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Orthographic neighborhood and concreteness effects in the lexical decision task

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Abstract

The experiment reported here investigated the sensitivity of concreteness effects to orthographic neighborhood density and frequency in the visual lexical decision task. The concreteness effect was replicated with a sample of concrete and abstract words that were not matched for orthographic neighborhood features and in which concrete words turned out to have a higher neighborhood density than abstract words. No consistent effect of concreteness was found with a sample of concrete and abstract words matched for orthographic neighborhood density and frequency and having fewer neighbors and higher-frequency neighbors than the words of the first sample. Post hoc analyses of the results showed that orthographic neighborhood density was not a nuisance variable producing a spurious effect of concreteness but, instead, that the existence of higher-frequency neighbors constitutes a necessary condition for concreteness effects to appear in the lexical decision task. This finding is consistent with the hypothesis that semantic information is accessed and used to generate the responses in lexical decision when inhibition from orthographic forms delays the target word recognition.

Keywords: Concreteness; Orthographic neighborhood; Lexical decision

1. Introduction

Words expressing concrete concepts (e.g., *glass*) have consistently been found to be processed more quickly and accurately than words expressing abstract concepts (e.g., *skill*). This has been observed in a variety of tasks like lexical decision and naming (Bleasdale, 1987; Chiarello, Senehi, & Nuding, 1987; de Groot, 1989; James, 1975; Kroll & Merves, 1986; Strain, Patterson, & Seidenberg, 1995), word association (de Groot, 1989), free and cued recall (Marschark & Surian, 1992; Nelson & Schreiber, 1992; Paivio, Walsh, & Bons, 1994; Schwanenflugel, Akin, & Luh, 1992), and sentence comprehension (Haberlandt & Graesser, 1985; Schwanenflugel & Shoben, 1983). The focus of the empirical study to be reported here is on such "concreteness effects" found in the visual lexical decision task.[1]

The theoretical accounts that have been put forward for concreteness effects obtained in the various linguistic or memory tasks, including lexical decision, all share the assumption that they arise as a direct consequence of the semantic structure of concrete and abstract concepts being quantitatively or qualitatively different (see, for a review, Schwanenflugel, 1991). Thus, the first account

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[1] Although the terms "abstract," "concrete," and "concreteness effects" are used here (and throughout this paper), the actual distinction is between low- vs high-imageability words. In virtually all previous studies on "concreteness effects," the "abstract" and "concrete" words selected in the experiments were in fact low- and high-imageability words, respectively, and mostly nouns. The imageability value of words was taken from published norms established by asking subjects to rate on a five- or seven-point scale the ease or rapidity with which a particular word generates a mental image. Imageability and concreteness are highly correlated and, to our knowledge, there have been very few attempts to theoretically and empirically distinguish between the two notions (see, for example, Richardson, 1975).

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assumes that the semantic representation of concrete concepts has more features than the semantic representation of abstract concepts, so that it reaches a stable state of activation more quickly (Plaut & Shallice, 1993). According to the second account, the "context-availability model" (Schwanenflugel & Stowe, 1989; Wattenmaker & Shoben, 1987), concreteness effects arise from the concrete words having greater contextual associations in semantic memory than abstract words. The third account, the "dual-coding theory" (Paivio, 1986, 1991), argues that access to the meaning of concrete words is facilitated because they are linked both to a "verbal" and an "imagistic" semantic representation in memory, while abstract words are associated primarily with a "verbal" semantic representation.

However, in contrast to naming, free recall, or sentence comprehension, visual lexical decision in principle does not *require* access to semantic representations. Indeed, this task could be performed on the basis of the recognition of the string of characters as familiar, that is, seen in text before. How is it, then, that effects presumably originating from semantic structure have been consistently found in the context of this task? Although many researchers in visual word recognition would adopt the view that semantic information *can* be used in combination to orthographic (and phonological) information to make a visual lexical decision (Carr & Pollatsek, 1985; Posner & Carr, 1992), models of word recognition often assume that access to orthographic information is sufficient to perform the task, at least in some conditions (Coltheart, Davelaar, Jonasson, & Besner, 1977; Grainger & Jacobs, 1996; Seidenberg & McClelland, 1989). If, indeed, responses in a lexical decision task could be based on orthographic information alone, then the concern could be raised of whether concreteness effects are truly semantic effects, not effects originating from some uncontrolled orthographic factor co-varying with concreteness. Alternatively, if, in some conditions at least, responses are based on a combination of orthographic and semantic information, then the issue is raised of which exactly are these conditions. The empirical study to be reported here was designed as an attempt at clarifying both these questions by investigating the sensitivity of concreteness effects to a specific orthographic property of words, namely, their orthographic neighborhood (i.e., the set of words sharing letters with the target word).

Our attention to orthographic neighborhood properties was drawn from the contradicting pattern of results we obtained in previous unpublished experiments. In a series of experiments varying experimental procedures, we consistently failed to replicate concreteness effects with one set of words and consistently found significant concreteness effects with another set of words. The only factor that we found to differentiate both sets of words was orthographic neighborhood, defined with Coltheart et al.' s (1977) *N* metric, which refers to the number of words that can be created by changing one letter of the stimulus while preserving letter positions and word length (i.e., number of letters). In the set of words for which concreteness effects were obtained, concrete and abstract words were not matched for orthographic neighborhood. In contrast, in the set of words for which we failed to replicate concreteness effects, concrete and abstract words were closely matched for orthographic neighborhood (concrete and abstract words had the same number of orthographic neighbors and, in most cases, no orthographic neighbor at all). Such a pattern led us to entertain the hypothesis that concreteness effects were dependent on the orthographic neighborhood properties of the words.

