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THE WORD FREQUENCY EFFECT AND LEXICAL ACCESS*

JUAN SEGUI†

Laboratoire de Psychologie Expérimentale, Université René Descartes et EPHE, Associé au CNRS, Paris, France

JACQUES MEHLER and ULI FRAUENFELDER‡

Laboratoire de Psychologie, EHESS, CNRS, Paris, France

and

JOHN MORTON

MRC Applied Psychology Unit, Cambridge, England

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Abstract—Some recent experiments suggest that only open class words show a frequency effect. Closed class items are accessed independently of their frequency. We carried out five experiments to test the validity of this hypothesis for the French language. All our results suggest that the frequency effect applies equally well to the open and closed class items.

ONE OF the best established findings in experimental psycholinguistics relates the frequency of occurrence of a word to the time required for its recognition. HOWES and SOLOMON [1] showed that the visual recognition threshold for tachistoscopically presented words is a function of the logarithm of their frequency. Similarly, HOWES [2] found a correlation between the frequency of a word and the signal to noise ratio necessary for the recognition of that word. Other tasks such as lexical decision [3], naming time [4] have also revealed a frequency effect. These results have been replicated with other languages. FRAISSE [5] found a good correlation between visual threshold, naming time and word frequency in French. So pervasive was this effect of frequency that most theories of lexical access have acknowledged it in one form or another [6, 7]. Specially MORTON [8] and FORSTER [9] have constructed models in which word frequency plays a critical role.

In a recent series of lexical decision experiments, however, BRADLEY [10] has found a frequency effect for words belonging to the open class and not to the closed class. While a formal distinction between the open and closed classes has not yet been established (and may not even be possible), it is generally thought that the open class syntactic categories like verbs and nouns have many members with the possibility of adding new ones. The members of the closed class syntactic categories like prepositions, conjunctions, and pronouns, on the other hand, form a restricted and non-productive set.

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†Reprint requests should be sent to Dr. Juan Segui, Laboratoire de Psychologie Expérimentale, 28 rue Serpente, 75006, Paris.

‡Present address: Center for Cognitive Science, MIT, Cambridge, MA, U.S.A.

Bradley conducted lexical decision experiments with Broca's aphasics and found a frequency effect for both open and closed class items. These results for aphasic and normal subjects are concordant with GARRETT's interpretation of speech errors observed for open and closed class words [11–13]. On the basis of her results Bradley postulates the existence of two different access routes: one general purpose (frequency dependent) and another specialized (frequency independent) for closed class items. Syntactic processing difficulties found in Broca's aphasics can thus be explained by assuming that their specialized access route is no longer functional. This view of Broca's aphasia has received a great deal of attention in the last few years [14–17].

Given the importance of these experimental findings and their potential impact on lexical access models, it is essential to enlarge the data base to languages other than English. This study constitutes an attempt to replicate such findings in French. In what follows we present experiments further investigating the effect of word frequency on lexical decisions for open and closed class items. Since the nature of the linguistic materials (word lists, sentences, texts, etc.) used in evaluating lexical access is often critical, different lists, both homogeneous and heterogeneous with respect to word class, were constructed. In the first experiment we have tried to replicate Bradley's experiments using a single heterogeneous list containing both open and closed class words. In the second and third experiments, homogeneous lists of either open or closed class items were used. In the final experiments both the French and English frequency tables were compared with subjective frequency measures in order to evaluate the former.

EXPERIMENT I

Subjects

Twenty French students at the University of Paris V served as subjects.

