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The processing of singular and plural nouns in French and English[☆]

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Abstract

Contradictory data have been obtained about the processing of singular and plural nouns in Dutch and English. Whereas the Dutch findings point to an influence of the base frequency of the singular and the plural word forms on lexical decision times (Baayen, Dijkstra, & Schreuder, 1997), the English reaction times depend on the surface frequency of the presented word form only (Sereno & Jongman, 1997). To settle this contradiction, we first examined the issue in the French language to see which interpretation generalized to a new language. Having found that the French data were similar to the Dutch data, we then reassessed the English evidence. On the basis of our findings, we conclude that the similarities among the languages are greater than the differences, and that the data are more in line with the Dutch pattern than with the previously reported English pattern. These data rule out the full-storage model as a viable account of the recognition of singular and plural noun forms.

Keywords: Word recognition; Lexical decision; Inflectional morphology; Dual-route model; Number

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Many words used in daily life are variants of other words, either obtained by a combination of two words (compound words; e.g., *blackberry*, *snowman*), or by adding an affix (a prefix or a suffix) to a previously unaffixed word (e.g., ***un****clean*, ***dis****trust*; *clean****er***, *trust****y***). An important question in the theory of reading is how such words are recognized. In this article, we will limit ourselves to the question of how suffixed words are recognized. Suffixed words can be inflections or derivations of the original (stem) word. Inflections are variations in the form of the original word that do not result in a change of grammatical word class and that produce either no or a predictable change of meaning. Typical examples are the different verb forms as a function of person, tense, and number (e.g., differ**s**, differ**ed**, differ**ing**), or the plurals of nouns (e.g., pencil**s**). Derivations are formations of new words from the original word, which often change the meaning and/or the grammatical class of the original word in a predictable manner (e.g., kind**ness**, read**able**, knight**hood**).

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Models of morphological processing can be divided into three main classes: full storage models (e.g., Butterworth, 1983; Bybee, 1995; Rumelhart, McClelland, & the PDP Group , 1986), obligatory decomposition models (e.g., Clahsen, 1999; Giraudo & Grainger, 2000; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Rastle, Davis, & New, in press; Taft, 1979, 2004), and dual-route (race) models (e.g., Baayen, Dijkstra, & Schreuder, 1997; Bertram, Schreuder, & Baayen, 2000; Caramazza, Laudanna, & Romani, 1988; Pinker & Ullman, 2002). Full storage models posit that stems are stored separately from their derivations and inflections; there is no morphemic level of representation. Obligatory decomposition models posit a level of representation at which morphologically complex words are necessarily decomposed. These models do not necessarily preclude the existence of whole-word representations (e.g., Giraudo & Grainger, 2000; Rastle et al., in press; Taft, 1979), but stipulate that most classes of complex words are represented and processed in a decomposed form. Finally, the dual-route race models postulate that complex forms can be processed either as whole words or through morphological decomposition.

The experimental work presented in this article is based on one of the most successful of the dual-route models—that of Baayen, Schreuder, and their colleagues (e.g., Baayen et al., 1997; Baayen, Schreuder, & Sproat, 2000; Bertram et al., 2000; Schreuder & Baayen, 1995). According to this model, the storage and decomposition routes are activated in parallel, and their relative contribution to the recognition of morphologically complex words depends on a number of factors. For the processing of suffixed words, Bertram et al. (2000) proposed a taxonomy based on three factors: word formation type, suffix productivity, and whether or not the same suffix is used in more than one type of derivation or inflection. The word formation type variable refers to the meaning relationship between the morphologically complex word and the base word, and is considered to reside on a continuum. At one extreme, there are the inflections that do not alter the meaning of the stem word (e.g., person and number markings of verbs and case markings of nouns in languages such as Italian and German). At the other extreme, there are derivations with a substantially different meaning from the stem word (e.g., *fruitful*). The productivity of a suffix refers both to its frequency of occurrence in complex word forms and to the ease with which novel words comprising the suffix can be understood. For example, the suffix 'ness' in the construction "adjective + -ness" is very productive (*alertness*, *bluntness*, *cautiousness*,…, "*scanableness*"); by contrast, an example of an unproductive suffix is "adjective + -th" (*warmth*,…, "*scanableth?*"). Finally, the balance of whole-word versus decomposition procedures depends on whether a certain suffix is used in more than one type of derivation/inflection. For example in English, the end *-er* is used both to make a noun from a verb (*digger*, *looker*) and to make a comparative form of short adjectives (*larger*, *smaller*). Bertram et al. (2000) proposed that decomposition is the most important procedure for words with a productive, meaning-invariant suffix that does not have a productive rival use (e.g., "verb + -ed" in English). On the other hand, the whole-word recognition procedure makes the greatest contribution for suffixes that are not productive ('-th'; *warmth*), or ones that have a more frequent rival with a different semantic function ('-er'; *smaller*, *builder*). The importance of whole-word recognition also increases if the meaning of the morphologically complex word deviates from that of its stem, even if those complex words comprise productive suffixes without rival uses (e.g., *fruitless*).

Bertram et al. (2000) investigated the importance of the processing pathways by manipulating the surface frequencies and the base frequencies of stimulus words. The surface frequency of a word form is the token frequency (per million) with which this particular word form appears in a representative corpus. The base frequency is the sum of the frequencies of all inflections of a word (e.g., for an English noun, it is the sum of the singular and the plural word forms). The general idea is that effects of surface and base frequency can reveal the work of whole-word and decomposition procedures. For example, Bertram et al. (2000) investigated the visual recognition of words comprising the suffix *-te* in Dutch. In a few instances, this suffix is added to an adjective to form a noun (e.g., *warm—warmte* [*warmth*]). However, the predominant use of the suffix is to form the past tense singular of verbs (e.g., *blaf-te* [*bark-ed*]). For the first type of words (*warmte*), Bertram et al. (2000) observed an effect of surface frequency only; there was no difference in word processing times due to the frequency of the base word *warm*. In contrast, lexical decision times to the second type of words (*blafte*) correlated with the base frequency of the verb stem and not with the surface frequency of the verb form.

For most suffixed words, Bertram and colleagues postulated a contribution of both surface frequency and base frequency, because the storage and the decomposition route work in parallel, and overlap in time. This prediction is derived largely from the work of Baayen et al. (1997), who investigated the processing of Dutch singular and plural noun forms. In a first experiment, they kept the base frequency of the stimuli constant and manipulated the surface frequency. Half of the words had high-frequency singular forms and low-frequency plural forms (hence called singular dominant words), because the instances to which they referred usually occur alone (e.g. *bruid—bruiden* [*bride—brides*]). The other half of the words had low-frequency singular forms and high-frequency plural forms (hence called plural dominant words) because the instances to which they referred usually are encountered in multiples (e.g., *wolk—wolken* [*cloud—clouds*]). Baayen et al. observed that for the first type of word (singular dominant), lexical decision times were significantly longer for the low-frequency plurals than for the high-frequency singulars. In contrast, for the second type of word (plural dominant), lexical decision times were equivalent for the low-frequency singulars and the high-frequency plurals; lexical decisions times for these words were also statistically equivalent to those for the singular forms of the singular-dominant words. In a second experiment, Baayen et al. kept the surface frequency of the singular nouns constant, but manipulated the frequency of the plural forms (and, hence, the base frequency). They observed a significant effect of the base frequency on the lexical decision times to the singular word forms.