How could orthographic neighborhood properties interact with concreteness? A number of recent studies in visual word recognition have found that lexical decision times were affected by orthographic neighborhood, measured with Coltheart et al.'s (1977) *N* metric. Two features of the orthographic neighborhood have been shown to influence lexical decision times: the number of orthographic neighbors ("the orthographic neighborhood density or size") and the number of orthographic neighbors of higher frequency than the target stimulus ("the orthographic neighborhood frequency"). Response latencies have been found to be shorter for words with high than low neighborhood density (Andrews, 1989, 1992; Foster & Shen, 1996; Sears, Hino, & Lupker, 1995). This is usually interpreted as resulting from a beneficial support of the neighbors' activation. In contrast, responses for a target word having higher-frequency neighbors were found to be slowed down (Grainger, 1990; Grainger & Jacobs, 1996; Grainger, O'Regan, Jacobs, & Segui, 1992; Marslen-Wilson, 1990; Paap & Johansen, 1994; Perea & Pollatsek, 1998; Pugh, Rexer, Peter, & Katz, 1994; however, see Foster & Shen, 1996; Sears et al., 1995, for failures to replicate the inhibitory effect of a higher-frequency neighbor). This inhibitory effect would originate from the lexical competition induced by the higher-frequency neighbors. It is worth noting that, typically, both neighborhood-density and neighborhood-frequency effects were found to be strongest with low-frequency words and that, typically also, concreteness effects were found to be sensitive to word frequency in the same way. This pattern might suggest that concreteness effects in lexical decision task are somewhat related to or dependent on the orthographic neighborhood properties of the material selected in the experiments. To our knowledge, no study having reported concreteness effects in a lexical decision task had controlled for orthographic neighborhood. We are not aware either of evidence that would indicate that concrete and abstract words do not characteristically differ in orthographic neighborhood density or frequency. Thus, at this step, the hypothesis of an artefactual origin of concreteness effects cannot be ruled out. Given the facilitatory effects observed for words having a large number of neighbors, concrete words could have in general more neighbors than abstract words and be therefore recognized more easily. Conversely, and in line with the inhibitory effects observed for words having higher-frequency neighbors, abstract words might be more likely than concrete words to have higher-frequency neighbors which could explain why they are recognized less easily.

There is, however, another way to conceive of the role of orthographic neighborhood, especially neighborhood frequency, on the emergence of concreteness effects in a lexical decision task. Models of visual word recognition (e.g, Foster, 1976; McClelland & Rumelhart, 1981; Norris, 1986; Paap, Newsome, McDonald, & Schvaneveldt, 1982) generally assume that words that are orthographically similar to a given target word will compete in some way in the recognition process and that the more frequent the competitors are the stronger the competition will be (cf. Carreiras, Perea, & Grainger, 1997). Given that low-frequency words are more likely to have higher-frequency neighbors than high-frequency words, they are also more likely to be subjected to strong competition from neighbors during lexical access. That concreteness effects mostly arise with low-frequency words thus might suggest that strong competition between lexical candidates, by delaying the selection of the target word, allows for semantic information to come into play in the lexical decision process. Within this hypothesis, orthographic neighborhood frequency would not be viewed as a potential nuisance variable producing artefactual effects of concreteness. Rather, the existence of higher-frequency neighbors would be viewed as a necessary condition under which semantic information is actually used to generate the responses in a lexical decision task.

The experiment to be reported below was designed to address these issues by testing whether (1) concreteness effects are caused by uncontrolled orthographic neighborhood features; (2) concreteness effects are dependent on orthographic neighborhood frequency. Two sets of words were contrasted: a set of concrete and abstract words that were not matched for orthographic neighborhood density and another set of concrete and abstract words that were closely matched for both orthographic neighborhood density and frequency.

2. Experimental study

2.1. Method

2.1.1. Stimuli

Two sets of items were selected, each consisting of 90 words and 90 nonwords. The words in the Set 1 consisted of 45 concrete words (C1) and 45 abstract words (A1) selected on the sole basis of their concreteness and noun status and matched for word frequency and word length only. Similarly to all the previous studies reporting concreteness effects, no particular precaution was taken as regards the features of orthographic neighborhood when selecting the material. Concreteness was defined according to two criteria: imageability value and direct vs indirect perception of the word's referent by one of the five senses. The imageability values were based on the ratings from Desrochers (1992), which were collected by means of a seven-point scale (1 = low imageability; 7 = high imageability). Words with an imageability value higher than 6 and the referent of which can be directly perceived by one of our five senses were classified as "concrete"; words with an imageability value lower than 3.5 and the referent of which cannot be directly perceived by one of the five senses were classified as "abstract." The words were divided into three frequency classes on the basis of the *Dictionnaire des fréquences du Trésor de la Langue française* (absolute frequency of occurrence of the 20th century; Imbs, 1971). Words with a frequency value higher than 2000 (per 37,653,685) were classified as high-frequency words; words with a frequency value between 2000 and 500 were classified as middle-frequency words, and words with a frequency value lower than 500 were classified as low-frequency words. Once these 90 words were selected, we calculated, for each word, the number of orthographic neighbors and the number of higher-frequency neighbors. Orthographic neighbors were identified from Brulex's corpus of words (Content, Mousty, & Radeau, 1990) by considering all French words of same length as the target stimulus that can be obtained by a single letter substitution (cf. *N*-metric by Coltheart et al., 1977). Table 1 shows the descriptive statistics of the words selected. As it can be seen, selecting concrete and abstract words by controlling the same parameters as in the previous studies and without care of orthographic neighborhood features, led to an imbalance of the orthographic neighborhood density, with the concrete words having on average significantly more orthographic neighbors than abstract words. Nevertheless, concrete and abstract words happened to be similar, on average, as regards neighborhood frequency.

The words of Set 2 consisted of 45 concrete (C2) and 45 abstract words (A2) matched for word frequency, number of letters, number of orthographic neighbors, and number of higher-frequency neighbors and were divided into the same three frequency classes as the words of Set 1[2] (see Table 1).

[2] One abstract word had been selected in both sets of items.

Table 1
Descriptive statistics of the concrete (C1) and abstract (A1) words presented in Set 1 and the concrete (C2) and abstract (A2) words presented in Set 2