Materials

An experimental list of 100 items (56 words and 44 nonwords) was constructed. Of the 56 words, half belonged to the open class and the other half to the closed class. The open class words were all nouns (singular), verbs (infinitive), and adjectives (masculine singular) and the closed class were prepositions, morphologically unmarked adverbs, conjunctions, pronouns and possessive adjectives. The list was so constructed that for each open class word there was a corresponding closed class word matching in frequency and syllabic length (see Appendix 1). The estimated frequencies were taken from the GOUGENHEIM *et al.* [18] frequency tables for colloquial French in the early sixties. The frequencies of the words used, expressed in base 10 logarithmic units, ranged from 0 to 3.378. The syllabic length of the words and legal, pronounceable nonwords varied between 1 and 2 syllables. Nonwords were not systematically derived from a particular class of words (open or closed).

Procedure

The experimental items in the list were presented one by one at the centre of a Hewlett-Packard CRT screen. Stimulus presentation was controlled by a Telémécanique T1600 computer. Items were presented pseudo-randomly to each subject (with the constraints that there were never more than three successive words or nonwords and never more than two successive occurrences of words from the same class) giving an order of presentation that varied from subject to subject. Subjects were told to judge the lexical status (word/nonword) of the letter strings presented by pressing as quickly as possible one of the two response buttons ("yes/no") placed in front of them. The "yes" response button (word) was associated with the subject's dominant hand (in most cases the right hand). The subjects triggered the presentation of the first item on the list. Each item remained on the screen until the subject had given a response. A constant interval of 750 msec separated the subject's response and the arrival of the next stimulus. The computer recorded the nature and latency of each response.

Results

The mean reaction times (RTs) for the correct responses to each of the words (listed in

Appendix 1) were obtained using a double cut off criterion. The RT for a particular subject for a given item was excluded when it exceeded by two standard deviations the subject's mean RT for all other items or the mean RT of all the other subjects for that item. This combing procedure led to the exclusion of 2.2% of the data of each list.

A correlation (r of Bravais–Pearson) between the base 10 log of the frequency of the words and the response latency (expressed in milliseconds) was computed. One item ("tien") was omitted from the computation of this correlation because it had an error rate of more than 10%. In addition, the RT for the open class word "tango"* was not included in this computation because it exceeded the mean RTs for the other items of this class by more than three standard deviations. Table 1 summarizes the data.

Table 1. Effects of frequency on RTs for open and closed class items

	Open class	Closed class
Mean RTs (msec)	661	654
% Errors	2.5	3.1
Correlation coefficient	−0.57	−0.63
Slope of linear regression	−22	−21
Zero intercept (msec)	704	695
Frequency range	0–3.378	0–3.378

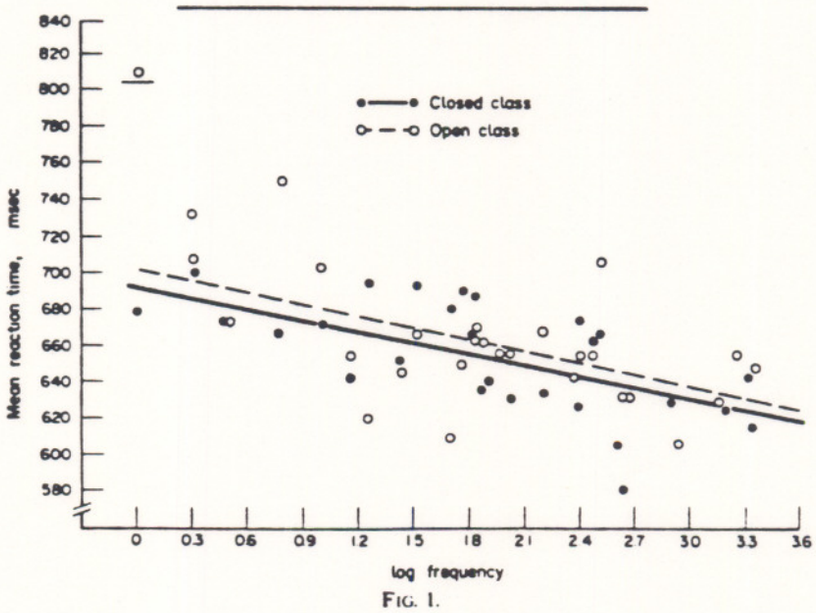

FIG. 1.