To explain these findings, Baayen et al. (1997) proposed the Parallel Dual-Route model. This model consists of three stages. In the first stage, the visual input activates a number of stored representations in long-term memory. These include the word as a whole (unless the morphologically complex word is novel or has a very low frequency), but also, in parallel, the segments within the stimulus word that form meaningful units. Thus, a stimulus word like *dogs* not only activates the long-term memory representation of *dogs*, but also of *do*, *dog*, and *-s*. Representations that exceed a threshold value of activation are entered into a morphological short-term memory buffer, which forms the basis of the second stage. In this stage, a process of licensing takes place for those segments that are shorter than the stimulus word. The licensing process ensures that the selected combinations of segments are as long as the original stimulus word (excluding combinations like *do* + *s*), and that the combination of selected morphemes is grammatically allowed (excluding combinations like *ear* + *th*, because *ear* is not an adjective). Finally, in the last stage the syntactic and semantic features of the licensed segments are activated. For combinations of sub-word segments, this involves the computation of meaning on the basis of the constituting segments.

Because stimulus words simultaneously activate representations that correspond to the complete input and representations that correspond to meaningful segments within the input, Baayen and Schreuder's model incorporates a whole-word "route" as well as a decomposition "route."[1] The speed of the routes depends on the frequency of the whole word on the one hand, and on the frequency of the segments increased by the time costs for segmentation, licensing, and composition on the other hand. For plural nouns, the frequency of the whole word route corresponds to the surface frequency of the plural word form. Thus, the whole-word route will be faster for a high-frequency plural like "*clouds*" than for a low-frequency word like "*brides*." For singular nouns, the frequency effect in the whole word route depends on the summed frequencies of the singular and the plural form (i.e., on the base frequency), because singular nouns are activated not only when the input is the singular noun but also when the input is the plural noun. The speed of the decomposition route depends on the frequency of the constituent segments (e.g., *cloud* and *-s*, *bride* and *-s*), and on the parsing cost for the affix. Therefore, for plural nouns with a high-frequency plural and a low-frequency singular (e.g., *clouds*), the whole-word route will usually be faster than the decomposition route, because the former depends on the plural surface frequency, and the latter on the base frequency (which is not much higher than the plural surface frequency) plus the parsing cost. For this type of word, processing times will be sensitive to the surface frequency of the plural word form. In contrast, low-frequency plurals have more chance of being recognized via the decomposition route and, thus, the RTs to them will be more sensitive to the base frequency + the parsing time. According to Baayen et al. (1997), these principles explain their pattern of results: reaction times to singular nouns depend on the base frequency, and reaction times to plural nouns partly depend on the surface frequency of these forms.

A limitation of the work by Bertram et al. (2000) and Baayen et al. (1997) is that it is nearly exclusively based on Dutch and Finnish findings [although Baayen, Burani, and Schreuder (1996) and Dominguez, Cuetos, and Segui (1999) presented some data on Italian and Spanish]. This limited scope is a problem, because the only study on the processing of singular and plural nouns in English seems to contradict both Bertram et al.'s (2000) taxonomy and Baayen et al.'s (1997) Parallel Dual-Route model. This study was published by Sereno and Jongman (1997) and contained Baayen et al.'s (1997) basic experiments. In a first experiment, Sereno and Jongman presented singular nouns that were much more frequent in the singular form than in the plural form (e.g., *kitchen*), and nouns that were much more frequent in the plural from than in the singular form (e.g., *error*). They found faster lexical decision times to the former group of (singular-dominant) nouns than to the latter group of (plural-dominant) nouns. In a second experiment, Sereno and Jongman presented the same words in plural form and now obtained faster lexical decisions to the plural-dominant nouns than to the singular-dominant nouns. Finally, in a third experiment, Sereno and Jongman presented the singular forms of two groups of nouns with equivalent surface frequencies

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[1] In the first versions of the model (Baayen et al., 1997; Schreuder & Baayen, 1995), the routes operated independently; in more recent versions (Baayen et al., 2000), the routes are no longer functionally separated. They make use of the same "machinery," as has been described here.

but different base frequencies (because the surface frequencies of the plural forms differed). Performance of the participants was the same for both groups of nouns. On the basis of these results, Sereno and Jongman concluded that lexical decisions to English nouns are a function of the surface frequency of the presented word form only and, hence, are evidence for a full-storage model.

Sereno and Jongman's (1997) findings question Bertram et al.'s (2000) taxonomy of suffixed words: adding the suffix -s to a noun is an extremely productive way of forming plurals in English; it does not dramatically change the meaning of the word; and the suffix *-s* does not have to compete with a higher frequency alternative use (the other productive use of *-s* is limited to the third person singular present of verbs). So, according to the taxonomy, English plurals should be processed predominantly by parsing, not by whole-word retrieval. Sereno and Jongman's findings are also problematic for Baayen et al.'s (1997) Parallel Dual-Route model, not only because there is little evidence for a decomposition route, but also because the lexical decision times to singulars do not seem to depend on the base frequency (which they should if the singular form is co-activated upon seeing the plural form).

In this article, we address the contradiction between these Dutch and English data. First, we examined the effects in the French language (Experiments 1 and 2). This investigation allowed us to assess which model (Baayen et al.'s or Sereno & Jongman's) generalizes best to a new language and, therefore, is the most interesting starting point. Having found that our French findings were in line with those of the Dutch language, we then re-assessed the English evidence by repeating Sereno and Jongman's study with better stimuli and an improved research design (Experiments 3 and 4).

Experiment 1

Given the results obtained in Dutch by Baayen et al. (1997) and the conflicting results in English reported by Sereno and Jongman (1997), we designed Experiment 1 to assess the importance of surface frequency in the French language. Specifically, Experiment 1 examined the contribution of surface frequency to the processing of singular and plural noun forms. We composed two lists of words with the same base frequency, but with different surface frequencies for the singular and the plural forms. Half of the stimuli were singular dominant, meaning that the frequency of the singular form was higher than that of the plural form; the other half of the stimuli were plural dominant. The stimuli were presented to the participants either in the uninflected singular form or in the inflected plural form. The experimental task was lexical decision.

The end morpheme *-s* in French plurals is extremely regular and productive (more than 98% of plural adjectives and nouns end in -s). It has a competitor in some verb endings (in particular the second person singular; *tu manges* [*you eat*]), but the frequency of this rival is much lower. According to Bertram et al. (2000), these characteristics imply that French plurals should predominantly be computed on-line rather than retrieved as a whole from memory.

Method

Participants

Thirty-two students from the Université René Descartes, Paris V, took part in the experiment in return for course credits. They were all native French speakers and had normal or corrected-to-normal vision.

Stimulus materials

The stimuli were 48 nouns drawn from the database *Lexique*[2] (New, Pallier, Ferrand, & Matos, 2001), which is a newly created database of French word forms with accompanying frequencies based on a corpus of written texts (31 million word tokens). Inflectional studies in the French language were difficult to run before the release of this database, because the existing databases lacked frequencies for inflected forms. In this and all subsequent experiments, frequency is reported as the number of appearances per million. Special care was taken to select only those words for which the singular and the plural did not exist as other word forms (e.g., as inflections of a verb, as in *danse* [*dance*]), and for which the singular and the plural were the only possible realizations (e.g., some nouns exist in a male and female form, as in *chien*, *chienne* [*dog*]). In addition, for each word the plural consisted of the orthographic form of the singular with the end-morpheme *-s* (e.g., *nuage–nuages* [*cloud-s*]).