Factors	C1	A1		C2	A2	
All frequency classes confounded						
Mean frequency (log 10)	2.94	2.94	$t(88) < 1$	2.95	2.95	$t(88) < 1$
Mean word length (number of letters)	5.64	5.91	$t(88) = 1.10, p = .27$	7.71	8.00	$t(88) < 1$
Mean imageability	6.67	2.98	$t(78) = 57.3, p < .001$	6.63	2.57	$t(78.7) = 73.7, p < .001$
Mean number of neighbors	2.18	1.24	$t(88) = 2.03, p < .05$	0.38	0.40	$t(88) < 1$
Mean number of higher-frequency neighbors	0.60	0.58	$t(88) < 1$	0.07	0.07	$t(88) < 1$
High-frequency words						
Mean frequency (log 10)	3.63	3.61	$t(28) < 1$	3.62	3.62	$t(28) < 1$
Mean word length (number of letters)	5.07	6.00	$t(28) = 2.23, p < .04$	6.33	6.67	$t(28) < 1$
Mean imageability	6.56	2.93	$t(28) = 32.1, p < .001$	6.73	2.68	$t(28) = 51.2, p < .001$
Mean number of neighbors	2.87	1.47	$t(28) = 1.46, p = .16$	0.53	0.53	$t(28) < 1$
Mean number of higher-frequency neighbors	0.53	0.33	$t(28) < 1$	0	0	—
Middle-frequency words						
Mean frequency (log 10)	2.87	2.92	$t(28) < 1$	3.01	3.02	$t(28) < 1$
Mean word length (number of letters)	6.27	5.93	$t(28) < 1$	8.60	9.07	$t(28) < 1$
Mean imageability	6.75	3.00	$t(28) = 33, p < .001$	6.56	2.56	$t(28) = 41.5, p < .001$
Mean number of neighbors	2.07	0.53	$t(19.4) = 2.28, p < .04$	0.20	0.20	$t(28) < 1$
Mean number of higher-frequency neighbors	0.47	0.27	$t(28) < 1$	0	0	—
Low-frequency words						
Mean frequency (log 10)	2.31	2.28	$t(28) < 1$	2.22	2.22	$t(28) < 1$
Mean word length (number of letters)	5.60	5.80	$t(28) < 1$	8.20	8.27	$t(28) < 1$
Mean imageability	6.69	3.00	$t(20.2) = 33.8, p < .001$	6.59	2.47	$t(28) = 40.9, p < .001$
Mean number of neighbors	1.60	1.73	$t(28) < 1$	0.40	0.47	$t(28) < 1$
Mean number of higher-frequency neighbors	0.80	1.13	$t(28) < 1$	0.20	0.20	$t(28) < 1$

The comparison of the mean frequency value across the four groups of words selected (C1, A1, C2, and A2) showed no significant difference for high- and low-frequency words (all $F < 1$). The difference in mean frequency was marginally significant for middle-frequency words ($F(3,56) = 2.56$, $p = .06$), C1 words being slightly less frequent than C2 words.

Note that by comparison to Set 1, the words in Set 2 had, on average, less neighbors and less higher-frequency neighbors. Concrete and abstract words in Set 1 had a mean number of neighbors of 2.18 and 1.24, respectively, and a mean number of higher-frequency neighbors of 0.60 and 0.58, respectively. By contrast, concrete and abstract words in Set 2 had a mean number of neighbors of 0.38 and 0.40, respectively, and a mean number of higher-frequency neighbors of 0.07. These differences between Set 1 and Set 2 are found not only when considering the whole sets of words, but also when each of the three frequency classes of words are considered (see Table 1).

The 180 nonwords were constructed from the 180 target words by changing one letter at the beginning, in the middle, or at the end of the word. All nonwords conformed to phonological and orthographical French rules (see Appendix A for the full list of items).

The 360 items were divided into 13 lists of 30 items each, a first list consisting of practice items, the six next lists consisting of the items of Set 1, and the six last lists consisting of the items of Set 2.

2.1.2. Procedure

The experiment was run on a PC and was piloted by the MEL2 software. A fixation point was presented on the screen for 1 s indicating where the stimulus would appear. Twenty milliseconds after the fixation point had disappeared, the target item was displayed in lower case in the middle of the screen. The item remained on the screen until the subject gave his response by pressing with his dominant hand one of two visible keys of the numerical keyboard. Subject were asked to press a "yes" key with the index finger if the item presented was a word and the "no" key with the middle finger if the item presented was not a word. Twenty millisecond after the subject's response, a feedback message was displayed on the screen for 2 s: if the subject's response was correct, the message "CORRECT" was displayed, if the subject's response was wrong, the message "INCORRECT" was displayed. If the subject's reaction time exceeded 800 ms, the message "LENT" (*slow*) was displayed instead of the accuracy feedback message. The intertrial interval was 1 s. At the end of each block, the subject's mean reaction time as well as his mean percentage of incorrect responses for the preceding block were displayed on the screen. If the number of incorrect responses exceeded 20%, an additional feedback message appeared on the screen inviting the subject to try to be more accurate. After the feedback message disappeared, the subject was instructed to rest for at least 10 s and could then decide when to start the next block by pressing the space bar.

Table 2
Reaction times (ms) and error rate for the words in Set 1 and Set 2

	Set 1		Set 2	
	Mean RT (*SD*)	% errors	Mean RT (*SD*)	% errors
Concreteness				
Concrete	582 (45.78)	3.33	615 (66.14)	7.67
Abstract	616 (75.72)	12.00	606 (62.74)	6.00
Frequency				
High frequency	568 (30.59)	4.00	557 (38.70)	2.50
Middle frequency	588 (43.22)	6.00	616 (48.11)	6.33
Low frequency	642 (83.61)	13.00	658 (59.68)	11.67
Concreteness × frequency				
High frequency concrete	560 (28.94)	3.33	563 (46.72)	2.33
High frequency abstract	576 (31.13)	4.67	551 (29.01)	2.67
Middle frequency concrete	584 (39.99)	5.33	611 (51.43)	7.00
Middle frequency abstract	591 (47.38)	6.67	622 (45.70)	5.67
Low frequency concrete	601 (59.94)	1.33	670 (52.81)	13.67
Low frequency abstract	682 (87.81)	24.67	645 (65.34)	9.67

2.1.3. Subjects

Twenty subjects participated in this experiment. They were undergraduate or Ph.D. students in Psychology from the *Université catholique de Louvain*, who participated for course credit or voluntarily. All subjects were native French speakers.

2.2. Results and discussion

The three factors introduced in the ANOVA analysis were the set of items (Set 1 vs Set 2), word frequency (high vs middle vs low frequency), and concreteness (concrete vs abstract). All three variables were considered as within-subject in the subject analysis (F_1) and between-item in the item analysis (F_2). The mean RTs and the rate of errors for each condition are displayed in Table 2.

2.2.1. RTs analysis

RTs for incorrect responses as well as RTs longer than 2000 ms were excluded from the analysis (263 observations, 7.3%). Among the main effects, only the frequency effect was significant ($F_1(1.6, 29.6) = 83.06$, $p < .001$[3]; $F_2(2, 168) = 43.69$, $p < .001$). Planned comparisons indicated that responses for high-frequency words were faster than for middle-frequency words (by subject: $F(1, 19) = 79.73$, $p < .001$; by item: $t(108.36) = 5.16$, $p < .001$) and responses were faster for middle-frequency words than for low-frequency words (by subject: $F(1, 19) = 29.42$, $p < .001$; by item: $t(101.91) = 4.27$, $p < .001$). The effect of set of items was not significant ($F_1(1, 19) = 1.85, p = .19; F_2(1, 168) = 2.27, p = .13$) and the effect of concreteness did not reach significance either ($F_1(1, 19) = 3.91, p = .06; F_2(1, 168) = 2.90, p = .09$).