The frequency effect for open and closed class words is similar in magnitude. Both correlations were significant ($P<0.01$). The results (plotted in Fig. 1) confirm the previous

*The mean RT obtained for "tango" was high (810 msec) because many subjects considered it to be a Spanish word (and not a French one). In a control experiment using a list of 15 bisyllabic words with a frequency of 1 (like "tango") we observed a mean RT of 702 msec. The inclusion of the RT for "tango" gave $r=0.65$ for the open class with a slope of linear regression of −31.

findings of a negative correlation between the estimated frequency and the lexical decision times for open class items. However, they also showed an equally strong effect of frequency on the lexical decision times for closed class items.

Another way of seeing the frequency effect is by comparing the mean RTs for the 10 most frequent and 10 least frequent words for both classes. These are given in Table 2.

Table 2. Mean RTs for the 10 most and 10 least frequent open and closed class items

	Open class	Closed class
Most frequent	647	633
Least frequent	696	676

A comparison of the RTs obtained for the 10 most and least frequent items using a Student t-test for independent groups showed a significant difference for open class words ($t18 = 2.52$: $P < 0.05$) and for the closed class words ($t18 = 3.91$; $P < 0.01$).

The results obtained in this experiment show a strong frequency effect on lexical decision times for both open and closed class items. Before presenting a discussion of these results, the same items will be tested in homogeneous lists to examine the generality of this finding.

EXPERIMENT II

Subjects

Forty French students at the University of Paris V served as subjects. Twenty subjects received the first list and the remaining twenty received the second list.

Materials

Two homogeneous lists of 50 items each (28 words and 22 nonwords) were constructed. Both the open class words in List 1 and the closed class words in List 2 were the same as those used in the mixed list from the previous experiment. Similarly, the nonwords used in both lists were the same as those used in Experiment I.

Procedure

The experimental procedure is identical to that used in Experiment I.

Results

The analysis procedure previously described in Experiment I was used. Thus, 2.3% and 2.1% of the data corresponding to the open and closed class items, respectively, were dropped. For the same reasons as those expressed in Experiment I, the words "tien" (20% errors) and "tango"* (mean RT 832 msec) were excluded from the calculation of the correlation between the RTs and the log of the frequency. Table 3 and Fig. 2 present the data.

These results confirm the existence of a negative correlation between word frequency and the lexical decision times for both open and closed class items. Table 4 gives the mean RTs for the 10 most and least frequent items in both classes.

A comparison of the RTs obtained for the 10 most and least frequent items using a Student t-test for independent groups showed a significant difference for open class words ($t18 = 2.25$; $P < 0.05$) and for the closed class words ($t18 = 3.28$; $P < 0.01$).

Both Experiments I and II used a relatively small number of items since they were stringently controlled, specially in length and syllabicity. It may be interesting to replicate

*The inclusion of the latter RT gave a correlation of $r = 0.60$ with a slope of -30 for the open class words.