The first list consisted of 24 words, of which the singular form was more frequent than the plural form (the singular dominant items). The mean frequency of the singular and the plural forms were respectively 47 and 15 per million. The second list of 24 words consisted of plural dominant items, with an average frequency of 15 for the singular form and 41 for the plural form. The base frequencies (i.e., the cumulative frequency of the two forms) did not differ significantly between the lists (List 1 = 62, List 2 = 56; $t = 0.62$; $p > .1$). Stimuli were also matched for the number of letters (6.6 and 6.6) and the number of syllables (1.8 and 1.8). Stimuli of the two lists were matched in pairs on length and base frequency, so that we could partial out much of the with-

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[2] This database is available at the following website: http://www.lexique.org.

in-group heterogeneity by using a repeated measures design for the analysis over stimuli. A complete list of the stimuli is presented in Appendix A. Two versions of the word lists were constructed. Half of the words had their singular form in one version and the plural in the other; for the other half, the assignment was reversed.

In addition, 48 nonword stimuli were created from French words by replacing a single consonant with another consonant, or a single vowel with another vowel (see Appendix B). These nonwords were phonotactically legal, and were matched to the word stimuli in terms of number of letters (6.6) and number of syllables (1.8). Half of the nonwords ended in *-s* to match the plural word forms that were presented.

Procedure

Participants were tested individually in a soundproof room. They were asked to indicate as quickly and accurately as possible whether the presented letter string formed an existing French word or not. They did so by pressing one of two buttons of a joypad "Logitech Wingman Extreme." Each trial began with a 200 ms fixation cross (a plus sign in the center of the screen), followed by the stimulus which remained visible until the participant responded (with a maximum time period of 4 s). Between trials, there was a 1 s black screen interval. Each participant saw one of the two word list versions (counterbalanced across participants). The stimuli were randomized anew for each participant and presented with the use of DMDX (Forster & Forster, 2003). The test items were preceded by 20 practice trials.

Results

Table 1 shows mean reaction time and percentage error, as a function of word type (singular dominant vs. plural dominant) and as a function of the word form presented (singular vs. plural). Only response times of correct responses were included in the RT analyses. In addition, response times of more than two standard deviations above or below the mean were discarded as outliers. In total, 6.2% of the RT data in the subjects analysis as well as 5.2% in the item analysis were discarded. Because the error rates were low and fully in line with the RTs, they were not analyzed separately.

ANOVAs on the RTs of the correct responses returned a significant main effect of word form (singular vs. plural; $F1(1,31) = 7.48$, $MSe = 732.84$, $p < .05$; $F2(1,46) = 6.24$, $MSe = 981.27$, $p < .05$), and a significant interaction between word type and word form ($F1(1,31) = 5.46$, $MSe = 1339.22$, $p < .05$; $F2(1,46) = 6.57$, $MSe = 981.27$, $p < .05$). Statistics are not needed to see that this interaction was due to the longer RTs in the condition where participants had to respond to the plural form of a singular dominant noun.

Discussion

The basic question addressed by Experiment 1 was to what extent lexical decision times to singular and plural noun forms are determined by the surface frequency of the form when the base frequency is controlled. Table 1 shows that the data are completely in line with Baayen et al. (1997). For singular dominant items, a reliable difference was observed between the singular, and the plural forms, whereas for plural dominant items, no significant difference was obtained. In addition, the RTs to singular nouns did not differ as a function of the word type (singular dominant or plural dominant). These findings are in line with the hypothesis that RTs to singular nouns are a function of the base frequency of the noun, whereas RTs to plural nouns partly depend on the surface frequency of the word form. In Experiment 2, we investigated whether reaction times to singular nouns in the French language are influenced by the base frequency of the nouns.

Experiment 2

After investigating the effects of surface frequency in our Experiment 1, we assessed the contribution of the base frequency on the processing of singular noun forms. Therefore, we looked at the lexical decision times to singular French nouns that had the same surface frequency but different base frequencies (because the frequency of the plural form was high or low).

Method

Participants

Fifteen new students from the Université René Descartes, Paris V, took part in the experiment in return for course credits. They were native French-speakers and had normal or corrected-to-normal vision.

Table 1
Mean reaction time (in ms), standard deviation, and percentage error in Experiment 1

	Presented form: singular			Presented form: plural		
	M	*SD*	%ER	*M*	*SD*	%ER
Singular dominant Ex: *Plafond* [*Ceiling*]	546	26	2.3	574	45	3.9
Plural dominant Ex: *Nuage* [*Cloud*]	548	37	2.0	546	32	2.9

Stimulus materials

Forty-four words were selected from Lexique and 44 matching nonwords were constructed. Selection and construction criteria were the same as in Experiment 1, except for the frequencies of the word forms. One list of 22 words had a singular frequency of 16, and a plural frequency of 43; the other list had a singular frequency of 16, and a plural frequency of 4. The two lists of words were matched on the number of letters (6.4 and 6.3) and the number of syllables (1.7 and 1.7). A complete list of the words is given in Appendix A (see also Appendix B for the nonwords).

Procedure

The procedure was identical to that described in Experiment 1, except that in this experiment only the singular word forms were presented. Because of this, no non-word ended in *-s*.

Results

Table 2 displays mean reaction time and percentage error for Experiment 2. Extreme reaction times were removed according to the procedure described in Experiment 1. In total, 5.5% of the RT data in the subjects analysis as well as 4.7% in the item analysis were discarded. ANOVAs with one repeated measure revealed a main effect of the frequency of the plural form both in the analysis over participants ($F1(1,14) = 24.09$, $Mse = 946.06$, $p < .001$) and in the analysis over items ($F2(1,21) = 19.57$, $Mse = 1371.50$, $p < .001$). Participants responded faster to singular word forms with high-frequency plurals than to singular word forms with low-frequency plurals.

Discussion

The main finding of Experiment 2 was the presence of a base frequency effect when the singular forms were matched on surface frequency. When two singular forms have the same surface frequency but differ in the frequency of their plural forms, the singular with the more frequent plural is processed faster. This result agrees with Baayen et al.'s findings in Dutch, but deviates from Sereno and Jongman's findings in English.

Table 2
Mean reaction time (in ms), standard deviation and percentage error in Experiment 2

Frequency of the complementary form	Presented forms: singular		
	M	*SD*	%ER
High-frequency plural Ex: *Ongle* [*Nail*]	540	50	2.1
Low-frequency plural Ex: *Frère* [*Brother*]	596	63	3.6

So, on the basis of the two experiments reported thus far, it seems that Dutch and French plurals are processed in the same way, and both differ significantly from the findings in English. In addition, there is some suggestive evidence that the Dutch/French pattern could also be present in Italian (Baayen et al., 1996) and in Spanish (Dominguez et al., 1999), making the English finding even more isolated. Therefore, we decided to repeat the Sereno and Jongman experiments.

Experiment 3

A closer look at Sereno and Jongman (1997) revealed a number of methodological differences between that study and all of the other studies. For a start, Sereno and Jongman presented their singular and plural stimuli in two different experiments (their Experiments 2A and 2B). This blocked presentation may have encouraged participants to ignore the end *-s* in the experiment with the plural stimuli. Another problem is that Sereno and Jongman's word frequencies were based on the Brown corpus which only includes one million words. This is a quite limited corpus if we compare it to the French corpus used in Lexique (31 million tokens) and the English corpus used in Celex (17.9 million tokens). For these reasons, we decided to repeat the Sereno and Jongman experiments, following the same procedure as in our French studies (and in the Dutch studies).

Method

Participants

Thirty-eight students from Royal Holloway, University of London, took part in the experiment in return for course credits. They were all native English-speakers and had normal or corrected-to-normal vision.

Stimulus materials

The word stimuli were two lists of 24 nouns drawn from the *Celex* database (Baayen, Piepenbrock, & Gulikers, 1995), based on a corpus of 16.6 million written words and 1.3 million spoken words. The first list consisted of singular dominant items, with an average frequency of 25 per million for the singular forms and eight for the plural forms. The second list consisted of plural dominant items with average frequencies of 9 and 26, respectively. The base frequencies (34 vs. 35) did not differ between the lists. The stimuli were further matched on the number of letters (6.3 and 6.3) and the number of syllables (2 and 2). A complete list of the stimuli is presented in Appendix A. As in Experiment 1, two versions of the word list were created, so that each participant saw only one form of a word.

