serial visual presentation (RSVP) paradigm. This involves presenting a sentence, word by word, at a rate of 275 ms per word. On critical trials, a picture was presented instead of a word, and the participant's task was to name the picture. The relationship between the picture and the expected word was then varied. In semantically related trials, the relationship between the expected word and the picture was purely semantic—for example, "the woman went to the convent to become a . . . (expected word '*nun*')", followed by the picture "*priest*". In contrast, in semantic–homophonic trials, the picture was semantically related to a homophone of the expected word—for example, "I thought that there would still be some cookies left, but there were . . . (expected word '*none*')", followed by the picture "*priest*". The results showed that the homophones of the words that were semantically related to the pictures produced interference in naming (e.g., "*none*" produces interference with "*priest*", which is semantically related to the homophone "*nun*"). (See also Cutting & Ferreira, 1999, for further evidence using a picture–word interference task.) However, the locus of this effect within the production process is not clear.

All of these studies are consistent with the hypothesis that homophones, despite having distinct representations at the lemma level, share the same representation at the level of the lexeme (Cutting & Ferreira, 1999; Ferreira & Griffin, 2003). This hypothesis also receives some support from studies of brain-damaged patients. For example, Biedermann, Blanken, and Nickels (2002) reported the case of an anomic German patient, M.W., for whom a word-naming treatment improved naming not just on the trained words, but also on the homophones of those words. Similar results were obtained

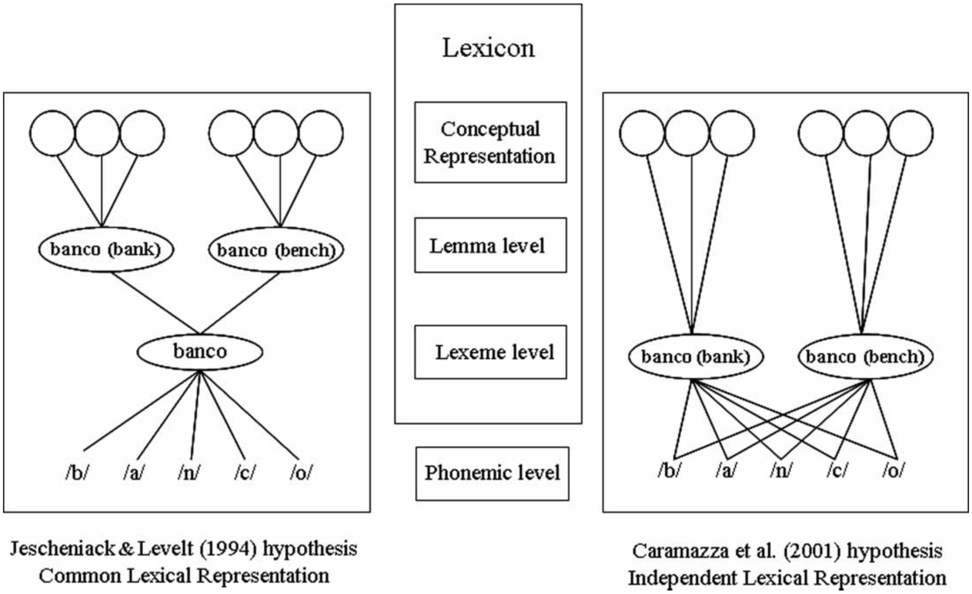

Figure 1. *Common versus independent lexical representation models.*

with an English-speaking patient both for homographic homophones (Biedermann & Nickels, 2008b) and for heterographic homophones (Biedermann & Nickels, 2008a; but see also Miozzo, Jacobs, & Singer, 2004). But here, too, the precise locus of this effect is not clear.

However, other researchers (Bonin & Fayol, 2002; Caramazza, Costa, Miozzo, & Bi, 2001; Shatzman & Schiller, 2004) failed to find a homophone frequency effect. Furthermore, Caramazza et al. (2001) found instead that specific-word and not homophone frequency determines the production latencies of homophones. In their study, Caramazza et al. used a picture-naming task in which three types of stimuli were compared: (a) pictures with homophonic names (e.g., "*nun*", which is homophonous with "*none*"), (b) pictures whose names were similar in frequency to the specific-word frequency of the pictured homophone (e.g., "*owl*", which has the same frequency as "*nun*"), and (c) pictures with names similar in frequency to the cumulative frequency of the homophone (e.g., "*tooth*", which has the same frequency as the sum of the frequencies of "*nun*" and "*none*"). They found that the naming latencies of the homophones were similar to those of the specific-word frequency controls and slower than those of the homophone frequency controls. In other words, the time required to name "*nun*" was similar to the time required to name "*owl*" and different from that needed to name "*tooth*".

To confirm that the relatively slow response times for homophones were not due to particular difficulties in recognizing the pictures corresponding to these words, thereby masking an effect of homophone frequency, Caramazza et al. (2001) carried out a control picture-naming experiment with the same pictures in Italian. Since the homophone stimuli in English were not homophones in Italian, the participants in the control experiment should have performed poorly in naming the homophone pictures if these were particularly hard to recognize. However, the Italian participants named the homophone pictures as fast as the low-frequency specific-word pictures. Furthermore, Caramazza et al. replicated the specific-word frequency effect in picture naming in an experiment with Mandarin Chinese speakers. They found that homophone-naming times were similar to those of specific-word frequency controls and significantly different from those of homophone frequency controls. Finally, these researchers carried out a Spanish–English translation experiment similar to the translation experiment reported by Jescheniak and Levelt (1994) and again found that the production latencies for homophones were similar to those of specific-word frequency controls and significantly slower than those of homophone frequency controls.

Bonin and Fayol (2002) used a picture-naming experiment in which participants were asked to name both members of a homophone pair on separate occasions. For example, they were asked to name both a picture of a glass (the name of which in French, "*verre*", is of high frequency and is pronounced /vEr/),and one of a worm ("*ver*" in French), which are pronounced the same way. In other words, if homophones inherit the frequency of their homophone mates, there should be no difference in the naming of the two pictures (e.g., "*worm*" and "*glass*") of a homophone. However, Bonin and Fayol found that the pictures of the high-frequency homophone members (e.g., "*glass*") were named faster than the pictures of the low-frequency homophone members (e.g., "*worm*"). These findings cannot be ascribed to greater difficulty recognizing the low-frequency member of a homophone pair since, in a semantic categorization task in which participants classified the pictures as "natural kind" or "artefact", participants classified the low-frequency homophones faster than the high-frequency homophones. However, as stressed by Biedermann and Nickels (2008a), one potential weakness of the Bonin and Fayol (2002) study was the lack of a low-frequency nonhomophone control condition matched to the low-frequency homophone condition.

Using a similar methodology, Shatzman and Schiller (2004) found that naming latencies were slower for low-frequency homophones than for high-frequency homophones. However, Shatzman and Schiller (2004) considered that these findings could be due to differences related to the picture complexity, since participants were also slower with the low-frequency homophones in a picture verification task. One possible alternative is that the differences could have been due to name agreement since the low-frequency homophones had a lower name agreement level than the high-frequency ones.