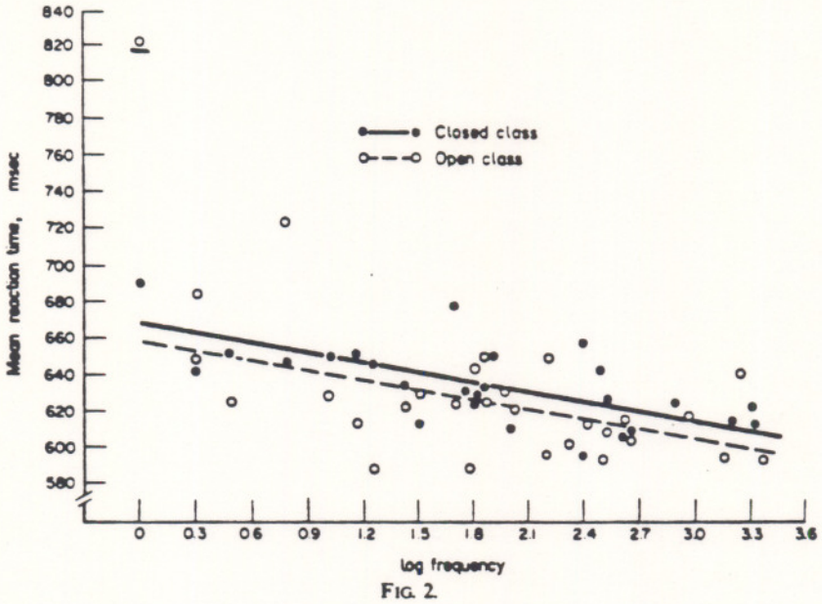

FIG. 2.

Table 3. Effects of frequency on RTs for open and closed class items

	Open class	Closed class
Mean RTs (msec)	624	632
%Errors	2.7	2.6
Correlation coefficient	−0.51	−0.63
Slope of linear regression	−17	−16
Zero intercept	658	663
Frequency range	0–3.378	0–3.378

these results with equally well controlled items at least in as far as the frequency is concerned but using longer lists. Unfortunately, this will lead to a stronger variability in length and morphological complexity of items.

Table 4. Mean RTs for the 10 most and 10 least frequent open and closed class items

	Open class	Closed class
Most frequent	608	621
Least frequent	658	650

EXPERIMENT III

Subjects

Fifty French students at the University of Paris V served as subjects. Twenty-five received the first list and the remaining 25 received the second list.

Materials

Two homogeneous experimental lists each containing 40 words and 40 nonwords were constructed. As in Experiment II, the lists were constructed such that for each open class word in List 1 there was a corresponding closed class word in List 2 matching in frequency and syllabic length (see Appendix 2). The frequencies of the words used, expressed in base 10 logarithmic units, ranged from 0 to 3.161. The syllabic length of the words and the legal, pronounceable nonwords varied between one and three syllables. The nonwords which were constructed as in the other experiments were the same for both lists.

Procedure

The experimental procedure is identical to the one used in Experiment II.

Results

The same data analysis procedure as in the previous experiments was used. 1.6% and 2.0% of the data corresponding to closed and open class items, respectively, were omitted. Three items on each list (L1: dos, gosse, border; L2: desquels, jadis, tes) were eliminated from the calculation of the correlation between the base 10 log of the frequency of the words and the response latencies (expressed in milliseconds) because they had error rates of greater than 10%. The results obtained are summarized in Table 5.

Table 5. Effects of frequency on RTs for open and closed class items

	Open class	Closed class
Mean RTs (msec)	657	642
% Errors	1.9	2.0
Correlation coefficient	−0.58	−0.57
Slope of linear regression	−23.9	−28.4
Zero intercept	695	691
Frequency range	0–3.158	0–3.161

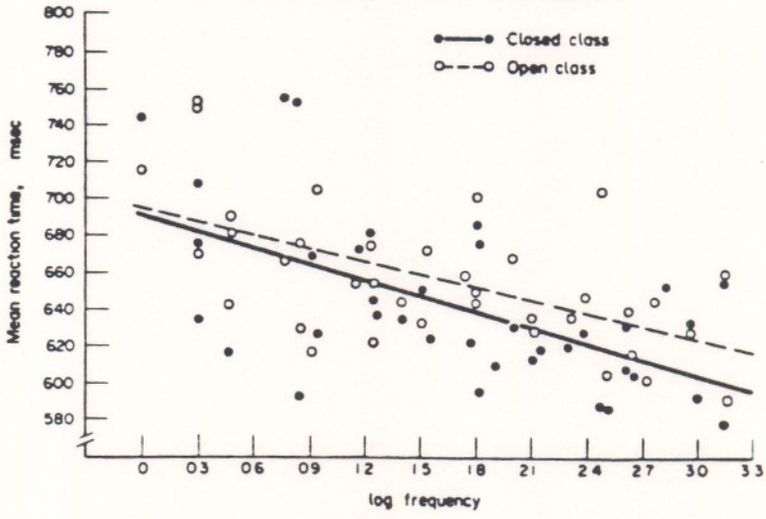

FIG. 3.