In addition, 48 nonword stimuli were created (Appendix B). These nonwords were phonotactically legal, and were matched to the word stimuli in terms of mean number of letters (6.3), number of syllables (2), and the number of orthographic neighbors.[3] Half of the nonwords ended in *-s*.

Procedure

Stimulus presentation was the same as in Experiment 1, except that an external button response box was used for response collection.

Results

Table 3 displays mean reaction time and percentage error for Experiment 3. Extreme reaction times and reaction times for incorrect responses were removed by the procedure followed in the first experiment. Thus, 5.4% of the data in the subjects analysis as well as 5.52% in the item analysis were discarded. We also removed one plural dominant item and its control singular dominant that led to high error rates (*deficits*, 66%). Two-way ANOVAs revealed a main effect of word form ($F1(1,37) = 9.25$, $MSe = 790.02$, $p < .01$; $F2(1,44) = 6.71$, $MSe = 452.81$, $p < .05$), and a significant interaction between word type and word form ($F1(1,37) = 12.87$, $MSe = 1098.38$, $p < .001$; $F2(1,44) = 16.41$, $MSe = 452.81$, $p < .001$). No main effect of word type (singular dominant vs. plural dominant) was found ($F1(1,37) < 1$, $MSe = 1081.13$; $F2(1,44) < 1$, $MSe = 4201.32$). Planned comparisons indicated a significant difference in the RTs to the singular noun forms between the singular dominant and the plural dominant words in the analysis over participants only ($F1(1,37) = 8.76$, $MSe = 910.93$, $p < .01$). This difference was not reliable over items ($F2(1,44) = 1.00$, $MSe = 2326.10$). There was a significant difference between the singular and the plural forms for the singular dominant items ($F1(1,37) = 30.93$, $MSe = 675.36$, $p < .001$; $F2(1,22) = 16.10$, $MSe = 620.67$, $p < .001$), but not for the plural dominant items ($F1(1,37) < 1$, $MSe = 1213.04$; $F2(1,22) = 1.69$, $MSe = 284.94$).

Table 3
Mean reaction time (in ms), standard deviation, and percentage error in Experiment 3

	Presented form: singular			Presented form: plural		
	M	*SD*	%ER	*M*	*SD*	%ER
Singular dominant Ex: *journal*	482	44	2.1	516	44	4.4
Plural dominant Ex: *biscuit*	503	46	2.7	497	52	4.2

Discussion

A comparison of Table 3 (English language) with Table 1 (French language) and Sereno and Jongman (1997, English language) reveals a rather intriguing picture. On the one hand, we found a pattern in English that is very similar to the pattern found in French. There was a significant difference in decision latencies between singulars and plurals for the singular-dominant nouns but not for the plural-dominant nouns. On the other hand, we also obtained a pattern that is reminiscent of the claims made by Sereno and Jongman. When, we look selectively at the reaction times to the singular forms, we find that RTs are faster (albeit not significantly in the analysis over items) for the singular-dominant nouns than for the plural-dominant nouns. When, we focus on the reaction times to the plural forms, we observe the reverse effect, with faster RTs to the plural-dominant nouns than to the singular-dominant nouns. Still, this pattern is not in line with the full storage model, as claimed by Sereno and Jongman, because for the plural dominant items reaction times were not faster to the plural forms than to the singular forms. We will return to these findings in the General Discussion. First, however, we need to know whether singular noun forms in English are indeed insensitive to their base frequency, as claimed by Sereno and Jongman, because this finding would have major implications for the interpretation of our findings.

Experiment 4

Sereno and Jongman (Experiments 3A and 3B) failed to find an effect of base frequency on lexical decision times to singular nouns in English. However, a closer look at their stimuli reveals a possible difficulty. They used singular forms with high frequencies (on average 95 occurrences per million). This contrasts with the Dutch and the French studies, which were based on medium frequency items (10–15 occurrences per million). It is possible that Sereno and Jongman did not find a base frequency effect, because their high frequency singular items were already close to the ceiling level and could not profit very much from the additional activation due to the plurals. Therefore, we selected two lists of singular words with a medium surface frequency and with highly different plural frequencies.

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[3] This extra control was added to a replication of the original Experiment 3 after the first round of reviews. The original experiment included more word-like nonwords (and partly different words) and resulted in the following RTs: singular form of singular-dominant words: 527 ms; plural form of singular-dominant words: 565 ms; singular form of plural-dominant words: 555 ms; plural form of plural-dominant words: 557 ms.

Method

Participants

Nineteen new students from Royal Holloway, University of London, took part in this experiment. They were paid £5 for their participation. All participants were native English speakers and had normal or corrected-to-normal vision.

Materials

The stimuli were 48 nouns drawn from the *Celex* database. The first list consisted of 24 singular nouns with a high frequency plural (frequencies of 15 and 39 for singular and plural, respectively). The second list consisted of 24 singular nouns with a low frequency plural (frequencies of 16 and 1.9). The lists were matched for number of letters (6 and 6.2) and number of syllables (2 and 1.9). A complete list of the stimuli is presented in Appendix A. Again, a list of 48 nonwords was made that were matched on length in numbers of letters and numbers of syllables (see Appendix B).

Procedure

The procedure was identical to that described in Experiment 2.

Results

Table 4 shows the mean reaction times and percentages of errors. Extreme reaction times and reaction times to wrong responses were removed by the procedure followed in the first experiment. Thus, 5.57% of the data in the subjects analysis as well as 5.45% in the item analysis were discarded. A one-way ANOVA with repeated measures revealed a main effect of the frequency of the plural form ($F1(1,18) = 13.39$, $MSe = 479.61$, $p < .01$; $F2(1,46) = 6.67$, $MSe = 1350.82$, $p < .05$). Participants reacted 26 ms faster to singular forms with high-frequency plurals than to singular forms with low frequency plurals. Subject and item analyses were also conducted for the error data. No significant differences were found.

Discussion

In this experiment we showed that in English, lexical decision times to singular nouns are affected by the frequency of the plural forms, as previously shown in Dutch and in French. This adds credit to our reservation about Sereno and Jongman's findings, which were based on high-frequency singular nouns. A cautionary note to our finding is that the effect of base frequency seems be stronger in French (56 ms; Table 4) than in English (26 ms; Table 4). However, because this finding is based on a between-items and between-participants analysis, it should be treated with caution.

Table 4
Mean reaction time (in ms), standard deviation and percentage error in Experiment 4

Frequency of the complementary form	Presented forms: singular		
	M	*SD*	%ER
High-frequency plural Ex: *heel*	522	56	5.4
Low-frequency plural Ex: *flint*	548	70	7.2

General discussion

The present study was set up to further investigate how visually presented singular and plural nouns are recognized. Previous research in Dutch (Baayen et al., 1997) suggested that lexical decision times to singular nouns depend on the combined frequencies of the singular and plural word forms (i.e., the base frequency). In contrast, lexical decision times to plural noun forms partly depend on the surface frequency of the plural forms. Baayen et al. (1997) interpreted these findings as evidence for a dual-route account of morphological processing, with parallel retrieval of whole word forms and computation on the basis of the constituent morphemes. Parts of the Dutch findings were replicated in Italian (Baayen et al., 1996) and Spanish (Dominguez et al., 1999), but the model did not seem to apply to the English language. For this language, Sereno and Jongman (1997) reported that only surface frequency mattered, in line with a full storage model and against the Parallel Dual-Route model.