Miozzo and Caramazza (2005) investigated word frequency effects in homophones by examining the magnitude of the interference they created when presented as distractors during a naming task. Specifically, they found that a homophone's specific frequency was a better predictor of its effect on picture naming than was its combined frequency. In their Experiment 1, they used low-frequency homophones with a high cumulative frequency (e.g., "*brake*") and two controls, one of similar specific frequency (e.g., "*chord*") and other of similar cumulative frequency (e.g., "*offer*"). The results showed that naming latencies to the pictures in the homophone contexts were similar to those of the low-frequency controls. A second experiment used the higher frequency counterpart of the homophones used in Experiment 1 (e.g., "*break*"), but kept the same control conditions. In this experiment, the interference effects of the high-frequency homophones were similar to those observed with the high-frequency controls.

In a more recent study, Gahl (2008) investigated the homophone frequency effect by considering the word durations of homophones. The study took advantage of the observation that frequent words tend to shorten and that, therefore, if low-frequency homophones inherit the frequency advantage of their high-frequency mates, the word durations of the low- and the high-frequency members of a homophone pair should be the same. Gahl (2008) found instead that the high-frequency member of homophone pairs (e.g., time) have shorter durations than their low-frequency homophones (e.g., thyme). In other words, low-frequency words do not inherit the frequency advantage of their high-frequency homophones.

Jescheniak et al. (2003; but see Caramazza, Bi, Costa, & Miozzo, 2004) have pointed out that there are several potentially important differences between the studies that show a homophone frequency effect and those that have failed to find such an effect. First, whereas Jescheniak and

Levelt (1994) used *homographic* homophones in their experiment, Caramazza et al. (2001) and Bonin and Fayol (2002) used *heterographic* homophones.[1] They also noted that the control task used by Caramazza et al. (2001), to assess the possible contribution of differences in the ease with which the pictures of homophone and control words are recognized, was different from the task (semantic classification) used by Jescheniak and Levelt. Finally, they point out that in the Bonin and Fayol study, no controls were used to assess whether homophone or specific-word frequency is the better predictor of homophone naming latencies (see Biedermann & Nickels, 2008a, for a similar criticism).

In the current study, we used a picture-naming task with homophones to assess whether the reason why Caramazza et al. (2001) and Bonin and Fayol (2002) failed to find a homophone frequency effect was related to the methodological differences noted by Jescheniak et al. (2003). In particular, we tested whether the differences in the results reflect the use of languages with transparent (Dutch—where a homophone frequency effect was found) versus opaque orthographies (English, Mandarin Chinese, and French—where no homophone effect was found). In two experiments, we tested speakers of Spanish in a picture-naming task using homographic homophones and both specific-word and homophone frequency controls. Spanish orthography is quite transparent, and there are many words that have the same pronunciation and the same spelling, but completely different meanings (for example, "*banco*" means *bank* or *bench*; "*vela*" means *candle* or *sail*, etc.). Furthermore, we carried out control experiments that used a semantic classification task to assess the possible effects of differences in picture recognition in the naming task. In a third experiment, we tested French speakers. Although French is like English, in that homophones can be heterographic—for example, "*ver*" (worm) and "*verre*" (glass) are both pronounced /vEr/—its phonology in reading is transparent in the same way as Dutch and Spanish, since specific orthographic patterns in French are associated with only one pronunciation. We also introduced a control, for specific-word frequency, that was not included in the Bonin and Fayol (2002) study. Finally, in the experiments reported here, we also controlled for other variables that could affect naming times, such as name agreement (see Shatzman & Schiller, 2004) and visual complexity.

EXPERIMENT 1A: PICTURE NAMING IN SPANISH

The aim of this experiment was to determine whether naming latencies of homophones are better predicted by homophone frequency or specific-word frequency. We used homographic homophonous words such as "*banco*", which has a cumulative frequency of 50 appearances per million, and specific-word frequencies of 30 and 13 for the senses *bank* and *bench*, respectively (the remaining seven uses are for other homophones such as *fish bank* or *data bank*). If the homophone frequency inheritance hypothesis put forward by Jescheniack and Levelt (1994) is correct, there should be no difference in the naming times for the two homophones ("*bank*" and "*bench*"), since the two words would inherit each other's frequency, thus resulting in the same effective frequency. However, if the specific-word frequency hypothesis proposed by Caramazza et al. (2001) is correct, each different use of "*banco*" should be associated with a response time that is specific to its own frequency, independently of the frequencies of its homophone mates. Thus, the bench sense of "*banco*" should have a response time similar to that for "*cuna*" ("*cradle*", with a frequency of 14), and the bank sense of "*banco*" should have a response time similar to "*chaqueta*" ("*jacket*", with a frequency of 31).

[1] Caramazza et al. (2001) used both homographic and heterographic homophones and, in a post hoc analysis, found no differences between the two types of homophone.

We would have liked to have manipulated the age of acquisition (AoA) of the words as well (i.e., the age at which the words were learned), especially since many experiments have shown that some of the effects attributed to frequency may be due to AoA (e.g., Barry, Morrison, & Ellis, 1997; Cuetos, Ellis, & Alvarez, 1999; Morrison, Ellis, & Quinlan, 1992; for a review, see Johnston & Barry, 2006). However, given the scarcity of depictable homophones and the fact that high-frequency stimuli are also those that tend to be acquired early, it is very difficult to manipulate these two variables. Therefore, we only considered lexical frequency in the following experiments (although AoA is introduced as a covariate in the analyses of variance, ANOVAs).

Method

Participants

A total of 25 native speakers of Spanish (8 males and 17 females with a mean age of 21.1 years), who were students at the School of Education of the University of Huelva, participated in this experiment. All had normal or corrected-to-normal vision.

Stimuli

A total of 95 simple black-and-white line drawings were presented. The majority of the items were taken from the Snodgrass and Vanderwart (1980) database. The other pictures were drawn by an artist in a style that was similar with regard to visual complexity, thickness of line, and so on. A total of 38 of the pictures corresponded to 19 homophones: 19 low- and 19 high-frequency names. The other 38 pictures were controls: 19 with names similar in frequency to the high-frequency homophones and 19 with names similar in frequency to the low-frequency homophones. The 19 remaining pictures were fillers. The frequencies of the stimuli were obtained from a two-million-word corpus (Alameda & Cuetos, 1995). The frequency of each homophone was estimated specifically for each sense by computing the number of times that each meaning appeared in the corpus (e.g., for the word "*banco*", we counted the number of times that the word appeared with the meaning signified by "*bank*" and the number of times it appeared with the meaning "*bench*"). The stimuli are listed in Appendix A.

As can be seen in Table 1, the four conditions were matched on name agreement and visual complexity (*F*s < 1). The items were not matched on length, although a majority of them had two or three syllables. Name agreement and visual complexity scores were obtained from 30 students who had to name the pictures and rate the complexity of each drawing on a 7-point scale, where 1 indicated "a very simple drawing" and 7 "a very complex drawing".

Apparatus

A PC with an external voice key was used. The software Superlab Pro (Abboud & Sugar, 1997) was used for stimulus presentation and the collection of data.