Except for the concreteness × frequency interaction ($F_1(2, 38) = 1.49, p = .24; F_2(2, 168) = 1.09, p = .34$), all the interactions were significant. The effect of set of items × frequency was significant in the subject analysis ($F_1(2, 38) = 6.97$, $p < .01$) but not in the item analysis ($F_2(2, 168) = 2.32$, $p = .10$). The effect of set of items × concreteness interaction was also significant ($F_1(1, 19) = 18.21$, $p < .001$; $F_2(1, 168) = 8.02$, $p < .01$). The analysis of the concreteness effect performed separately for each set of items showed that the concreteness effect was significant in Set 1 ($F_1(1, 19) = 14.76$, $p < .01$; $F_2(1, 88) = 6.88$, $p < .02$) but was not significant in Set 2 ($F_1(1, 19) = 1.80$, $p = .20$; $F_2(1, 88) < 1$). Finally, the effect of the triple interaction set of items × concreteness × frequency was significant ($F_1(2, 38) = 11.94$, $p < .001$; $F_2(2, 168) = 4.53$, $p < .02$). The analysis of the concreteness effect performed for each frequency class and set of items separately showed that, for Set 1, the concreteness effect was only significant for the low frequency subset of words ($F_1(1, 19) = 16.93$, $p < .001$; $F_2(1, 28) = 9.01$, $p < .01$). This concreteness effect took the form of the usual effect with concrete words being responded to faster than abstract words. The concreteness effect was not significant for middle-frequency words ($F_1(1, 19) < 1$; $F_2(1, 28) < 1$) and high-frequency words ($F_1(1, 19) = 2.19$, $p = .16$; $F_2(1, 28) = 2.03$, $p = .17$). For Set 2, the concreteness effect was marginally significant for low-frequency words only ($F_1(1,19) = 5.79$, $p < .03$; $F_2(1,28) = 1.26$, $p = .27$). However, in contrast to the expected pattern, abstract words were responded to *faster* than concrete words. The concreteness effect was not significant for middle-frequency words ($F_1(1,19) = 2.10$, $p = .16$; $F_2(1,28) < 1$) and high-frequency words ($F_1(1,19) = 1.51$, $p = .23$; $F_2(1,28) < 1$).

[3] Because the Mauchly's test of sphericity was significant for the frequency variable ($\chi^2 = 6.04$, $p < .05$), we report here the F and p values corrected by the Greenhouse–Geisser Epsilon.

2.2.2. Error analysis

The analysis showed a significant main effect of frequency ($F_1(2,38) = 38.58$, $p < .001$; $F_2(2,168) = 11.33$, $p < .001$). Planned comparisons indicated that subjects made more errors for low-frequency words than middle-frequency words (by subject: $F(1,19) = 36.65$, $p < .001$; by item: $t(72.1) = 2.45$, $p < .02$) as well as more errors for middle-frequency words than high-frequency words (by subject: $F(1,19) = 7.48$, $p < .02$; by item: $t(102.3) = 3.04$, $p < .01$). The main effect of concreteness was significant ($F_1(1,19) = 16.84$, $p < .001$; $F_2(1,168) = 4.84$, $p < .03$) and showed that subjects made more errors for abstract than concrete words. The main effect of set of items was not significant ($F_1(1,19) = 1.02$, $p = .33$; $F_2(1,168) < 1$).

Among the double interactions, the concreteness $\times$ frequency one was significant ($F_1(2,38) = 20.32$, $p < .001$; $F_2(2,168) = 3.78$, $p < .03$). The analysis of the concreteness effect performed separately for the three classes of frequency indicated that the concreteness effect was significant for low-frequency words ($F_1(1,19) = 44.4$, $p < .001$; $F_2(1,58) = 4.33$, $p < .05$) but not for middle-frequency words ($F_1(1,19) < 1$; $F_2(1,58) < 1$) or high-frequency words ($F_1(1,19) < 1$; $F_2(1,58) < 1$). The effect of concreteness $\times$ set of items was significant as well ($F_1(1,19) = 35.60$, $p < .001$; $F_2(1,168) = 10.55$, $p < .01$). The analysis of the concreteness effect performed separately for the two sets of items showed a significant concreteness effect for Set 1 ($F_1(1,19) = 54.66$, $p < .001$; $F_2(1,88) = 10.42$, $p < .01$) but no significant concreteness effect for Set 2 ($F_1(1,19) = 1.87$, $p = .19$; $F_2(1,88) < 1$). The effect of frequency $\times$ set of items interaction was not significant ($F_1(2,38) < 1$; $F_2(2,168) < 1$). Finally, the effect of the triple interaction set of items $\times$ concreteness $\times$ frequency was significant ($F_1(2,38) = 18.21$, $p < .001$; $F_2(2,168) = 7.16$, $p < .01$). The analysis of the concreteness effect performed separately by frequency classes and by set of items showed a significant effect of concreteness for low-frequency words of Set 1 only ($F_1(1,19) = 87.70$, $p < .001$; $F_2(1,28) = 13.0$, $p < .01$), with concrete words being responded to more accurately than abstract words. For the two other frequency classes of Set 1, the concreteness effect was not significant (all $F < 1$) and for Set 2, the concreteness effect was not significant for any of the frequency classes (for high- and middle-frequency words: all $F < 1$, for low-frequency words: $F_1(1,19) = 2.92$, $p = .10$; $F_2(1,28) < 1$, with, if anything, a trend for concrete words to be *more* error prone).

Thus, the concreteness effect, both in the RT and error analyses, was significant for the set of words that were not matched for orthographic neighborhood density (Set 1) but was not significant for the set of words that were matched for their number of orthographic neighbors and number of higher-frequency neighbors (Set 2).