The correlations obtained for the effect of frequency of occurrence on RTs for open and closed class words were both significant at $P<0.01$. The results are plotted in Fig. 3.

Table 6 gives the mean RTs for both the 10 most frequent and 10 least frequent words for both classes.

A comparison of the RTs obtained for the 10 most and least frequent items using a Student t-test for independent groups showed a significant difference for open class words ($t18 = 3.06$; $P < 0.05$) and for the closed class words ($t18 = 3.20$; $P < 0.01$).

Table 6. Mean RTs for the 10 most and 10 least frequent open and closed class items

	Open class	Closed class
Most frequent	634	613
Least frequent	687	678

Discussion

The results of Experiments I and II showed a strong frequency effect for both open and closed class words in homogeneous and heterogeneous lists. Indeed, in the latter experiment where the separate presentation of open and closed class items could have incited the subjects to rely on the class specific accessing route, the results were comparable to the ones obtained in Experiment I. It could be argued that the failure to replicate Bradley's results was a function of the limited number of items from each class tested. However, the replication of the first two experiments by Experiment III (with a greater number of items) makes this explanation unlikely to be true. All three experiments revealed a very similar frequency effect for both classes of items.

Another possible explanation for the discrepancy between the results obtained here and those of Bradley relates to differences in quality of the frequency tables for the two languages. The French frequency tables [18] were established on the basis of a corpus of 312,000 token occurrences of words taken from normal conversation (the number from the written corpus based tables of KUCERA and FRANCIS [19]). However, inaccuracies in the estimation of the values of the independent variable would lead one to expect no effects rather than the strong dependencies between dependent and independent variables obtained in the first three experiments presented here. Nevertheless, this possibility was investigated in two further experiments in which subjective frequency measures were compared with the objective frequency measures found in tables. It has been reported (HOWES [20] and SHAPIRO [21]) that subjective estimations of relative frequency are correlated with the frequency counts as given in frequency tables. A similar observation for French was made by FRAISSE *et al.* [22]. In this experiment, subjects were asked to estimate the relative "familiarity" of 25 words chosen from five frequency levels: 1, 4, 16, 64, 256. A high correlation ($r = 0.90$) between "familiarity" and the table estimates of frequency was observed. However, in the above experiments the words used were almost exclusively from the open class. It is, therefore, important to determine how well subjects can estimate relative frequencies for closed class words. In Experiment IV subjective frequency judgments for English open and closed class items will be compared with the objective frequency tables [19] to determine whether subjects can rank closed class words for frequency. The same comparison will be made for the French language in Experiment V using the French tables [18]. Similar correlations for open and closed class words in both languages will provide a strong indication that the differences in lexical decision results are not due to the French frequency tables.

EXPERIMENT IV

Subjects

The subjects in this experiment were drawn from the Applied Psychology Unit Subject Panel. They were of both sexes and aged between 21 and 60 yr. They were tested in four groups of between 10 and 15 subjects. Two groups served in a ranking experiment and two groups in a scaling experiment.

Materials

The experimental materials were made up of a set of 50 words (25 open class words and 25 closed class words). The words from each class were chosen in an American frequency table [19] from five logarithmic levels of frequency centering on the frequencies 4, 32, 128, 384, 1024. Five closed class words and five open class words were chosen from each frequency level.