Procedure

Participants were tested individually. Before the beginning of the experiment itself, they were asked to name the pictures in an untimed task,

Table 1. *Summary of the statistical characteristics from Experiments 1a and 1b*

	HF		*LF*	
	Homophones	*Controls*	*Homophones*	*Controls*
Frequency	21.42 (23.68)	21.47 (23.83)	3.37 (3.82)	3.42 (3.96)
Name agreement	90.28 (0.14)	93.08 (0.09)	93.14 (0.10)	94.14 (0.8)
Visual complexity	2.65 (0.70)	2.98 (0.72)	2.80 (0.60)	3.11 (0.72)
Length	4.74 (0.71)	5.89 (1.12)	4.74 (0.71)	5.79 (1.32)

Note: HF = high frequency, LF = low frequency. Standard deviations in parentheses.

and errors were corrected. The total number of words corrected was: 16 (3.37%) with the high-frequency homophones; 15 (3.16%) with the low-frequency homophones; 14 (2.95%) with the high-frequency controls, and 21 (4.42%) with the low-frequency controls. The screen was placed approximately 55 cm from the participants. In the experiment proper, the stimuli were presented in a quasi-random order at the centre of the screen, preceded by four asterisks (****). The asterisks were presented for 1,500 ms and acted as a fixation point. The line drawings remained on the screen until the participant initiated a response or 3,000 ms had elapsed. The participants had to name each picture as fast as possible without making errors. Latencies were recorded from picture onset and were monitored online by an experimenter who recorded any errors. The experiment started with 10 warm-up trials.

Results and discussion

Prior to the analysis of the naming latencies, we excluded both errors and outliers (i.e., latencies that were three standard deviations above or below the mean) and trials in which the voice key failed to record a response. A total of 5.5% of the responses were therefore discarded—3.24% corresponded to naming errors and 2.26% to voice-key failures and outliers. Mean naming latencies and error rates are reported in Table 2.

As shown in Table 2, high-frequency homophones were named faster than low-frequency homophones (76 ms). Moreover, naming latencies for the low- and high-frequency homophones were very similar to those for their respective frequency-matched, nonhomophone controls. An analysis of variance with word type (homophone vs. nonhomophone) and frequency (high vs. low frequency) introduced as factors revealed no significant main effect of word type, F_1 and $F_2 < 1$, but a reliable effect of frequency, $F_1(1, 24) = 106.29$, $p < .001$, $MSE = 147{,}478.27$; $F_2(1, 18) = 17.59$, $p < .01$, $MSE = 106{,}552.02$. The interaction between the two factors was not significant, F_1 and $F_2 < 1$. Since we had collected AoA data for these stimuli (subjective ratings, on a 7-point scale, from 25 other students), AoA was introduced as a covariate in a new analysis of variance. The AoA covariate was not significant ($F < 1$). Matched-pairs t tests were performed to further explore the nature of the frequency effect. High-frequency homophones were produced significantly faster than low-frequency homophones, $t_1(24) = 8.71$, $p < .001$; $t_2(18) = 2.34$, $p < .05$, and high-frequency controls were produced significantly faster than low-frequency controls, $t_1(24) = 5.62$, $p < .001$; $t_2(18) = 3.36$, $p < .01$. However, no reliable difference was observed between low-frequency homophones and low-frequency controls, t_1 and $t_2 < 1$, while a significant difference was observed between low-frequency homophones and high-frequency controls, $t_1(24) = 10.18$, $p < .001$; $t_2(18) = 3.39$, $p < .01$. That is, the naming times of the low-frequency homophones were similar to those of the low-frequency controls and different from those of the high-frequency controls.

The same pattern of results was found for errors. The main effect of word type was not significant, Fs < 1. The main effect of frequency was significant by participants only, $F_1(1, 24) = 4.38$, $p < .05$, $MSE = 0.81$; $F_2 < 1$. The interaction between frequency and word type was not significant, Fs < 1.

These results are consistent with those reported by Caramazza et al. (2001) and Bonin and Fayol (2002; at least with regard to the difference between high- and low-frequency homophones in the latter study) and differ from those obtained by Jescheniak and Levelt (1994). Low-frequency

Table 2. *Mean naming latencies and percentage of errors as a function of word frequency and homophony in Experiment 1a*

	HF		*LF*	
	Latencies	*Errors*	*Latencies*	*Errors*
Homophones	643 (78)	3.16	719 (79)	3.16
Controls	638 (87)	2.53	715 (113)	4.42

Note: HF = high frequency, LF = low frequency. Latencies in ms. Standard deviations in parentheses.

homophones produced significantly longer naming times than did high-frequency homophones and high-frequency nonhomophone controls. Thus, picture naming latencies appear to be determined by specific-word frequency and not homophone frequency. These results were obtained in a language (Spanish) with a transparent orthography like Dutch—the language used in the original experiment by Jescheniak and Levelt. Thus, orthographic transparency cannot be the reason for the contrasting results obtained by Caramazza et al. and by Bonin and Fayol, and by Jescheniak and Levelt.

One possible explanation for the results in Experiment 1a is that the difference between the low- and high-frequency homophones is due to differences in the ease of recognition of the pictures used in the two sets of stimuli. It is possible that the pictures used for the low-frequency homophones were particularly hard to recognize, thus offsetting any advantage conferred by their homophone status. In other words, it is possible that the longer naming times obtained with the low-frequency homophones were the result of the very slow recognition times for the pictures used for these stimuli compared to the recognition times for the high-frequency homophones and the nonhomophone control stimuli. Although this seems to be an unlikely explanation, we tested this possibility in a second experiment with the same stimuli in a task in which the participants did not have to name the objects but only to recognize them.

EXPERIMENT 1B: OBJECT DECISION IN SPANISH

In this experiment, we used an object-decision task similar to the one used by Kroll and Potter (1984). The participants had to decide whether or not a stimulus was a familiar object. This task evaluates the cognitive operation necessary to pair perceived visual representations with stored structural object representations (Humphreys, Riddoch, & Quinlan, 1988) and can therefore serve as a reasonable index of the ease with which an object is recognized.

Method

Participants

A total of 25 native speakers of Spanish (9 males and 16 females with a mean age of 21.0 years), taken from the same pool as that in the previous experiment, participated in this experiment. All had normal or corrected-to-normal vision, and none had taken part in the previous experiment.

Stimuli

The stimuli were the same line drawings as those that were used in the previous experiment, along with 95 line drawings of nonobjects: 88 line drawings used by Kroll and Potter (1984) plus 7 new line drawings prepared specifically for this task.

Apparatus

The apparatus was the same as that in the previous experiment, except that instead of a voice key, two external buttons connected to the keyboard were used to record responses.

Procedure

The participants had to decide as fast as possible whether each given line drawing corresponded to a "real" or to an "unreal" object, and reaction times (RTs) were recorded. The "real" button was assigned to the participant's dominant hand, and the "not-real" button to the nondominant hand.

Results and discussion

Prior to the analysis of response times, errors were removed from the data. This resulted in the removal of 7.9% of the responses: 2.4% for objects and 5.5% for nonobjects. Of the data eliminated, 4.3% were trials on which participants responded erroneously, and the remaining 3.6% were outliers (three standard deviations above or below the mean).

The mean decision latencies and error rates in the different experimental conditions are presented in Table 3. The differences in RTs across conditions were minimal (except in the comparison with the response times for nonobjects), and, importantly, the results indicate that

Table 3. *Mean object decision latencies and percentage of errors in Experiment 1b*

	HF		*LF*	
	Latencies	*Errors*	*Latencies*	*Errors*
Homophones	612 (80)	3.79	593 (80)	3.79
Controls	612 (76)	2.11	607 (80)	3.58

Note: HF = high frequency, LF = low frequency. Latencies in ms. Standard deviations in parentheses.

the low-frequency homophones were not more difficult to recognize than the other stimuli. As in Experiment 1a, ANOVAs were carried out for decision latencies, with word type and frequency as experimental factors. The main effect of word type (homophone vs. nonhomophone) was not significant, Fs < 1. High-frequency pictures took longer to categorize than low-frequency pictures. The main effect of frequency was significant by participants, $F_1(1,\ 24) = 4.46$, $p < .05$, $MSE =$ 3,641.40, but not by items, $F_2 < 1$. The direction of this effect is opposite to the one found in Experiment 1a, where high-frequency words were produced faster than low-frequency words. The interaction between word type and frequency was not significant, $F_1(1,\ 24) = 1.69$, $MSE =$ 1,309.28; $F_2 < 1$. There were no reliable effects for errors, all Fs < 1.