How could the discrepancies between the results found for Set 1 and Set 2 be explained? Let us remind that there were two features distinguishing the items of Set 1, for which significant concreteness effects were found, from items of Set 2, for which no consistent effect was obtained. First, in Set 1, concrete words had on average significantly more neighbors than abstract words, while the mean number of neighbors was matched between concrete and abstract words in Set 2. (As for the number of higher-frequency neighbors, it was matched between concrete and abstract words both in Set 1 and Set 2.) Second, both concrete and abstract words of Set 1 had more neighbors and more higher-frequency neighbors than words in Set 2. Let us remind also that studies in word recognition consistently found that words with high orthographic neighborhood density (words having many neighbors) are facilitated in lexical decision in comparison with words having low neighborhood density. This facilitatory effect could be explained by assuming that the activation of a high number of neighbors increases the general level of lexical activation, on which a lexical decision response might be based. In contrast, orthographic neighborhood frequency is usually found to have an inhibitory effect on lexical decision responses, the effect being accounted for by assuming that the activation of higher-frequency neighbors increases the amount of lexical inhibition necessary to recognize the target item (cf. Grainger & Jacobs, 1996). On this basis, two alternative explanations could be entertained for the discrepancies found across the two sets of words in our experiment. The first one is that lexical decision responses for concrete words of Set 1 were facilitated as compared to abstract words because of their higher neighborhood density. Under this explanation, the concreteness effect would be an artefact of uncontrolled neighborhood density. The second explanation would be that concreteness effects were detected only for the words within Set 1 because the inhibition from higher-frequency neighbors, by delaying the target word recognition, allows semantic information to be accessed and used in the generation of the response. Under this explanation, only words having higher-frequency neighbors and, hence, being subjected to inhibition during lexical access, should be subjected to semantic influence in lexical decision.

Inspection of the statistics displayed in Table 1 provides some initial evidence that does not support the first, "artefactual," explanation. In fact, it appears that the concrete words from the low-frequency class of Set 1 were the sole set of concrete words that did *not* have more neighbors than the abstract words (1.60 vs 1.73, for concrete and abstract words, respectively). Yet the amplitude of the concreteness effect was the highest for this low-frequency class of words. This suggests that having a higher number of neighbors was not the determining (artefactual) factor underlying the concreteness effect.

On the other hand, low-frequency concrete and abstract words from Set 1 did have more neighbors and more higher-frequency neighbors than the corresponding items from Set 2. This pattern suggests that concreteness effects are dependent on words having a relatively high number of neighbors and/or number of higher-frequency neighbors. This account was evaluated in the post hoc analyses presented hereafter.

2.2.3. Post hoc analyses

We re-analyzed the RTs for the concrete and abstract words of Set 1 by introducing as an additional factor either orthographic neighborhood frequency or orthographic neighborhood density. If concreteness effects were dependent on words being subjected to inhibition from higher-frequency neighbors, consistent concreteness effects should be found for words having higher-frequency neighbors but not for words having no higher-frequency neighbor. However, given that neighborhood density per se is not supposed to produce lexical inhibition, no significant interaction between concreteness and orthographic neighborhood should be found when neighborhood density is taken in consideration rather than neighborhood frequency.

Two analyses were carried out separately. In the first analysis, we split the items of Set 1 into two classes: concrete and abstract words that have no higher-frequency neighbor, on the one hand, and concrete and abstract words that have at least one higher-frequency neighbor, on the other hand (see Table 3 for the descriptive statistics of the word subsets). Then, an ANOVA was performed on the mean RTs and mean number of errors with as independent variables concreteness (concrete vs abstract) and orthographic neighborhood frequency (number of higher-frequency neighbors: 0 vs >0). In addition, word frequency (log 10) and number of orthographic neighbors were introduced as co-variables in the analysis, in order to control for the imbalance of the two classes of words as regards these factors. In the second analysis, the items of Set 1 were split into one class comprising concrete and abstract words having no neighbor, and another class comprising concrete and abstract words having at least one neighbor (see Table 3 for the descriptive statistics of the word subsets). A second ANOVA was thus performed with concreteness (concrete vs abstract) and orthographic neighborhood density (total number of neighbors: 0 vs >0) as independent variables, and word frequency and number of higher-frequency orthographic neighbors as co-variables. The mean RTs and number of errors for each condition are shown in Figs. 1 and 2.

The results of the statistical analyses to be reported here correspond to the values obtained once the effects of the factors introduced as co-variables have been partialled out. The RTs analysis with concreteness and orthographic neighborhood frequency as independent variables showed that the main effect of neighborhood frequency failed to reach significance ($F(1,84) = 2.85$, $p = .10$). However, there was a trend for words having at least one higher-frequency neighbor to be responded to slower than words having no higher-frequency neighbor. The effect of the neighborhood frequency × concreteness was significant ($F(1,84) = 6.89$, $p < .02$). The analysis of the concreteness effect performed separately for each neighborhood frequency class showed that concreteness was significant for words having at least one higher-

Table 3
Descriptive statistics of the concrete and abstract words of Set 1 within the different orthographic neighborhood subclasses (no neighbor: $N = 0$; at least one neighbor: $N > 0$)

Factors	$N = 0$			$N > 0$		
	C ($n = 27$)	A ($n = 33$)		C ($n = 18$)	A ($n = 12$)	
Orthographic neighborhood frequency						
Mean frequency (log 10)	2.89	3.04	$t(58) < 1$	3.01	2.67	$t(28) = 1.67, p = .11$
Mean word length (number of letters)	5.93	6.06	$t(58) < 1$	5.22	5.50	$t(28) < 1$
Mean imageability	6.65	2.99	$t(58) = 46.8, p < .001$	6.69	2.96	$t(16) = 28.1, p < .001$
Mean number of neighbors	0.93	0.58	$t(58) = 1.27, p = .21$	4.06	3.08	$t(28) < 1$
Mean number of higher-frequency neighbors	0	0	—	1.50	2.17	$t(28) = 1.42, p = .17$
	C ($n = 10$)	A ($n = 21$)		C ($n = 35$)	A ($n = 24$)	
Orthographic neighborhood density						
Mean frequency (log 10)	2.48	2.99	$t(29) = 2.09, p < .05$	3.06	2.90	$t(57) = 1.12, p = .27$
Mean word length (number of letters)	6.20	6.29	$t(29) < 1$	5.49	5.58	$t(57) < 1$
Mean imageability	6.71	2.94	$t(29) = 31.3, p < .001$	6.65	3.01	$t(57) = 45.2, p < .001$
Mean number of neighbors	0	0	—	2.80	2.33	$t(57) < 1$
Mean number of higher-frequency neighbors	0	0	—	0.77	1.08	$t(57) < 1$