Procedure

Ranking condition. Each subject received a booklet with 10 pages. On each page were five words. These words were either all open class or all closed class with one word coming from each of the five frequency levels. On each page in the booklet the subjects were required to rank order the five words "according to their frequency of occurrence in general written materials". The number 1 was used for the highest frequency and 5 for the lowest frequency. Pages of the closed and open class words were randomly interspersed. A total of 24 subjects were used for this procedure.

Scaling procedure. The 50 words were presented in random order to the subjects on five sheets with 10 words each. Next to each word was a scale going from "very frequent" to "very infrequent". Subjects were asked "to make an estimate of how frequently you think each of these words occurs in written language". Subjects did this by making a mark on the scale. There was no time limit. When scoring these responses, the line was divided into five equal sections and a score of 1-5 was assigned with 1 being the most frequent and 5 being the least frequent section. A total of 25 subjects were used in this condition.

Results

In the ranking condition, the mean rank for each word was computed across the subjects. In the scaling experiment, a mean value was computed for each word from the subjective estimates of the subjects. The results from both conditions for open and closed class words are shown in Table 7.

Table 7. Mean rank and scaled frequency for open and closed class word groups

	Word group	Frequency range	Mean rank	Scaled frequency
Closed words	1	923-1895	1.16	1.44
	2	307-495	2.79	2.26
	3	101-173	3.03	2.22
	4	27-41	3.20	2.41
	5	1-9	4.81	4.14
Open class words	1	665-1599	1.38	1.85
	2	202-542	1.97	2.23
	3	103-171	2.97	3.20
	4	27-40	3.94	3.70
	5	1-9	4.74	4.30

Table 7 shows a good correlation between the frequency estimates furnished in the tables and the subjective frequency estimations obtained in the two conditions. In order to estimate the strength of this correlation, a correlation coefficient r was computed for each word class between the log frequency and the mean rank obtained for each item ($n = 25$). The correlation coefficient r for the ranking condition was -0.94 for the open class words and -0.86 for the

closed class words. For the scaling condition the r correlation coefficient between the log frequency and the mean scaled value for each item was -0.90 for the open class words and -0.86 for the closed class words.

These results show a high correlation ($P<0.01$) between the subjective and objective frequency measures for both open and closed class items. Subjects seemed to be able to estimate the subjective frequency for closed class items. In the next experiment, the subjective frequencies for French will be measured.

EXPERIMENT V

Subjects

Two groups of 20 subjects from the Parisian university community served as subjects in this experiment. One group received booklets containing the open class words and the other those containing the closed class words.

Materials

The experimental materials were made up of a set of 40 words (20 open class words and 20 closed class words). The words from each class were chosen in the French frequency tables [18] from five logarithmic levels of frequency centering on the frequencies 1, 4, 16, 64, 256. Four open class words and four closed class words were selected from each frequency level.

Procedure

Each subject received a different booklet with four pages. On every page there was a list of five words (presented in random order one on top of the other) each taken from a different frequency level. The words in a booklet belonged either to the open or the closed class. Subjects were told to estimate the relative frequency of the five words for the four different pages in the booklet. Subjects had to rank the words from 1 to 5 with 1 for the most frequent word and 5 the least frequent. Subjects were tested in small groups of two or three with no time limit.

Results

The mean rank for each word used was computed from the subjective estimations of the subjects. In addition, a mean ranking for all the words belonging to the same frequency level was obtained. The results are shown in Table 8.

Table 8. Mean rank for open and closed class word groups

	Word group	Frequency range	Mean rank
Closed words	1	181–325	1.97
	2	60–70	2.05
	3	13–18	2.82
	4	3–6	4.05
	5	1–2	4.22
Open words	1	181–337	1.85
	2	61–70	2.17
	3	13–18	2.78
	4	3–6	3.57
	5	1–2	4.50

This table shows a good correlation between the frequency estimates furnished in the tables and the subjective frequency estimations obtained from the subjects. The correlation between the log frequency and the mean rank for the items of each list ($n=20$) was -0.84 for both the open and the closed class words.