To summarize, in object decision there were no significant differences between any of the experimental conditions. The only minor trend was for low-frequency homophones, which were recognized faster than other stimuli—an effect that runs counter to the one observed in the naming experiment. Thus, the naming latency differences found between high- and low-frequency homophones and between low-frequency homophones and high-frequency controls cannot be ascribed to the object recognition stage but originate at some stage of lexical access.

EXPERIMENT 2A: PICTURE NAMING IN SPANISH

The findings of Experiments 1a and 1b are fully consistent with those reported by Caramazza et al. (2001) in that the crucial variable in determining naming latencies seems to be specific-word frequency and not homophone frequency. However, a number of potentially problematic properties associated with the materials used in these two experiments demand caution in interpreting the results. In effect, it could be argued that the frequency differences between the high- and low-frequency members of the homophone pairs we used were not very large, thus perhaps masking a real homophone effect. It should be noted, however, that we did obtain significant frequency effects consistent with the predictions of the specific-word frequency hypothesis, therefore making it unlikely that the absence of a homophone effect was due to the small differences in frequencies between the high- and low-frequency members of the homophonous pairs.

Another potential problem concerns the fact that the experimental (homophone) and control (nonhomophone) words were not perfectly matched on length. However, length differences cannot be responsible for the specific-word frequency effects obtained with the homophone words since the same phonological form was produced for the high- and low-frequency member of the homophone pair. Furthermore, the small differences in length between the experimental and control items should have favoured the faster production of homophones and, therefore, could not be responsible for the differential effect of specific-word versus homophone frequency obtained in Experiment 1a.

Finally, there is the potential concern that the experimental and control items were not matched for initial phoneme. Therefore, it remains possible that the differences observed for the initial phonemes of the picture names contributed to the pattern of results reported here.

As stated above, it is unlikely that the three potentially problematic factors mentioned above are responsible for the pattern of results obtained in Experiment 1a, which suggests that it is specific-word and not homophone frequency that determines the speed of lexical access. Nonetheless, in order to take account of these potential concerns, we replicated Experiments 1a and 1b with a new set of stimuli.

Method

Participants

A total of 25 native speakers of Spanish (8 males and 17 females with a mean age of 21.9 years), taken from the same pool as that in the previous experiments, were recruited for this study. All had normal or corrected-to-normal vision, and none had participated in any of the previous experiments.

Stimuli

A total of 72 simple black-and-white drawings were used. As in the previous experiment, a majority of the items were taken from the Snodgrass and Vanderwart (1980) database, and a few pictures were drawn by an artist in a style that was similar with regard to visual complexity and line thickness. A total of 36 of these drawings corresponded to homophones: 18 representing the more frequent meaning, and 18 the less frequent meaning. The other 36 drawings were controls: 18 drawings whose names were similar in frequency to the high-frequency homophones, and 18 similar in frequency to the low-frequency homophones. Homophones and control items were matched on length and initial phoneme. The frequency was obtained from a two-million-word corpus (Alameda & Cuetos, 1995). Name agreement and visual complexity scores were obtained from a separate group of 30 students who had to name the pictures and to rate the complexity of each drawing on a 7-point scale.

As shown in Table 4, the four conditions were matched on name agreement, number of phonemes, and visual complexity (Fs < 1). The stimuli are listed in Appendix B.

Apparatus

The apparatus was identical to that used in Experiments 1a and 1b.

Procedure

The procedure was identical in all respects to that of Experiment 1a. Before the beginning of the experiment, the participants were asked to name the pictures in an untimed task, and errors were corrected. The total number of words corrected was: 20 (4.4%) in the high-frequency homophones; 30 (6.6%) in the low-frequency homophones; 30 (6.6%) in the high-frequency controls; and 38 (8.4%) in the low-frequency controls.

Results and discussion

Prior to the analysis of the naming latencies, errors were removed, as were outliers and other errors caused by problems with the voice key. A total of 9.8% of the trials were eliminated: 6.6% for naming errors and the remainder (3.2%) as outliers and voice-key failures.

The mean naming latencies and percentages of errors for the experimental and control conditions are shown in Table 5.

High-frequency homophones were named faster (89 ms) than their low-frequency mates, and both were named as fast as their respective non-homophone frequency controls. There was no effect of word type, F_1 and $F_2 < 1$, but a clear reliable effect of frequency, $F_1(1, 24) = 43.09$,

Table 4. *Summary of the statistical characteristics from Experiments 2a and 2b*

	HF		*LF*	
	Homophones	*Controls*	*Homophones*	*Controls*
Frequency	23.61 (22.19)	24.00 (21.83)	2.44 (2.85)	2.50 (2.41)
Name agreement	96.11 (0.45)	94.8 (0.94)	93.33 (0.07)	94.81 (0.06)
Visual complexity	2.39 (0.49)	2.60 (0.69)	2.72 (0.79)	2.76 (0.61)
Length	4.89 (0.99)	4.67 (0.94)	4.89 (0.99)	5.22 (0.97)

Note: HF = high frequency, LF = low frequency. Standard deviations in parentheses.

Table 5. *Mean naming latencies and percentage of errors as a function of word frequency and homophone in Experiment 2a*

	HF		*LF*	
	Latencies	*Errors*	*Latencies*	*Errors*
Homophones	781 (90)	4.22	870 (124)	7.78
Controls	799 (88)	6.00	873 (113)	8.22

Note: HF = high frequency, LF = low frequency. Latencies in ms. Standard deviations in parentheses.

$p < .001$, $MSE = 167{,}289.18$; $F_2(1, 17) = 6.65$, $p < .05$, $MSE = 106{,}702.23$. The interaction between the two factors was not significant, Fs < 1.

Matched-pairs *t* tests show that high-frequency homophones were named significantly faster than low-frequency homophones, $t_1(24) = 5.94$, $p < .001$; $t_2(17) = 2.40$, $p < .05$, and that high-frequency controls were named significantly faster than low-frequency controls, $t_1(24) = 5.27$, $p < .001$; $t_2(17) = 2.05$, $p < .05$. No reliable difference was observed between low-frequency homophones and low-frequency nonhomophone controls, ts < 1.

As far as errors are concerned, the main effect of frequency was reliable, $F_1(1, 24) = 9.99$, $p < .01$, $MSE = 6.76$; $F_2(1, 17) = 12.17$, $p < .05$, $MSE = 9.39$, but the effect of word type was not, F_1 and F_2. The interaction between frequency and word type was also not significant, Fs < 1. Again an age of acquisition covariate was included in the model, but its effect was not significant ($F < 1$).

The results obtained here fully replicate those obtained in Experiment 1a. However, before discussing these results further, it is important to consider the possibility that these effects are due to recognition differences. Experiment 2b was designed to address this possibility by means of a word–picture matching task.