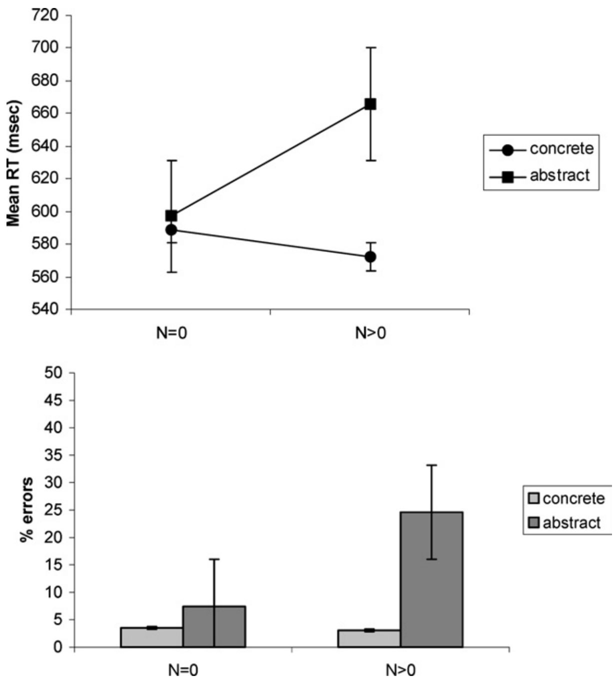

Fig. 1. Orthographic neighborhood *frequency* and concreteness. Mean RT (upper graph) and % of errors (lower graph) for concrete and abstract words having no higher-frequency neighbor ($N = 0$) vs for concrete and abstract words having at least one higher-frequency neighbor ($N > 0$).

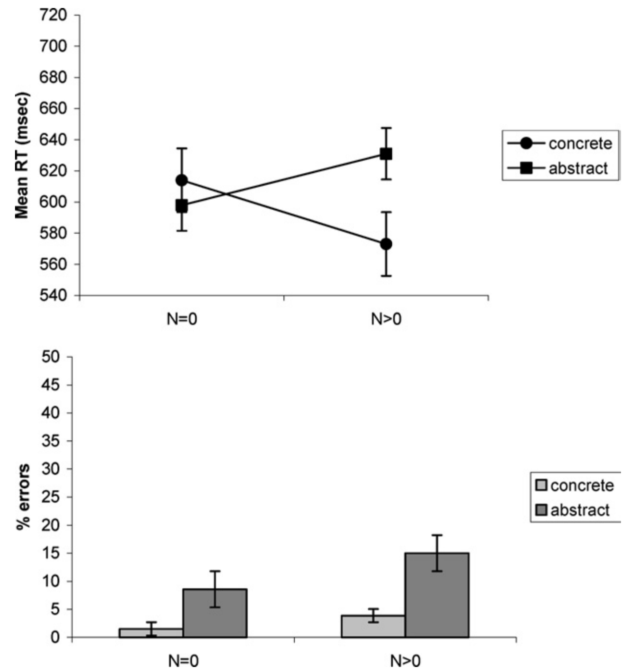

Fig. 2. Orthographic neighborhood *density* and concreteness. Mean RT (upper graph) and % of errors (lower graph) for concrete and abstract words having no orthographic neighbors ($N = 0$) vs for concrete and abstract words having at least one orthographic neighbor ($N > 0$).

frequency neighbor ($F(1,26) = 10.85$, $p < .01$)[4] but was not significant for words having no higher-frequency neighbor ($F(1,56) = 1.20$, $p = .28$). As for the error analysis, the effect of neighborhood frequency failed as well to reach significance ($F(1,84) = 3.24$, $p = .08$), there was, however, a trend for the number of errors being higher for words that have at least one higher-frequency neighbor than for words that have no higher-frequency neighbor. The effect of the neighborhood frequency × concreteness interaction was significant ($F(1,84) = 8.82$, $p < .01$). The analysis of the concreteness effect performed separately for each class of neighborhood frequency showed that the concreteness effect was more consistent for words having at least one higher-frequency neighbor ($F(1,26) = 8.07$, $p < .01$)[5] than for words having no higher-frequency neighbor ($F(1,56) = 5.14$, $p < .03$).

The RTs analysis with concreteness and orthographic neighborhood density as independent variables showed that response latencies were globally not influenced by the total number of neighbors ($F(1,84) < 1$). The effect of the neighborhood density × concreteness interaction was not significant either ($F(1,84) = 2.70$, $p = .10$). However, there was a trend for the concreteness effect to be more marked for words having at least one neighbor. The error analysis showed no significant effect of orthographic neighborhood density ($F(1,84) = 2.78$, $p = .10$) but there was a trend for subjects making more errors for words that have at least one neighbor than for words that have no neighbor. The effect of the neighborhood density × concreteness interaction was not significant ($F(1,84) < 1$).

Consistent with the inhibitory effects of orthographic neighborhood frequency reported in the literature, we found that responses to words having at least one higher-frequency neighbor were slower and more error prone than responses to words having no higher-frequency neighbor (the effect was, however, only marginally significant). The effect of orthographic neighborhood density was also marginal and was observed in the error analysis only. In contrast to the facilitatory effect described in the literature, our results showed that subjects make *more* errors for words that have at least one neighbor than for words that have no neighbor.

[4] Within the subset of words that have at least one higher-frequency neighbor, abstract words had slightly more higher-frequency neighbors than concrete words (see Table 3). In order to exclude that the concreteness effect observed for this subset of words was due to this slight imbalance, we performed an additional analysis of the concreteness effect for this subset of words. In addition to word frequency and number of neighbors, we also introduced the number of higher-frequency neighbors as co-variables. The concreteness effect was still significant once all these variables were controlled ($F(1,25) = 15.32$, $p < .001$).

[5] The additional analysis of the effect of concreteness on words having at least one higher-frequency neighbor with as co-variables word frequency, number of neighbors and number of higher-frequency neighbors was also significant ($F(1,25) = 15.87$, $p < .001$).

The important point is that the post hoc analyses showed a significant interaction effect between concreteness and orthographic neighborhood frequency, while no consistent interaction was found between concreteness and orthographic neighborhood density. Namely, concreteness effects were only observed for words that have at least one higher-frequency neighbor. This finding is consistent with the hypothesis that inhibition from higher-frequency neighbors constitutes a necessary condition for concreteness effects to appear in the lexical decision task.

3. General discussion

The results of the experiment carried out in this study clearly indicate that concreteness effects cannot be found for any sample of concrete and abstract words in a lexical decision task. In our first sample of words (Set 1), concrete and abstract words were matched in terms of word frequency and word length only, a procedure similar to the one usually adopted in previous studies investigating concreteness effects (de Groot, 1989; Kounios & Holcomb, 1994; Kroll & Merves, 1986). The results showed that, for that sample of words, concrete words were responded to faster and were less error prone than abstract words. In our second sample of words (Set 2), concrete and abstract words were additionally matched for orthographic neighborhood density and frequency, which besides were kept to minimum values. For that sample, no consistent effect of concreteness was found nor even a tendency for the responses to concrete words to be facilitated as compared to abstract words.