The findings obtained in the present article clarify considerably the empirical evidence. First, in English and French, like in Dutch, lexical decisions to singular word forms are influenced by the frequencies of the plural forms (Experiments 2 and 4). Second, in all three languages, reaction times to the plural forms are slower than those to the singular forms when the nouns are singular dominant (i.e., have a higher frequency in singular than in plural; Experiments 1 and 3). Third, in all languages, reaction times to the plural forms are not significantly different from those to the singular forms when the nouns are plural dominant (Experiments 1 and 3).

The data of Experiments 1 and 3 are depicted in Fig. 1, together with those of Baayen et al. (1997, in Dutch) and Sereno and Jongman (1997, in English). In each part of the figure, we see the same pattern emerging. For the singular-dominant words, there is a substantial difference in decision times between the singular and the plural forms. In contrast, for the plural-dominant nouns, there is no difference. The latter finding is evidence against the full storage hypothesis, because for plural-dominant nouns RTs should be faster to plural forms than to singular forms, if surface frequency were the only important factor. This result has not been obtained in any of the studies.

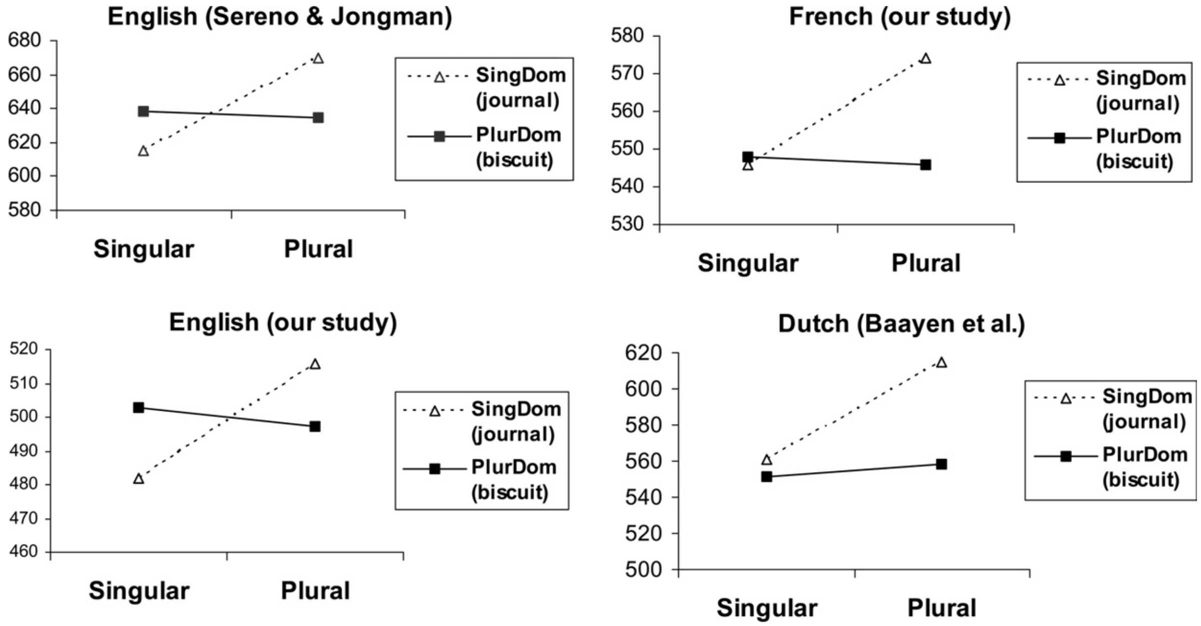

Fig. 1. Lexical decision to singular and plural forms of singular-dominant and plural dominant nouns in English (present study, Experiment 3; Sereno and Jongman, 1997, Experiments 2A and 2B), Dutch (Baayen et al., 1997; Experiment 1), and French (present study, Experiment 1).

The only deviation that is present between English on the one hand, and French and Dutch on the other hand, is the position of the plural-dominant words relative to that of the singular-dominant words. Whereas in Dutch and French, reaction times to the plural-dominant words are as fast as those to the singulars of the singular dominant words, in English the RTs are slightly elevated, so that the reaction times to the plural-dominant words fall in-between those to the singular forms and the plural forms of the singular-dominant words.

It is difficult to assess the impact of the remaining difference between English and the other two languages. On the one hand, the relative position of the two lines in each panel of Fig. 1 is the weakest aspect of the experimental design. Because this position is based on a comparison between two different groups of stimulus words, we cannot completely exclude the possibility that some uncontrolled confound in one of the many possible word features is responsible for the language difference, the more because the RTs to the singular forms of the singular-dominant nouns in English were not significantly different from those to the singular forms of the plural-dominant nouns in the item-based ANOVA ($F = 1$). On the other hand, we really worked hard to come up with the best possible stimuli for Experiment 3 (which forced us to limit the frequency range we could examine, in order to find 24 matched stimulus pairs). Further, we observed very much the same pattern in another (unpublished) study with somewhat different stimuli (see footnote 3), suggesting that the pattern reported by Sereno and Jongman (1997) and in Experiment 3 of the present experiment is a robust one and unlikely to be due to random fluctuations. We will return to the possible implications of the English data later on. First, we discuss the French findings.

Given that the French data are in line with those of Baayen et al. (1997), they can readily be accounted for by the Parallel Dual-Route model. According to this model, singular nouns are always recognized by the whole-word recognition route, and lexical decision times to them are a function of the base frequency (i.e., the cumulative frequencies of the singular and the plural forms). The lexical decision times to the plural forms are determined by the faster of two possible routes.[4]

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[4] A problem in reviews of models of visual word recognition, is that in recent years a transition is happening from horse-race models to activation-based models. In horse-race models, the faster route determines the output. In activation-based models, both routes always contribute to the output, because one route is not faster than the other (both make use of the same processing cycle). In these models, the contribution of a route depends on the amount of activation it adds to the output units per processing cycle. A similar transition is taking place in Baayen and Schreuder's thinking (e.g., compare Baayen et al., 2000, to Baayen et al., 1997). However, because the model consists of three, largely serial, stages, the horse-race model can still be used as a rough approximation.

The first route is the decomposition route. In this route, reaction times equal the reaction time to the singular form, increased by a time constant needed to segment the stimulus input, license the combination of segments, and compute the meaning on the basis of the singular and the suffix (together summarized under the term "parsing cost"). The second route is the whole-word recognition route. Here, RTs depend on the surface frequency of the plural word form. The only remaining question is how much each route contributes to the recognition of plural nouns. This can be estimated on the basis of Tables 1 and 2. In the following section, we present rough estimates of the contribution of each route, using some simplifying assumptions. Interested readers who do not agree with these simplifications, can find all necessary data in the Tables and Appendix A to calculate their own figures.

If, we first look at the whole-word recognition route, the model says that (1) RTs to singular forms will be the same for the singular dominant nouns and the plural dominant nouns (because their base frequencies were matched; both around 59 per million), (2) RTs to the high-frequency plurals of the plural dominant nouns will be slightly longer than those to the singular forms, because the average surface frequency of the plural forms (41) is slightly lower than the base frequency, and (3) RTs to the low-frequency plurals of the singular dominant nouns will be substantially longer than those to the singular forms, because their average surface frequency (15) is much lower than the base frequency.