EXPERIMENT 2B: WORD–PICTURE MATCHING IN SPANISH

It is important to make sure that the picture-naming latency differences did not stem from differences in the ease of recognizing the pictured objects (Bonin, Chalard, Méot, & Barry, 2006). In effect, we cannot reject the hypothesis that low-frequency homophones were named more slowly than high-frequency homophones because of differences in the speed of recognizing the two sets of pictured objects (and not because of differences in the speed with which the two sets of items are accessed from the mental lexicon). Of course, frequency may affect both picture recognition and lexical access (but see Almeida, Knobel, Finkbeiner, & Caramazza, 2007; Bonin et al., 2006). As a result, it is not enough to compare naming performance on the high- and low-frequency members of a homophone pair. Instead, we need to compare performance on these two types of words with that observed for appropriately matched nonhomophone control words. This control condition makes it possible to assess the additional effect, if any, of homophony in picture naming. That is, the hypothesis that homophones inherit the frequency of their homophone mates makes two predictions: (a) Low-frequency members of homophone pairs should be named faster than specific-word frequency-matched controls (because homophones that have inherited the frequency of their homophone mates should actually be more frequent than the controls); and (b) low-frequency members of homophone pairs should be named as fast as the high-frequency members of the pairs unless the latter are recognized faster, thereby leading to faster naming latencies. It is therefore important to assess whether the pictured objects in the various experimental conditions differ in the ease with which they are recognized.

In Experiment 1b, this possibility was assessed by asking participants to perform an object decision task. We found that the pictures of the low-frequency homophone names were "recognized" as fast as those of their specific-word frequency controls and those of the high-frequency homophone names. This finding was taken as evidence that differences in picture recognition speed were not responsible for the naming latency effects observed in the picture-naming task. However, it could be argued that the object recognition task is not sufficiently sensitive to reveal subtle differences in the speed with which pictures are recognized. To address this concern, we used a picture–word matching task in Experiment 2b. This task has been widely used in speech production studies to control for nonlexical differences between picture stimuli. Evidence validating its use to control for difficulties arising at the level of nonlexical factors in picture naming has recently been provided by Stadhagen-Gonzalez, Damian, Pérez, Bowers, and Marin (2009).

Method

Participants
A total of 25 native speakers of Spanish (7 males and 18 females with a mean age of 21.9 years), again drawn from the same pool as in those involved in the previous experiments, participated. All had normal or corrected-to-normal vision, and none had participated in any of the previous experiments.

Stimuli
A total of 144 word–picture pairs were used. The 72 pictures used in the previous experiment were paired with semantically related words—for example, the picture of a key ("*llave*") was paired with the word "*puerta*" (door). A total of 72 other pictures were paired with their correct name (e.g., the picture of a gorilla and the word "*gorilla*") and were used as fillers. The reason for presenting the targets in the negative trials was to avoid word–object priming (and to use a different type of judgement from the one we used in Experiment 3b—see below).

Apparatus
The apparatus used in the previous experiments was utilized in this experiment as well.

Procedure
A ready signal (*) was presented for 1,000 ms at the centre of the screen. A word printed in bold (Times New Roman 50) was then presented for 500 ms. Finally, a picture replaced the word and remained on the screen until the participant pressed one of two buttons connected to the keyboard to indicate whether or not the word was the name of the picture.

Results and discussion

The results are summarized in Table 6. The errors produced by the participants, 4.6% of the trials, were excluded from the RT analyses (2.8% were trials on which participants had not pressed the correct key, and the remainder were outliers).

An ANOVA performed on the RTs failed to find any significant differences between the different experimental conditions: Neither word type, F_1 and $F_2 < 1$, nor frequency, F_1 and $F_2 < 1$, had a reliable effect. The interaction between these factors was also not significant, $F\text{s} < 1$. Furthermore, no reliable effects were found for errors, $F\text{s} < 1$.

The results of this experiment confirm that the differences in naming latencies obtained in Experiment 2a cannot be attributed to differences in the speed of picture recognition. Therefore, we feel confident that the results of Experiment 2a, in which low-frequency homophones were named more slowly than high-frequency homophones and no faster than specific-word frequency nonhomophone controls, were due to the fact that it is specific-word and not homophone frequency that determines the speed of lexical access in speech production.

The findings obtained in Experiments 1a–1b and 2a–2b are fully in line with those reported by Caramazza et al. (2001). They also partially replicate those reported by Bonin and Fayol (2002). However, as noted by both Jescheniak et al.

Table 6. *Mean naming latencies and number of errors as a function of word frequency and homophony in Experiment 2b*

	HF		*LF*	
	Latencies	*Errors*	*Latencies*	*Errors*
Homophones	679 (68)	3.78	688 (75)	2.67
Controls	677 (81)	2.67	682 (85)	1.56

Note: HF = high frequency, LF = low frequency. Latencies in ms. Standard deviations in parentheses.

(2003) and Biedermann and Nickels (2008a), Bonin and Fayol's experiments did not include a control condition necessary to evaluate whether it is specific-word or homophone frequency that determines the speed of lexical access. Specifically, Bonin and Fayol (2002) compared naming times between low- and high-frequency homophones (e.g., "*ver*", worm, and "*verre*", glass, both pronounced /vEr/) but did not include nonhomophone controls so that it could not be established whether homophony contributed to naming times. That is, even if it is true that low-frequency homophones do not fully inherit the frequency of their homophone mates (as found in Bonin & Fayol, 2002), it could still be the case that homophony contributes to the speed of lexical access. This issue was addressed in the following experiment.

EXPERIMENT 3A: PICTURE NAMING IN FRENCH

Experiments 3a–3b were formally identical to Experiments 1a–1b and 2a–2b, except for two aspects. First, the new experiments were in French and constituted a replication and, as noted, a necessary extension of the experiments reported by Bonin and Fayol (2002). Second, in Experiment 3a, participants were asked to name the same stimuli multiple times, thereby allowing an assessment of the robustness of the frequency effect (Jescheniak & Levelt, 1994).

Method

Participants

A total of 25 native speakers of French (6 males and 19 females, with mean age 19.0 years), who were students at Blaise Pascal University (Clermont-Ferrand, France), participated in the experiment. All participants had normal or corrected-to-normal vision. Students received course credit for their participation.

Stimuli

The stimuli consisted of 72 black-on-white drawings. Some were taken from various children's picture books, some were drawn by an artist, and some were taken from the Alario and Ferrand (1999) database or from the Bonin, Peereman, Malardier, Méot, and Chalard (2003) database. We selected four sets of pictures. Two sets consisted of 18 pairs of pictures with homophonic names in French. All homophones were also heterographic. The homophonic names for these picture targets were chosen such that one corresponded to a low-frequency (e.g., "*ver*", worm) and one to a high-frequency reading of the homophone (e.g., "*verre*", glass). These were the same items as those used in Bonin and Fayol's (2002) study. The remaining 36 items were control pictures with nonhomophonic names. One set of 18 pictures was the low-frequency, nonhomophone control group and was matched on specific-word frequency with the low-frequency homophones; the other 18 pictures were the nonhomophone controls for cumulative-homophone frequency. Frequency values were taken from LEXIQUE (New, Pallier, Ferrand, & Matos, 2001) and from MANULEX (Lété, Sprenger-Charolles, & Colé, 2004). The LEXIQUE database is a corpus of over 31 million words including sixteenth- to twentieth-century literacy texts, nineteenth- to twentieth-century scientific and technical texts, and regional variations; MANULEX provides frequency counts for words from a corpus of 1.9 million words in the main French primary school reading books for four levels (1st, 2nd, 3rd, to 5th grades) and for all grades. The picture names are listed in Appendix C.