The analysis of the neighborhood features of the first sample of words indicated that concrete words had on average a higher orthographic neighborhood density than abstract words. Because orthographic neighborhood density has been found to have a facilitatory effect on response latencies in lexical decision (Andrews, 1989, 1992; Foster & Shen, 1996; Sears et al., 1995), this observation raised the concern that concreteness effects were, in fact, artefactual effects of neighborhood density. This concern was suggested also by the very fact that effects of semantic nature could be observed in a lexical decision task, which in principle does not require access to the meaning of words. However, our results did not turn out to be consistent with the view that concreteness effects were *artefacts* of uncontrolled orthographic neighborhood density. We indeed noticed that, even if significant concreteness effects were found only with a sample of words in which, on the whole, concrete words had more neighbors than abstract words, the subset of low-frequency words within this sample, for which the concreteness effect was the most marked, was also the subset of concrete and abstract words that was the best matched for orthographic neighborhood density and frequency.

The post hoc analyses of the results of our experiment revealed that it was in fact the second neighborhood feature distinguishing our two samples of words that was responsible for the discrepancies between the results. Namely, the sample having produced a consistent concreteness effect comprised words having, on average, more higher-frequency neighbors. Consistent with the inhibitory effects of a high orthographic neighborhood frequency described in the literature (Grainger, 1990; Grainger & Jacobs, 1996; Grainger et al., 1992; Marslen-Wilson, 1990; Paap & Johansen, 1994; Perea & Pollatsek, 1998; Pugh et al., 1994), the results of the post hoc analyses showed a clear tendency for words having at least one higher-frequency neighbor to be responded to slower and to be more error prone than words that have no higher-frequency neighbor. The results also clearly showed that a consistent concreteness effect was obtained only on the condition that the words had at least one higher-frequency neighbor. These findings are consistent with the hypothesis that, *in some conditions at least*, lexical decision responses are based on a combination of orthographic and semantic information and, in particular, with the hypothesis that semantic information is accessed and used to generate the responses when inhibition from orthographic forms delays the target word recognition.

The mechanisms by which semantic information could impact on response generation in a lexical decision task and cause concreteness effects might be described in two ways. The first description is based on the theoretical framework of models postulating interactive processes between the orthographic lexicon and the semantic system (Balota, Ferraro, & Connor, 1991; Hino, Lupker, & Pexman, 2002; Plaut & Shallice, 1993). According to these models, units activated within the orthographic lexicon will activate their corresponding semantic representation and this semantic activation will in turn exert top-down reinforcement of the orthographic units. If the competition between units within the orthographic lexicon is relatively low, such as in the case in which the target stimulus has no or few orthographic neighbors, then the stimulus is likely to be recognized rapidly at the orthographic lexicon level with little influence of semantic top-down activation. In contrast, if the competition between orthographic units is high, which would be especially the case when the target stimulus has higher-frequency neighbors, then semantic activation is more likely to exert an influence within the word recognition process. Stemming from the assumption that the access to the semantic representation is quicker and easier for concrete than abstract words (Paivio, 1986; Plaut & Shallice, 1993; Schwanenflugel & Stowe, 1989), top-down activation should be faster and stronger for concrete words explaining why they are recognized more rapidly and accurately.

According to the second explanation, one does not have to assume interactive processes between the orthographic lexicon and the semantic system. It is based on an extrapolation of the model of the lexical decision task developed by Grainger and Jacobs (1996). According to that model, subjects performing a speeded lexical decision task base their "yes" decision on a response criterion relating to the local activity of a particular unit within the orthographic lexicon. If this criterion is reached, it means that a specific word within the lexicon has been recognized.[6] Simultaneous activation of neighbors, especially higher-frequency neighbors, would delay the time at which the criterion is reached by increasing local competition. If we assume cascaded processes between the orthographic lexicon and the semantic system (such that activation can be transmitted from the orthographic lexicon to the semantic system before a unit has reached the recognition threshold within the orthographic lexicon), we may extrapolate that during that delay, activated orthographic units would activate their corresponding semantic representation. In that case, subjects could base their decision not only on the criterion set for local activity within the orthographic lexicon but also on a criterion set for local activity within the semantic system. If semantic representation for concrete concepts are more rapidly accessed than abstract concepts (Paivio, 1986; Plaut & Shallice, 1993; Schwanenflugel & Stowe, 1989), the criterion set for local activity within the semantic system would be reached more rapidly for concrete than abstract target words, what would give rise to the concreteness effects observed in the subjects' performance.

Our findings would benefit from being replicated in experiments that would directly manipulate concreteness and orthographic neighborhood frequency in a crossed design (a project that we are currently undertaking). Also, it would be worth checking empirically whether other formal properties possibly confounded with orthographic neighborhood frequency, such as the *phonological* neighborhood frequency or the consistency of the orthographic-to-phonological mapping, could account for the results (see Andrews, 1997). These reservations being expressed, we think that they have important implications for the study of concreteness effects as well as, more generally, for studies investigating semantic effects by means of a lexical decision task.

First, controlling for orthographic neighborhood frequency might turn out to be a necessary methodological precaution for studies exploring the theoretical issue of which feature of semantic structure and representation—the greater number of semantic features, the availability of context, or the existence of an imagistic representation for concrete concepts—underlies concreteness effects in language processing. Typically, these studies contrast two samples of concrete and abstract words. In one sample, concreteness and the hypothesized semantic factor underlying concreteness effects are confounded; in the other sample, concrete and abstract words are matched for the hypothesized underlying semantic factor (e.g., van Hell & de Groot, 1998). Then, a significant concreteness effect on the first sample of words but not on the second sample is taken as evidence in support of the hypothesized semantic factor to underlie concreteness effects. Our findings indicate that, in the future, the various subsets of concrete and abstract words that are selected should be equivalent in terms of orthographic neighborhood frequency. Indeed, the absence of significant concreteness effects for one subset might simply result from the words in that subset having a lower neighborhood frequency.

Second, the interaction usually observed between concreteness and frequency, that is, a stronger concreteness effect for low-frequency words (de Groot, 1989; James, 1975; Kroll & Merves, 1986) could be (at least partly) explained in relation to orthographic neighborhood frequency. Indeed, low-frequency words are more likely than high-frequency words to have higher-frequency neighbors.