The estimates of the whole-route RTs are easy for the singular nouns, because these RTs are assumed to be due to the storage route alone. Table 1 informs us that these RTs (for singular nouns with a base frequency of 59) have a mean of 547 ms and a standard deviation of 40 ms. If we assume a normal distribution, most of the data will fall between 467 ms (mean minus two standard deviations) and 627 ms (mean plus two standard deviations). The estimates of the whole-route RTs for the plural forms are slightly more difficult to obtain because the data in Table 1 are a mixture of whole-word recognition and decomposition procedures. Therefore, we cannot use these data to get a reasonable estimate of the frequency effect due to the storage route alone. Such information, however, can be obtained from Table 2 (Experiment 2). Here, we see that RTs to singular nouns with a base frequency of 20 (596 ms) are 56 ms longer than the RTs to singular nouns with a base frequency of 59 (540 ms). Because the RTs in Table 2 are based on singular word forms, they are completely due to the storage route, so that the time difference of 56 ms can be considered as a reasonable estimate of the frequency effect in the whole-word recognition route (at least for a frequency difference between 59 and 20 per million). Thus, by combining the results of Experiments 2 and 1, and by assuming that the effects of base frequency are the same as those of surface frequency (as Baayen and colleagues do), we can conclude that if in Experiment 1 we had presented plural nouns with a surface frequency of 20 per million, we would have expected the storage route to result in a normal distribution of RTs with a mean of 547 + 56 ms = 603 ms, and a standard deviation of 40 ms. The single next step to make then, is to rescale the frequency effect from the low frequency of 20 used in Experiment 2, to the low frequencies of 15 and 41 used in Experiment 1. Assuming a logarithmic frequency function, this yields the following average values: for the plural forms with a surface frequency of 15, we get an estimate of 547 + 71 ms;[5] and for the plural forms with a surface frequency of 41, we get an estimate of 547 + 19 ms. Assuming equal standard deviations in all conditions,[6] we get the RT distributions shown in Table 5.

The predictions in Table 5 can be compared to the obtained data presented in Table 1. In the dual-route model, the differences between the predicted and the obtained values for the plural forms come from the second, decomposition route, which roughly will result in a normal distribution of RTs with mean equal to 547 + total parsing cost, and a standard deviation of 40 as well. With very small values of the estimated parsing cost, the RT distribution of the decomposition route will be nearly the same as the one for the singular forms. With very high values of the estimated parsing time, the RT distribution of the decomposition route will be so high that it will never be faster than the storage route. Simple simulations allow us to search for a value of the estimated parsing cost that is in line with the empirical data. Table 6 shows the effects of different values on the estimates RTs. They are based on 10,000 random values from the normal distributions defined for each route.

As can be seen in Table 6, the empirical data of Experiment 1 are captured better when in addition to the whole-word recognition route, the model includes a decomposition route with a parsing cost of some 25–30 ms. The decomposition route is faster in 80% of the instances for nouns with a low-frequency plural, and in 45% of the cases for nouns with a high-frequency plural. The strong impact of the decomposition route agrees with the fact that the -s morpheme is a productive morpheme to pluralize nouns in French,

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[5] The added time due to the lower frequency is estimated with the equation:

$$\text{added\_time} = \frac{\log(59) - \log(15)}{\log(59) - \log(20)} \times 56.$$

[6] The constant value of SD is clearly a simplifying assumption, because in RT data higher means are always accompanied by higher SDs, as can easily be verified in Tables 1–4.

Table 5
Predicted RTs using Baayen et al.'s storage route for the items from Experiment 1

	Presented form: singular			Presented form: plural		
	Frequency	RT	Range	Frequency	RT	Range
Singular dominant	59	547	467–627	15	618	538–698
Plural dominant	59	547	467–627	41	566	486–646

Table 6
Simulated data for decision latencies to singular and plural word forms when a decomposition route is added to the storage route with different values of the parsing time (PT)

Parsing time	Singular	Plural	
		SingDom	PlurDom
PT (ms)			
0	547 (40)	543 (37) 89%	533 (33) 63%
25	547 (40)	565 (35) 80%	546 (33) 47%
50	547 (40)	584 (34) 65%	556 (34) 30%
100	547 (40)	607 (34) 31%	564 (38) 8%
150	547 (40)	615 (39) 8%	565 (40) 1%
∞	547 (40)	618 (40) 0%	566 (40) 0%
Observed	547	574	546

First, the average RT is reported; then the standard deviation (between brackets). For the plural forms, we also indicate how often the decomposition route was faster than the whole-word recognition route.

without a higher-frequency competitor. At the same time, Table 6 reveals a weakness in Baayen et al.'s (1997) model based on the horse-race metaphor. When parsing costs are low, RTs to plural forms tend to be faster than those to singular forms and less variable. This is because singular forms are supposed to be processed by a single route only, whereas plural forms are processed by the faster of two parallel routes. It is also interesting that within the dual-route framework the impact of the decomposition route depends on the surface frequency of the plural form, and that its contribution is much higher than predicted by Caramazza et al. (1988), who hypothesized that for familiar words the storage route would normally outperform the decomposition route.

Unfortunately, the situation is less clear for English, because Baayen et al.'s Parallel Dual-Route model only applies if we assume that the RTs to the plural-dominant nouns are elevated for a reason *unrelated to the base frequencies of the nouns and the morphological processing*. In that case, we can use the above reasoning to estimate the contribution of the decomposition route for the processing of the plural forms. Table 4 informs us that the average RT to singular nouns with a base frequency of 18 equals 548 ms, and the average RT to singular nouns with a base frequency of 54 equals 522 ms, which gives us an estimated frequency effect in the storage route of 26 ms for a difference in frequency between 18 and 54. On the basis of this effect, we can estimate the frequency effect in the storage route for stimuli with a frequency of 8 (i.e., the surface frequency of the plural forms of the singular-dominant nouns) and a frequency of 26 (the surface frequency of the plural forms of the plural-dominant nouns). These estimates are respectively, 45 and 17 ms. So, the predictions of the storage route for the English stimuli are: singular forms of singular-dominant nouns = 482 ms, plural forms of singular-dominant nouns = 482 + 45 = 527 ms, singular forms of plural-dominant nouns = 503 ms, plural forms of plural-dominant nouns = 503 + 17 = 520 ms. Applying the same method as in Table 6, we obtain a reasonable fit (albeit less good than in French) at a parsing cost of some 50 ms (plurals of singular-dominant nouns: 507 ms, 47% decomposition route; plurals of plural-dominant nouns = 510 ms, 27% decomposition route).

The critical question, however, is whether we are justified to assume that the elevated response times to the plural-dominant nouns in English are unrelated to the base frequency and the morphological processing, or whether this difference is genuine and should be taken into account. If the latter is true, Baayen et al.'s (1997) model no longer applies in its current form and needs at least one extra assumption to account for the fact why RTs to singular nouns with equivalent base frequencies differ as a function of the distribution of the frequencies over the singular and the plural forms.

In this respect, it may be interesting to know that very recently an alternative explanation has been proposed for exactly the same stimulus materials as the ones we tested here. Davis, van Casteren, and Marslen-Wilson (2003) wondered whether the interaction between word form and surface frequency, as shown in Fig. 1, could have the same status as the interaction between grapheme–phoneme consistency and word frequency in the literature of word naming. When participants read aloud printed words, they are nearly as fast to read low-frequency words with consistent grapheme–phoneme mappings (e.g., bus) as high-frequency words with such mappings (e.g., big). However, they are much slower to name low-frequency words with inconsistent mappings (e.g., worm) than high-frequency words with such mappings (e.g., word). For many authors (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), the explanation of this interaction requires a dual-route model of word naming, with a decomposition (grapheme-to-phoneme-conversion) route for the translation of regular letter-sound mappings, and a storage route for the naming of irregular words. However, connectionist modelers (e.g., Seidenberg & McClelland, 1989) have shown that the same interaction can be obtained in a single-mechanism network, when the input and output are no longer considered as unitary, localist representations of words but as patterns of activation distributed over several units within the input and output layers, connected to one another through a layer of hidden units. In such models, the input–output translation is best for frequently presented input–output mappings, and in particular for those that do not have to compete with incompatible mappings (such as the pronunciation of the rhyme *-us*). Performance is worst for input–output mappings that have to compete against a lot of incompatible mappings (e.g., the pronunciation of *-int* in *pint*). The lower the frequency of the deviant pattern and the higher the frequency of the alternative patterns, the more difficult it is to reach the correct pronunciation.