The picture targets were matched as closely as possible on concreteness, name agreement, visual complexity, and word length (see Table 7). Name agreement and visual complexity scores were taken from Alario and Ferrand (1999) and from Bonin and Fayol (2002). Concreteness scores were taken from Bonin et al. (2003).

Apparatus

The experiment was performed with PsyScope, Version 1.2 (Cohen, MacWhinney, Flatt, & Provost, 1993), on a Macintosh computer. The computer controlled the presentation of the pictures and recorded the latencies. The spoken latencies

Table 7. *Summary of the statistical characteristics from Experiment 3a*

	HF		*LF*	
	Homophones	*Controls*	*Homophones*	*Controls*
Frantext freq.	123.7 (137.62)	116.8 (125.03)	13.5 (26.40)	14.4 (29.74)
Manulex freq.	104.73 (82.88)	185.55 (156.32)	21.71 (25.47)	28.34 (49.71)
Name agreement	83.06 (21.01)	76.28 (20.31)	66.39 (24.48)	70.78 (20.15)
Visual complexity	2.44 (1.11)	2.69 (1.16)	3.05 (0.99)	2.88 (0.62)
Length	4.44 (0.92)	5.17 (0.92)	4.39 (0.85)	5.06 (0.94)
Concreteness	4.07 (0.74)	4.24 (0.56)	4.31 (0.58)	4.52 (0.35)

Note: HF = high frequency, LF = low frequency; Frantext freq. = objective word frequency taken from Frantext (LEXIQUE: New et al., 2001); Manulex freq. = Child frequency taken from Lété et al. (2004). Standard deviations in parentheses.

were recorded with a button box connected to the computer and an AIWA CM-T6 small tie-pin microphone connected to the button box.

Procedure

Participants were tested individually. During a preliminary phase, participants had to review each picture and corresponding name. Since name agreement scores were lower than those in the previous experiments, a more stringent learning phase was used. To this end, each picture was presented on the screen with its name written below it, coupled with the auditory presentation of the name via headphones (Sennheiser HD 25 SP). The picture remained on the screen until the participant pressed the space bar. Participants were told to look at each picture carefully, to note its name and then, when they felt they knew its name, to press the key to proceed to the next picture. Each trial had the following structure: A ready signal (*) was presented for 1,000 ms, and the picture followed 200 ms later. The written and spoken names of the pictures were presented 50 ms after picture onset. When the participant pressed the space bar, the next trial began after a delay of 1,000 ms. To ensure that participants had correctly learned the names associated with the pictures, the experimenter tested them on all pictures. The test was repeated on the pictures on which participants failed to provide the correct, intended name.[2]

The second phase was the experimental phase. Participants were told that they would see a picture (presented on the screen at a viewing distance of approximately 60 cm), and they had to name the picture as quickly as possible. The four sets of pictures were randomly presented within a block. This block presentation was repeated four times, with a different randomization each time. The experimenter monitored the participants' responses and scored them for correctness. The duration of the experiment did not exceed one hour. A trial began with a ready signal (*), presented for 500 ms, and was followed by a picture. The picture remained on the screen until the participants initiated a spoken response. The next trial began 2,000 ms after the participants had initiated their response. The session began with warm-up trials.

Results and discussion

ANOVA was performed with frequency (high frequency, low frequency), word type (homophone, nonhomophone), and presentation (first, second, third, fourth) as factors.

[2] Learning times were not recorded in this experiment. However, in the Bonin and Fayol (2002) study, in which learning times were recorded, the analyses revealed that they had no impact on the picture-naming performance. Meyer and Damian (2007) have investigated the impact of the familiarization phase on picture-naming performance. Using the picture–picture interference paradigm, they failed to find an effect of the practice phase on naming times.

Observations were discarded from the latency analyses if a participant did not respond within the allotted time window, a technical problem occurred, or an item other than the expected one was produced. Observations were also scored as errors when participants stuttered or produced nonlinguistic sounds (such as mouth clicks) or repaired the utterance after a dysfluency. Moreover, latencies exceeding two standard deviations above the participant and item means were discarded (2.11% of the data). Overall, 7.85% of the observations were discarded from the latency analyses.

As in the previous experiments, the analyses were performed on both latencies and error rates. Only the significant results of the latter analyses are reported.

Mean spoken latencies and error rates for each set of pictures and at each presentation level are shown in Table 8.

Latencies

Latencies were shorter with the repeated presentation of the items, $F_1(3, 72) = 87.33$, $MSE = 6{,}393.33$, $p < .001$; $F_2(3, 204) = 254.36$, $MSE = 1{,}598.26$, $p < .001$, and shorter on high-frequency items than on low-frequency ones, $F_1(1, 24) = 78.95$, $MSE = 2{,}760.40$, $p < .001$; $F_2(1, 68) = 8.13$, $MSE = 20{,}616.73$, $p < .01$. The main effect of word type was significant by participants, $F_1(1, 24) = 5.65$, $MSE = 3{,}202.86$, $p < .05$, but not in item-wise analyses, $F_2 < 1$. The size of the frequency effect decreased with repeated picture presentation. This interaction was significant in both the by-participant and by-item analyses, $F_1(3, 72) = 7.36$, $MSE = 1{,}494.73$, $p < .001$; $F_2(3, 204) = 4.65$, $MSE = 1{,}598.26$, $p < .005$. Word type did not interact significantly with either presentation, $F_1(3, 72) = 1.30$, $MSE = 1{,}119.18$; $F_2 < 1$, or frequency, Fs < 1. Finally, the size of the word frequency effect did not vary reliably as a function of either word type or presentation, $F_1(3, 72) = 1.04$, $MSE = 1{,}441.92$; $F_2 < 1$. Planned comparisons (all ps $< .05$) revealed that high-frequency homophonic pictures were named faster than low-frequency homophonic pictures at each level of presentation in both the subject-wise and item-wise analyses. Moreover, high-frequency nonhomophonic pictures produced faster responses than low-frequency nonhomophonic pictures, at each level of presentation. Except for the third presentation (and in the subject-wise analysis), high-frequency homophones did not produce faster responses than their high-frequency controls. Low-frequency homophones were not named faster than their controls (except for the second presentation in both the subject-wise and item-wise analyses). Finally, contrary to the expectations derived from Jescheniak and Levelt's (1994) homophone frequency inheritance hypothesis, low-frequency homophones produced slower responses than their matched cumulative frequency controls at each level of presentation.[3]

Errors

The number of errors decreased over repeated presentation of the items, $F_1(3, 72) = 33.95$, $MSE = 14.99$, $p < .001$; $F_2(3, 204) = 25.69$, $MSE = 14.26$, $p < .001$. Also, there were fewer errors on high- than on low-frequency items, $F_1(1, 24) = 16.53$, $MSE = 17.37$, $p < .001$; $F_2(1, 68) = 4.82$, $MSE = 42.89$, $p < .05$. The interaction between presentation and frequency was significant, $F_1(3, 72) = 5.93$, $MSE = 10.29$, $p < .01$; $F_2(3, 204) = 3.08$, $MSE = 14.26$, $p < .05$, and the interaction between word type and frequency was significant in the subject-wise analysis only, $F_1(1, 24) = 5.91$, $MSE = 17.86$, $p < .05$; $F_2(1, 68) = 1.77$, $MSE = 42.89$.