Finally, in contrast to semantic tasks commonly used in current research on semantic structure and representation, such as the semantic categorization or attribute verification tasks, the lexical decision task has the advantage to call upon relatively automatic processes. However, some authors have questioned the reliability of the lexical decision task to investigate issues on the structure of semantic representations, on the basis that this task does not require access to semantic representations (e.g., McRae, de Sa, & Seidenberg, 1997). Our study highlights the particular conditions under which semantic representations are indeed accessed in a lexical decision task and semantic effects can be empirically tested.

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[6] The model also assumes a second response criterion, which is under strategic control and relates to the overall activity within the orthographic lexicon. This global activity level is influenced by the number of orthographic neighbors a given stimulus activates in the lexicon. The more neighbors a target stimulus activates the higher the overall level of activity within the lexicon. If this response criterion is given a low value, it can be reached more rapidly than the response criterion linked to the word identification process. Subjects may thus respond "yes" even before the word has been recognized. However, setting a too low criterion value may lead to false positives especially when the nonwords used in the lexical decision task are very similar to existing words, as in our experiment. In that latter case, subjects tend to higher their criterion level and, as a consequence, rather base their decision on the criterion set for the local activity (i.e., the criterion linked to unique word identification).

Appendix A

Concrete words and matched nonwords		Abstract words and matched nonwords	
Lists of words and nonwords from Set 1			
Oeil	Ocil	Moyen	Mayen
Sang[a]	Fang	Désir	Désin
Fleur	Bleur	Effort	Affort
Papier	Popier	Service	Lervice
Chien	Crien	Propos	Prapos
Animal	Onimal	Occasion	Oclasion
Salon[a]	Salan	Malheur	Salheur
Pain[a]	Lain	Honte	Hinte
Peau[a]	Teau	Tort[a]	Gort
Chapeau	Chaleau	Illusion[a]	Illuvion
Désert	Désort	Pratique	Prataque
Arme	Irme	Souci	Souli
Paysage[a]	Paysoge	Défaut	Méfaut
Gorge	Garge	Mépris	Népris
Trou[a]	Crou	Choix[a]	Choin
Sable[a]	Soble	Série	Sarie
Mouton[a]	Moiton	Thème	Thède
Aiguille	Liguille	Bêtise	Bêtine
Tasse[a]	Tause	Excuse	Encuse
Bonnet	Bounet	Manque[a]	Maique
Oreiller	Obeiller	Facilité	Fapilité
Crayon	Craton	Mythe	Mèthe
Tablier	Taclier	Inverse	Anverse
Sapin[a]	Saxin	Dédain	Dédoin
Berceau	Bermeau	Maximum	Matimum
Radio	Madio	Sûreté	Suleté
Papillon[a]	Panillon	Utilité	Utalité
Beurre	Beurse	Anxiété	Onxiété
Chèvre	Chavre	Flux[a]	Flix
Camion	Casion	Défi	Réfi
Gilet[a]	Gilat	Labeur	Mabeur
Raisin[a]	Ransin	Gain[a]	Goin
Poupée[a]	Poipée	Flatteur	Fiatteur
Bague[a]	Bagie	Niais[a]	Nians
Taxi	Tavi	Grief	Grieu
Crochet	Drochet	Senteur[a]	Senleur
Autobus	Autocus	Ambiance	Ombiance
Savon[a]	Mavon	Bribe[a]	Brobe
Balai	Balan	Équité	Équimé
Poire[a]	Ponre	Monceau[a]	Manceau
Gobelet	Gibelet	Larron[a]	Larion
Vélo	Valo	Rejet	Rejot
Javelot	Jaselot	Machin	Maclin
Radis[a]	Ranis	Stage[a]	Stame
Caméra	Caméda	Tabou	Talou
Lists of words and nonwords from Set 2			
Soleil	Solein	Vérité	Cérité
Église	Églite	Volonté	Voloncé
Fenêtre	Fenâtre	Réalité	Béalité
Oreille	Oneille	Valeur	Valeux
Hôtel	Hitel	Avenir	Axenir

Appendix A (*continued*)

Concrete words and matched nonwords		Abstract words and matched nonwords	
Jambe	Jaube	Hasard	Habard
Genou	Genor	Espoir	Espoin
Escalier	Escaliet	Confiance	Condiance
Montagne	Moncagne	Instinct	Instince
Chaise	Craise	Attitude	Attilude
Fauteuil	Fanteuil	Curiosité	Cumiosité
Château	Chéteau	Méthode	Méthude
Neige	Neive	Santé	Sarté
Rideau	Fideau	Avis	Avos
Fleuve	Cleuve	Regret	Legret
Colline	Couline	Avantage	Avautage
Appartement	Appartiment	Signification	Signifidation
Bouteille	Jouteille	Hypothèse	Hypophèse
Couverture	Couvertume	Simplicité	Simplicive
Couteau	Couveau	Thème	Thève
Cathédrale	Cathéprale	Raisonnement	Laisonnement
Pantalon	Pantalin	Injustice	Inrustice
Restaurant	Vestaurant	Dimension	Dilension
Bâtiment	Botiment	Tentative	Tentatice
Abeille	Ébeille	Effroi	Effrou
Mâchoire	Mâchoise	Privilège	Privilege
Carnet	Carnat	Concept	Foncept
Mitrailleuse	Mibrailleuse	Fonctionnement	Fanctionnement
Casquette	Fasquette	Nostalgie	Costalgie
Bouquin	Bouquie	Louange	Vouange
Parapluie	Paracluse	Spontanéité	Spontanuité
Allumette	Allufette	Anarchie	Onarchie
Charrue	Chorrue	Humanisme	Humanisie
Baignoire	Baignoise	Vigilance	Vigilanie
Bourgeon	Bourgeot	Ambiguïté	Ambéguïté
Flocon	Flocou	Norme	Narme
Roulotte	Rounotte	Contexte	Cantexte
Sauterelle	Vauterelle	Prédiction	Prédaction
Civière	Citière	Critère	Critâme
Chaudière	Chaudiève	Cohérence	Coherence
Bretelle	Bremelle	Duperie	Duperée
Marionnette	Murionnette	Relativité	Relutivité
Pyjama	Pojama	Option	Ostion
Cendrier	Cengrier	Pénurie	Dénurie
Marmotte	Jarmotte	Mentalité	Mentalivé

[a] Words with at least one higher-frequency orthographic neighbor.

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