Davis et al. (2003) wondered whether a similar connectionist network with subword input units could simulate the Dutch data reported by Baayen et al. (1997). They used a standard, 3-layer feed-forward network that translated orthographic input into semantic output. The input consisted of 5 slot-based banks of 27 letter units (to represent 582 four- and five-letter, monosyllabic Dutch nouns) and two additional units to represent the Dutch plural suffix *-en* (*baard*, *baard**en*** [beard, beards]). The semantic output consisted of a randomly generated binary vector of 128 semantic units for each word, and 1 unit that indicated whether the word was singular or plural. When the model was trained, it resulted in response times that were largely in line with those predicted by a full-storage model. For singular-dominant nouns, the word threshold was reached sooner for singular forms than for plural forms. For plural-dominant nouns, the threshold was reached faster for plural forms than for singular forms. Things changed dramatically when Davis et al. (2003) added verbs to the input of their model. In the Dutch language, the plural suffix *-en* is also used for verb infinitives and plural verb forms, so that in the language as a whole there is uncertainty about the interpretation of the end *-en*. When the verbs were added to the input, the results of the model for the nouns were an exact replica of those obtained by Baayen et al. (1997, see the lower right panel of Fig. 1), even though the model consisted of a single “route” only.

Davis et al.’s (2003) work suggests two things. First, when distributed subword representations of morphologically complex orthographic input are used, the distinction between the whole-word storage route and the decomposition route fades, because words simultaneously activate representations at different levels (going from the single letters to the complete stimulus; see also Plaut & Gonnerman, 2000). Second, deviations in the model’s performance from the pattern predicted by a full-storage model do not necessarily point to another way of processing (decomposition instead of storage). They can also be due to competition between different (inconsistent) uses of the same morpheme (remember that this was also one of the factors retained by Bertram et al. (2000) in their taxonomy; see the Introduction).

When we look for a possible competition-based account that could explain the difference between English on the one hand and French and Dutch on the other hand, it seems unlikely that this candidate is related to the suffix used to pluralize nouns. The use of the suffix *-s* in French resembles the use of the morpheme *-s* in English much more than the use of the morpheme *-en* in Dutch,[7] so that we would rather expect a distinction between English and French on the one hand and Dutch on the other hand. A more likely candidate might be the word stem. One obvious characteristic of the English language is that word stems without suffixes point to verb forms (including the infinitive) as well as singular nouns (e.g., play). This is radically different from Dutch and French, where nouns and verbs often share the same stem but have different suffixes. So, for the interpretation of the English findings, we not only have to take into account the competition between the different uses of the suffix *-s* (like in French and in Dutch), but also the competition introduced by the absence of a suffix. This may have caused longer decision times in the English studies (which probably were perceived by the participants as requiring a decision between nouns and nonwords), in particular when the surface frequency of the singular noun was low. If the difference between English and the other two languages is genuine (see above), we strongly suspect that the ambiguity of the null-suffix is the most likely variable to look into.

Conclusion

Our data show that in English and French, just like in Dutch, lexical decision times to singular nouns are influenced by the frequencies of the plural forms. Similarly, lexical decision times to plural nouns are better explained if we do not assume that they exclusively depend on the

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[7] In the Lexique corpus, 36% of the French words ending on an -s are plural nouns, both when counted as a function of type frequency and as a function of token frequency.

surface frequency of the plural forms, but in a considerable percentage of the trials (ranging from 25 to 80% depending on the surface frequency of the plural and the language) are due to a decomposition into the singular and the plural suffix. These findings argue against the idea that familiar morphologically complex words are entirely recognized via direct look-up in the mental lexicon, as assumed by the full-storage view and some versions of the dual-route account. They also argue against the idea that plural nouns are normally recognized by parsing them, as assumed by the decomposition view and some other versions of the dual-route account. Rather, our data point to the view that morphologically complex words are processed by a combination of whole word recognition and segmentation. This can happen either in two parallel routes (as defended by dual-route models) or in a connectionist three-layer network with subword input units. Previous data in English that pointed to a full-storage model, are due to the fact that in English the nouns with low-frequency singulars seem to be more difficult to process than matched nouns with high-frequency singulars. A possible reason for this might be that in English, the singular form of a noun is also a possible infinitive form of a verb.

Appendix A

Materials used in Experiment 1

Word [in English]	Singular			Plural		
	Mean reaction	*SD*	Frequency	Mean reaction	*SD*	Frequency
Singular dominant items						
armoire [cupboard]	522	68	23	557	123	6
artiste [artist]	535	91	40	529	60	24
auteur [author]	507	72	63	638	249	38
bière [beer]	531	93	23	585	132	4
boîte [box]	498	110	59	557	131	27
commissaire [superintendent]	564	134	28	651	194	6
comptoir [bar]	562	93	21	619	83	2
contrat [contract]	580	121	22	579	151	11
écrivain [writer]	575	191	34	576	104	18
faiblesse [weakness]	590	108	23	555	83	6
fauteuil [armchair]	541	117	44	556	133	14
frère [borther]	515	92	100	519	85	49
hôtel [hotel]	544	111	84	577	144	15
immeuble [building]	589	169	28	586	160	16
manche [sleeve]	551	91	30	576	70	14
ministère [government department]	560	141	41	715	121	10
orage [storm]	525	53	20	554	150	5
pain [bread]	593	71	63	544	101	3
plafond [roof]	524	110	30	553	98	3
poète [poet]	555	78	41	548	150	14
réussite [success]	542	117	21	574	94	6
salle [room]	523	102	127	618	168	19
source [spring]	515	115	55	562	82	29
verre [glass]	529	89	115	519	64	34
Plural dominant items						
chaussure [shoe]	618	110	5	565	95	26
cuisse [thigh]	514	84	12	505	118	26
dent [tooth]	511	119	9	553	105	71
document [document]	542	103	18	522	77	44
doigt [finger]	507	64	47	509	100	100
facteur [postman]	517	57	32	516	99	45
fleur [flower]	485	88	33	530	83	83
fruit [fruit]	529	63	26	510	65	50
lèvre [lip]	557	125	11	527	95	107
lunette [glasses]	530	82	6	516	96	37
marchandise [goods]	626	131	8	623	185	19
nuage [cloud]	544	81	19	542	64	39

Appendix A (*continued*)

Word [in English]	Singular			Plural		
	Mean reaction	*SD*	Frequency	Mean reaction	*SD*	Frequency
ongle [nail]	529	67	6	532	61	20
organe [organ]	671	161	21	544	70	36
particule [particle]	625	70	10	621	139	31
paupière [eyelid]	550	91	4	597	150	30
recette [recipe]	548	124	8	609	147	20
soldat [soldier]	522	106	26	542	76	47
soulier [shoe]	549	94	3	567	89	18
sourcil [eyebrow]	535	64	4	547	73	20
touriste [tourist]	570	112	6	532	112	16
troupe [troop]	597	99	24	580	105	45
vêtement [cloth]	494	77	11	535	76	44
volet [shutter]	533	110	5	569	83	20