Before interpreting these results further, it is important to establish that they could not have

[3] It could be argued that the name agreement scores distribution is somewhat reflected in the naming latencies. However, when these scores were introduced as a covariate in the by-item analyses, the pattern of results remained the same. Moreover, and importantly, low-frequency homophones were named more slowly than their matched cumulative frequency controls with name agreement scores controlled for: The name agreement scores did not reliably differ between high-frequency controls (76%) and low-frequency homophones (66%).

Table 8. *Mean naming latencies and error rates as a function of word frequency, homophony, and presentation in Experiment 3a*

	HF				*LF*			
	Homophones		*Controls*		*Homophones*		*Controls*	
Presentation	*Latencies*	*Error rates*	*Latencies*	*Error rates*	*Latencies*	*Error rates*	*Latencies*	*Error rates*
1	925 (103)	4.0	931 (129)	4.0	1007 (97)	9.6	995 (145)	5.8
2	839 (97)	0.2	837 (96)	0.7	904 (113)	3.11	875 (119)	2.2
3	809 (72)	0.4	787 (79)	1.3	844 (83)	1.55	824 (72)	1.3
4	793 (74)	0.7	777 (81)	1.6	816 (66)	2.0	805 (65)	0.9
Overall	842 (100)	1.3	833 (114)	1.9	893 (116)	4.1	875 (128)	2.6

Note: HF = high frequency, LF = low frequency. Naming latencies in ms. Standard deviations in parentheses. Error rates in percentages.

arisen as a consequence of differences in the speed of recognition of the pictures used for the low- and high-frequency homophones and their controls. We address this issue in Experiment 3b.

EXPERIMENT 3B: WORD–PICTURE MATCHING IN FRENCH

Method

Participants
A total of 25 psychology students (5 males and 20 females, with a mean age of 18 years), drawn from the same pool as those who participated in Experiment 3a, participated in this experiment and received a course credit.

Procedure
Participants were tested individually. Participants were told that they would see a printed word followed by a picture, and they were instructed to decide as quickly as possible whether the word denoted the same concept as the picture. A "go/no-go" task was used instead of a "same/different" task. Participants responded by pressing a response button ("go" response) when the name and the picture referred to the same concept and made no response otherwise ("no-go" response). The type of task was chosen in order to contrast with the task used in Experiment 2b (same/different) and thus broaden the range of measures used to assess the potential contribution of picture recognition to participants' naming performance.

Each trial began with a warning signal (*), presented for 500 ms, which was followed by a printed word presented for 1,000 ms. After a delay of 1,000 ms, a picture was presented. In all cases, the picture disappeared after a delay of 2,000 ms. An intertrial interval of 2 s followed. In contrast to Experiment 3a, the pictures were presented only once. The session began with a warm-up trial and lasted approximately half an hour.

Stimuli and apparatus
We selected an additional set of 72 pictures with the same characteristics as the target pictures in order to create the no-go trials. The apparatus was the same as that in Experiment 3a.

Trials on which participants responded erroneously were discarded, and RTs exceeding two standard deviations above the participant and item means were excluded (2.17%). Overall, 4.89% of all trials were discarded. The analyses were performed on both RTs and error rates (only the significant results of the latter analyses are reported).

Results and discussion

Mean RTs and error rates (in percentages) are shown in Table 9.

Table 9. *Mean verification times and error rates as a function of word frequency and homophony in Experiment 3b*

		Latencies	*Error rates*
HF	Homophones	694 (113)	1.56
	Controls	641 (94)	2.22
LF	Homophones	711 (112)	5.56
	Controls	636 (101)	1.56

Note: HF = high frequency, LF = low frequency. Naming latencies in ms. Standard deviations in parentheses. Error rates in percentages.

Reaction times

The main effect of frequency was not significant, Fs < 1, but the main effect of word type was, $F_1(1, 24) = 38.76$, $MSE = 2{,}658.33$, $p < .001$; $F_2(1, 68) = 8.63$, $MSE = 9{,}828.20$, $p < .01$. The interaction between word type and frequency was not reliable, $F_1(1, 24) = 1.14$, $MSE = 2{,}433.93$; $F_2 < 1$.

Errors

There were more errors on low- than on high-frequency items. However, the main effect of frequency was significant only in the subject-wise analysis, $F_1(1,\ 24) = 5.68$, $MSE = 0.40$, $p < .05$; $F_2 < 1$. The interaction between word type and frequency was reliable, $F_1(1,\ 24) = 12.69$, $p < .01$; $MSE = 0.35$; $F_2(1,\ 68) = 4.03$, $MSE = 1.52$, $p < .05$.

The pattern of results obtained in the name–object verification task did not mirror the pattern of results found in the picture-naming task. More specifically, we did not find that the pictures of low-frequency homophones were recognized with substantially greater difficulty than those of high-frequency homophones or those of nonhomophone controls. Thus, the word frequency effects observed in Experiment 3a cannot be attributed to differences arising at the level of object identification. Moreover, additional analyses performed on the naming times in Experiment 3a, with object verification times introduced as covariates, did not alter the pattern of findings obtained in the picture-naming task.[4]

GENERAL DISCUSSION

In three picture-naming experiments and their associated control experiments we have confirmed that the frequency that determines the speed of lexical access in the production of homophones is specific-word frequency and not homophone frequency. That is, when producing the words "*vela*" (the Spanish word for "*candle*"), "*ver*" (the French word for "*worm*"), or "*nun*", what matters is the specific frequency of the word and not the sum of their individual frequencies and those of their respective homophones (e.g., the frequency of "*nun*" plus "*none*"). Across three experiments, we found that in lexical access for speech production, the naming of homophones such as /béla/ (candle) and /vɛr/ (worm) does not benefit from the existence of other words that have the same pronunciation in Spanish and French, respectively. That is to say, there are reliable differences between the production of the high- and the low-frequency uses of homophones (e.g., naming the pictures of a candle and a sail, both of which are pronounced /béla/ in Spanish or the pictures of a glass and a worm, both of which are pronounced /vɛr/ in French), and the

[4] We have tested whether frequency trajectories (which according to Bonin, Barry, Méot, & Chalard, 2004, and Zevin & Seidenberg, 2002, is an objective operationalization of the age/order of acquisition of the words) varied as a function of homophony and word frequency for the items used in the French experiments. Frequency trajectory norms did not vary reliably on either dimension. Therefore, on this reasoning, the word frequency effects found in picture-naming latencies in Experiment 3a cannot be attributed to AoA/order of acquisition.

production latencies of homophones are equivalent to those of other words of similar frequency that are not homophones. These results were obtained in the context of experiments in which we controlled for various factors—name agreement, visual complexity, and phonological complexity—that could have contributed to variation in naming latencies.

The picture-naming results cannot be attributed to processes other than lexical ones, since the results of the object decision and object–name matching tasks rule out an explanation in terms of differences in picture recognition. Nor can the differences be attributed to postlexical processes, since the relevant contrast involved the production of the same phonological forms (homophones). Therefore, the differences observed between high- and low-frequency homophones can arise only at some stage of lexical access (see Knobel, Finkbeiner, & Caramazza, 2008, for an extensive discussion of the locus of lexical frequency in speech production).

Finally, the results confirm that it is specific-word frequency of each sense of a homophone and not homophone frequency that determines naming latencies. This conclusion is supported by the observation that low-frequency homophones are produced significantly more slowly than nonhomophone controls matched on frequency with the cumulative frequency of the homophones and that they are produced no faster than nonhomophone controls matched on frequency with the frequency of the specific sense of the homophones that were tested.