Discussion

Just as for the results of Experiment IV for English, a strong correlation ($P<0.01$) was found between the subjective and objective frequencies for both word classes in French. It appears thus that the difference between the results obtained here and those found by Bradley are not explainable in terms of differences between the frequency tables used.

GENERAL DISCUSSION

Three experiments are reported showing a negative correlation between the frequency of open and closed class items in French and the lexical decision latencies. These results conflict with those of Bradley in English. The comparable correlations between subjective and objective word frequency measures for both French and English indicate that the differences are not attributable to differences in the frequency tables themselves. One possible explanation for the differences in results for French and English relates to the choice frequency range. In the experiments reported here there is a one-to-one correspondence between the frequency of the open and closed class items over a broad range of frequencies. This was not the case in the studies by Bradley. The words from the two classes were not matched in frequencies and, furthermore, did not totally overlap in the frequency range. However, Bradley analysed the overlapping portions of open and closed class items both in her Experiments I and II. The covered range in Experiment I was 1.7 to 3.4 and in Experiment II it was 2.1 to 3.5. In our own experiments the overlapping range covered was much broader than those in Bradley's experiments. In Experiment I Bradley found that the open class correlated better than the closed class with frequency although there was no significant difference between them. In her second experiment Bradley found a similar result which was now very significant. Although Bradley's choice of frequency ranges reflects more closely the frequency distribution of the two classes in the language, it seems unfair to make much comparison, specially since the frequency effect may itself depend on the frequency range examined. Thus, due to some kind of a floor effect, high frequency items (such as the closed class items) would tend to show less frequency dependence than less frequent words. Consequently, it appears to be preferable to have the items from the two classes matched in frequency as in the present study.

There is, of course, another possibility, namely, that closed class items do not serve the same special function in French as they do in English. However, recently another series of experiments reported by GORDON and CARAMAZZA [23] failed to replicate differential frequency sensitivity for open and closed class items in English*. Indeed, in general, the results reported in our study and in that of Gordon and Caramazza are very similar. Therefore, if their results as well as our own stand up under further testing then it may seem wise to consider those reported by Bradley with extreme caution. This observation is not sufficient to argue against the potential existence of two different processing mechanisms for the items in question. In fact, the absence of a frequency effect for the closed class items is not a logically necessary condition in order to postulate separate access routes for the two classes of words. Obviously, finding such an asymmetry in frequency sensitivity would have made

*While our manuscript was undergoing the review process, Gordon and Camarazza's article appeared in *Brain and Language*. The aim of comparing French and English that was at the base of our own work becomes subsidiary if Gordon and Caramazza's results are substantiated since then French and English would seem to behave in very similar ways.

the difference in access routes much more credible. Nonetheless, there are other findings such as Garrett's observations of speech errors; Bradley's experiment on open and closed class words embedded in nonwords; Bradley's experiment on functional asymmetries for both classes of words and all the observations with aphasic patients, which argue in favour of separate access routes.

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APPENDIX I

Closed class words

	Log_{10} freq.	RT (msec) Hom. list (Exp II)	RT (msec) Mixed list (Exp I)
sitôt	0	692	679
lors	9.301	642	700
selon	0.477	651	672
hors	0.778	647	666
guère	1.041	649	672
soit	1.176	650	643
parmi	1.255	644	696
voici	1.431	635	652
ainsi	1.518	613	696
ceci	1.707	676	680
celle	1.755	630	690
cela	1.812	622	666
dont	1.819	628	687
ceux	1.869	632	635
chaque	1.919	649	640
quoi	2.041	610	631
depuis	2.212	596	634
sans	2.396	658	674
donc	2.396	595	626
voilà	2.482	642	662
moins	2.507	625	665
après	2.628	605	605
aussi	2.657	609	580
même	2.908	625	630
comme	3.196	614	627
dans	3.315	622	642
pour	3.317	611	618