Materials used in Experiment 2

Word [in English]	Mean reaction time	*SD*	Singular frequency	Plural frequency
Singular with high frequency plural				
chaussure [shoe]	503	74	5	26
document [document]	515	64	18	44
doigt [finger]	491	52	47	100
facteur [postman]	509	33	32	45
fleur [flower]	502	69	33	83
fruit [fruit]	509	78	26	50
gant [glower]	668	207	4	17
larme [tear]	492	42	6	69
lèvre [lip]	555	88	11	107
marchandise [goods]	624	81	8	19
meuble [furniture]	544	88	19	37
nerf [nerve]	555	93	11	21
nuage [cloud]	483	58	19	39
organe [organ]	549	61	21	36
particule [particle]	630	136	10	31
paupière [eyelid]	599	108	4	30
recette [recipe]	526	78	8	20
soldat [soldier]	545	86	26	47
touriste [tourist]	538	71	6	16
troupe [troop]	631	78	24	45
vêtement [cloth]	525	100	11	44
volet [shutter]	568	87	5	20
Singular with low frequency plural				
bassin [basin]	572	72	21	6
camionnette [van]	686	110	8	2
cercueil [coffin]	660	181	11	2
chandail [pullover]	665	109	6	1
duvet [down]	589	93	5	1
grange [barn]	629	143	21	3
huile [oil]	532	70	33	3
impasse [dead end]	612	107	8	1
larme [tear]	550	86	6	69
mare [pool]	686	125	6	2
neige [snow]	507	65	48	4
nuque [nape]	589	114	26	1
orage [storm]	554	107	20	5
partition [partition]	730	137	10	3

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Appendix A (*continued*)

Word [in English]	Mean reaction time	*SD*	Singular frequency	Plural frequency
pavilion [bungalow]	491	71	17	4
perruque [wig]	536	58	4	2
prêtre [priest]	635	178	20	13
rivière [river]	584	107	34	8
sculpteur [sculptor]	625	95	5	3
tige [stem]	578	84	12	8
torse [chest]	618	113	12	2
vallée [valley]	520	76	26	6

Materials used in Experiment 3

Word	Singular			Plural		
	Mean reaction time	*SD*	Frequency	Mean reaction time	*SD*	Frequency
Singular dominant items						
beast	468	68	17	516	96	11
belief	439	43	67	477	58	24
cathedral	476	68	15	553	83	3
clinic	480	65	15	548	77	5
dragon	482	43	8	495	80	2
famine	525	52	7	642	145	1
hat	422	33	53	439	51	15
journal	495	78	18	456	52	6
lieutenant	603	67	14	609	132	1
monument	547	112	11	588	110	6
moustache	519	88	16	547	106	2
prophet	532	90	10	606	108	6
regiment	586	126	10	572	133	2
salad	490	78	16	470	63	4
sister	463	59	82	489	52	32
studio	450	67	22	498	81	6
sum	480	90	32	483	98	17
sword	467	73	13	490	78	4
talent	473	67	24	506	107	12
task	473	68	65	468	74	17
texture	433	45	11	490	65	2
tribe	478	65	23	505	78	15
valley	483	85	49	495	91	7
Plural dominant items						
acre	584	101	15	559	85	23
ancestor	569	77	6	568	95	22
biscuit	434	43	5	458	85	11
critic	546	92	12	534	85	23
disciple	560	114	4	533	137	13
dollar	514	65	15	503	76	53
glove	455	59	5	441	50	15
heel	490	94	11	479	48	18
ingredient	535	75	4	553	110	11
lip	444	50	17	482	67	61
molecule	498	57	5	515	83	12
neighbour	466	67	19	475	61	31
nostril	562	71	2	551	87	10
sandal	536	81	1	516	111	8
shoe	438	64	14	448	84	65
sock	434	56	3	441	64	16
soldier	466	35	26	448	42	57

Appendix A (*continued*)

Word	Singular			Plural		
	Mean reaction time	*SD*	Frequency	Mean reaction time	*SD*	Frequency
statistic	567	110	2	524	72	14
symptom	554	93	6	485	62	18
tablet	524	113	3	491	51	9
tactic	521	98	6	532	78	16
tool	433	39	16	439	36	29
weapon	462	64	24	469	86	79

Materials used in Experiment 4

Word	Mean reaction time	*SD*	Singular frequency	Plural frequency
Singular with high frequency plural				
acre	584	73	15	23
ancestor	595	82	6	22
boot	468	65	8	30
colleague	569	93	12	39
critic	547	76	12	23
curtain	500	78	19	24
customer	496	85	14	24
dollar	487	63	15	53
fee	540	106	13	19
heel	502	104	11	18
institution	698	178	25	56
knee	475	37	29	54
lip	478	92	17	61
metre	641	132	8	27
pig	487	68	18	26
politician	585	93	14	41
prisoner	474	71	16	32
pupil	453	67	14	34
resource	562	86	14	80
scientist	564	158	16	46
shoe	451	63	14	65
soldier	505	90	26	57
tool	461	61	16	29
weapon	490	103	24	79
Singular with low frequency plural				
aunt	514	100	30	4
deck	508	74	19	2
earl	607	113	15	1
enclosure	585	108	6	1
expenditure	646	162	28	4
federation	683	146	15	1
flint	583	134	12	1
foe	642	118	14	1
haven	575	78	8	1
lid	551	140	14	5
mayor	515	61	15	1
moustache	538	108	16	2
oak	465	63	14	3
outcome	504	125	19	2
pencil	465	65	15	3
promotion	563	100	15	2
receiver	552	104	14	1
reception	520	90	18	1

(*continued on next page*)

Appendix A (*continued*)

Word	Mean reaction time	*SD*	Singular frequency	Plural frequency
refuge	564	88	12	1
rubber	506	106	25	1
staircase	518	81	12	2
stove	618	169	16	4
supper	511	96	27	1
tub	534	122	8	1

Appendix B. Nonwords used in Experiment 1–4

Experiment 1: plaf, spise, plape, cloie, semo, ronue, doyer, dicin, ébole, punard, mécier, carban, cestaud, sonstat, foufiat, fassion, relition, intident, occlaire, vôtelier, senevois, dotémisme, cinérique, vendemiaire, lufes, gicons, stomes, flains, satits, nigles, soches, rumets, mansirs, ariages, sombets, chabols, fanseurs, serrares, rondeuls, sergints, inonités, cagillons, silatures, négatides, primoutés, harcelines, mélanistes, protiplasmes.

Experiment 2: spise, cloie, semo, ronue, doyer, dicin, ébole, gloure, punard, carban, cestaud, sonstat, foufiat, fassion, saterne, relition, occlaire, vôtelier, senevois, dotémisme, cinérique, rendemiaire, gicon, stome, flain, satit, nigle, soche, rumet, mansir, ariage, chabol, fanseur, serrare, rondeul, sergint, inonité, cagillon, silature, négatide, primouté, harceline, mélaniste, protiplasme.

Experiment 3: ekits, stilk, empastic, acrodes, critens, domip-e, purfle, jortles, slebs, gurst, sar, daps, glips, lorm, hean, anar-ps, commokes, rolper, tarm, voys, deavans, dother, gollert, vockines, cantiles, datance, sicherel, forliders, yeaves, shapt, pleathilod, soafritions, foonidins, impudion, misbane, dishoods, jondles, drucle, dulthoral, ordaiments, vodiques, leabime, reasel, extopes, monades, comirt, naikesque, polturests.

Experiment 4: communder, chup, het, pranet, trand, texe, gile, corridom, storach, jol, coar, documelt, expart, canvidate, oppolition, manazine, mistale, boal, frat, performanie, nist, respanse, pleagure, oblect, clearante, ric, balon, fabade, ribal, factian, recilent, mut, evam, tulf, lebon, rostriction, historiat, wot, monket, cathevral, fet, inserior, shart, disorce, cutton, topit, condiction, glain.

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