The results we report directly address the concerns expressed by Jescheniak et al. (2003) about the interpretation of previous research into specific-word and homophone frequency effects. First, it is now clear that differences in orthographic transparency across languages are not the cause of contrasting findings concerning the roles of specific-word and homophone frequency in lexical access to homophones. More specifically, we have found that it is specific-word and not homophone frequency that determines lexical access times in a language with transparent orthography (Spanish), thus replicating similar results in languages with opaque orthographies (English and Mandarin Chinese; Caramazza et al., 2001). Second, the specific-word frequency effect is obtained when controlling for possible differences in the ease of recognition across stimulus sets using a variety of control tasks (object decision, "no" responses in picture–word matching, and "go" responses in "go/no-go" picture–word matching) that are generally assumed to reveal effects occurring at the level of object recognition.

Third, because we used nonhomophone frequency-matched controls for both the low- and high-frequency uses of a homophone we can definitely conclude that the effective frequency in determining naming latencies is the frequency of each individual sense of a homophone, and therefore that homophones do not inherit the frequency of their homophone mates. And, finally, because we replicated the specific-word frequency effect in three experiments with different stimuli in two different languages, we can be sure that the effect is highly reliable. Indeed the empirical generalization that it is specific-word and not homophone frequency that determines the speed of lexical access has been shown to hold across four languages that vary considerably in orthographic transparency (Spanish > French > English > Chinese) and morphophonological complexity (Chinese > English > French > Spanish). This gives us considerable confidence that the phenomenon is a general property of lexical access in language production. As such it represents a crucial phenomenon that must be accounted for by theories of lexical access.

What are the implications of the specific-word frequency effect for theories of lexical access? One clear implication is that it is specifically the frequency of each individual meaning that determines the ease of lexical access in language production. This implies that the frequency effect has its locus at the level at which the different members of a homophone set are distinguished from each other, and a word's grammatical properties (grammatical class, grammatical gender, etc.) are specified (Finocchiaro & Caramazza, 2006). This conclusion is consistent with at least two types of model of the lexicon. One type of model consists of those models that assume (a) that there is only a single lexical layer mediating between a word's meaning and its phonological content and (b) that the members of a homophone set are represented as fully independent, frequency-sensitive lexical nodes (e.g., Caramazza, 1997; see Figure 1b). The other type of model consists of those that assume two lexical layers but locate the frequency effect at the lemma level where the members of a homophone set are distinguished (e.g., Dell, 1990). Our findings are not consistent with those two-layer models that (a) assume that homophones share a lexical representation (the lexeme level) and (b) locate the frequency effect at that level of lexical access (Jescheniak & Levelt, 1994; Levelt, Roelofs, & Meyer, 1999).

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APPENDIX A

Stimuli used in Experiments 1a and 1b

High frequency			*Low frequency*		
Homophones		*Controls*	*Homophones*		*Controls*
banco	bank	*chaqueta*	*banco*	bench	*cuna*
bota	boot	*tarta*	*bota*	wine skin	*mofeta*
bote	tin can	*martillo*	*bote*	boat	*foca*
carta	letter	*policía*	*carta*	playing-card	*aguacate*
cometa	comet	*mariposa*	*cometa*	kite	*ciruela*
gato	cat	*árbol*	*gato*	jack	*almeja*
globo	globe	*cerilla*	*globo*	balloon	*cascabel*
ladrón	thief	*máscara*	*ladrón*	multiple plug	*fuelle*
llama	flame	*navaja*	*llama*	llama	*guadaña*
metro	meter	*huevo*	*metro*	subway	*león*
muelle	quay	*jaula*	*muelle*	spring	*diana*
muñeca	wrist	*águila*	*muñeca*	doll	*grifo*
nuez	walnut	*piña*	*nuez*	Adam's apple	*langosta*
pala	shovel	*estufa*	*pala*	power shovel	*flexo*
pico	woodpecker	*antorcha*	*pico*	pickaxe	*cangrejo*
planta	plant	*anillo*	*planta*	foot	*arpón*
pluma	pen	*piscina*	*pluma*	feather	*tenedor*
radio	radio	*iglesia*	*radio*	radius	*lupa*
vela	candle	*monja*	*vela*	sail	*tiburón*

APPENDIX B

Stimuli used in Experiments 2a and 2b

High frequency			*Low frequency*		
Homophones		*Controls*	*Homophones*		*Controls*
bota	boot	*búho*	*bota*	wine skin	*buzo*
bote	tin can	*baúl*	*bote*	boat	*buzón*
carta	letter	*café*	*carta*	playing-card	*cebra*
cinta	strip	*cesta*	*cinta*	video	*cojín*
escalera	stairs	*estrella*	*escalera*	steps	*extintor*
falda	skirt	*barba*	*falda*	foothill	*farola*
gato	cat	*gafas*	*gato*	jack	*gong*
globo	globe	*grúa*	*globo*	balloon	*gaita*
ladrón	thief	*lavabo*	*ladrón*	multiple plug	*lombriz*
llama	flame	*león*	*llama*	llama	*llanta*
llave	key	*saco*	*llave*	monkey wrench	*lince*
metro	metre	*moneda*	*metro*	subway	*monja*

(*Continued overleaf*)

Appendix B (*Continued*)

High frequency			*Low frequency*		
Homophones		*Controls*	*Homophones*		*Controls*
pico	woodpecker	*pino*	*pico*	pickaxe	*pomo*
planta	plant	*placa*	*planta*	sole	*pañal*
pluma	pen	*preso*	*pluma*	feather	*poste*
radio	radio	*reloj*	*radio*	radius	*ropero*
ratón	mouse	*rosa*	*ratón*	mouse (PC)	*rifle*
vela	candle	*vaca*	*vela*	sail	*venda*

APPENDIX C

Stimuli used in Experiments 3a and 3b

High frequency				*Low frequency*			
Homophones		*Controls*		*Homophones*		*Controls*	
encre	ink	*corde*	rope	*ancre*	anchor	*crêpe*	pancake
balle	ball	*doigt*	finger	*bal*	dance	*rat*	rat
canne	cane	*jupe*	skirt	*cane*	duck	*cintre*	hanger
chaîne	chain	*règle*	ruler	*chêne*	oak	*bombe*	bomb
coeur	heart	*fille*	girl	*choeur*	chorus	*coffre*	treasure chest
col	collar	*cercle*	circle	*colle*	glue	*paume*	palm
coq	rooster	*masque*	mask	*coque*	hull	*brique*	brick
corps	body	*femme*	woman	*cor*	horn	*pion*	pawn
signe	sign	*lettre*	letter	*cygne*	swan	*puzzle*	jigsaw-puzzle
lait	milk	*lune*	moon	*laie*	wild sow	*chope*	beer mug
lac	lake	*lance*	spear	*laque*	hair spray	*urne*	urn
lutte	wrestling	*croix*	cross	*luth*	lute	*poulpe*	octopus
mur	wall	*langue*	tongue	*mûre*	blackberry	*sphinx*	sphinx
point	point	*porte*	door	*poing*	fist	*banc*	bench
poids	weight	*nez*	nose	*pois*	pea	*douche*	shower
reine	queen	*feuille*	leaf	*renne*	reindeer	*tank*	tank
sang	blood	*table*	table	*cent*	hundred	*pièce*	coin
verre	glass	*groupe*	group	*ver*	worm	*biche*	deer