Open class words

	Log_{10} freq.	RT (msec) Hom. list (Exp II)	RT (msec) Lised list (Exp I)
tango	0	823	810
laid	0.301	647	707
lard	0.301	684	731
savon	0.477	625	673
pois	0.778	724	750
boule	1.041	628	703
dent	1.176	612	657
lapin	1.255	589	620
arbre	1.431	622	646
huile	1.518	630	666
hiver	1.707	624	609
haut	1.763	588	651
peine	1.812	642	665
fils	1.838	651	670
dieu	1.869	624	662
drôle	1.949	630	656
prix	2.033	620	655
rendre	2.204	648	668
beau	2.359	601	642
soir	2.403	612	655
partir	2.484	593	655
vingt	2.525	609	706
grand	2.631	617	633
parler	2.650	603	634
petit	2.936	616	607
voir	3.158	596	632
aller	3.273	640	657
dire	3.378	593	648

APPENDIX II

Open class words

	Log_{10} freq.	RT(msec)
border	0	716
aube	0.301	749
intervalle	0.301	671
miniature	0.301	751
purée	0.477	643
caresser	0.477	691
nappe	0.477	682
fidèle	0.778	667
emballer	0.845	677
éclater	0.845	628
but	0.903	618
baignoire	0.954	706
dent	1.176	654
doigt	1.230	676
lourd	1.278	655
proposer	1.278	622
saison	1.414	645
champ	1.518	634
ancien	1.568	672
chaud	1.785	659
dame	1.838	702
fils	1.838	644
apporter	1.838	650
prix	2.033	669
homme	2.117	637
mot	2.158	628
appeler	2.334	637
soir	2.396	648
franc	2.485	705
moment	2.511	602
parler	2.655	639
chose	2.678	617
jour	2.730	603
venir	2.787	645
petit	2.936	629
savoir	3.155	660
voir	3.158	591

Closed class words

	Log_{10} freq.	RT(msec)
sitôt	0	745
lors	0.301	635
toutefois	0.301	676
quiconque	0.301	708
selon	0.477	617
durant	0.778	755
aussitôt	0.845	752
parfois	0.845	592
nul	0.903	670
cependant	0.954	626
soit	1.176	672
sinon	1.230	681
parmi	1.255	644
laquelle	1.278	638
dessous	1.414	634
ainsi	1.518	651
contre	1.568	623
aucun	1.785	622
cela	1.812	686
dont	1.819	676
pourtant	1.832	594
notre	2.037	610
quoi	2.041	631
souvent	2.120	612
toi	2.158	619
surtout	2.334	620
sans	2.396	628
votre	2.485	588
jamais	2.511	586
encore	2.628	609
aussi	2.657	631
rien	2.733	604
autre	2.841	653
quand	2.984	633
enfin	3.000	592
nous	3.141	579
comme	3.161	657

Résumé

Des travaux récents suggèrent que l'effet de fréquence dans l'accès lexical est limité aux seuls mots à contenu (ou mots "pleins"). L'accès aux mots fonctionnels serait indépendant de leur fréquence d'usage dans la langue. Afin de mettre à l'épreuve la validité de cette hypothèse de travail pour le français, nous avons effectué cinq expériences. Les résultats obtenus suggèrent que l'effet de fréquence est analogue pour les deux classes de mots étudiés.

Zusammenfassung

Einige jüngere Experimente zeigen, daß nur Wörter offener Klassen eine Frequenzabhängigkeit haben. Der Zugang zu Wörtern geschlossener Klassen ist unabhängig von ihrer Häufigkeit. Wir haben 5 Experimente ausgeführt, um die Validität dieser Hypothese für die französische Sprache zu überprüfen. Alle Ergebnisse legen die Annahme nahe, daß der Häufigkeitseffekt auf beide Klassen von Wörtern, offene und geschlossene, zutrifft.