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The Word Frequency Effect for Open- and Closed-Class Items

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A previous attempt (Segui, Mehler, Frauenfelder, & Morton, 1982) to assess in French the putative computational asymmetry between open- and closed-class words failed to reveal a difference in frequency sensitivity for these two types of words. In the present paper, two further lexical decision experiments are presented. The experimental conditions were chosen to maximise the chances of finding differences in frequency sensitivity between the two word classes (speeded responses and stimulus masking). Both experiments revealed strong frequency effects for open- and closed-class items and thus no asymmetry in frequency sensitivity. The implications of these results for both normal and aphasic populations are discussed.

INTRODUCTION

The word frequency effect, that is, the relationship between the frequency of a word in a language and the time required for its recognition, constitutes

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one of the most robust findings in psycholinguistics. It has been replicated many times in different languages with a variety of experimental methods. Despite the solidity of the experimental evidence, considerable uncertainty persists as how best to explain this effect. Indeed, frequency effects have been interpreted in terms of radically different components of the lexical processes. These include the early encoding stages (direct visual access versus phonological recoding; McCusker, Hillinger, & Bias, 1981), access to — and the internal structure of — the lexicon (ordered search models versus stochastic search models; Forster, 1978 and Landauer, 1975), and more recently post-access decision processes (Balota & Chumbley, 1984).

One of the most original and far-reaching hypotheses about the locus of frequency effects was proposed by Bradley (1983). In a series of experiments, Bradley found differences in the sensitivity to lexical frequency between open-class (nouns, verbs, and adjectives) and closed-class (pronouns, articles, etc.) words. In a lexical decision task normal subjects showed the expected frequency effect for open- but not for closed-class words. However, comparable frequency effects were obtained for open- and closed-class items with a group of agrammatic Broca's aphasics. These results led Bradley, Garrett, and Zurif (1980) to propose the existence of a general frequency-sensitive access system and a specialised frequency-insensitive system that mediates the retrieval of closed-class items.

The frequency effect for the closed-class items in Broca's aphasics suggests that these subjects can still retrieve closed-class words via the postulated "general" frequency-sensitive access route, but not via the "specialised" system. The loss of this system was taken to explain the difficulty these subjects have in computing syntactic representations in on-line processing.

The difficulty in processing open-class words has also been observed for Wernicke's patients. The selective preservation of closed-class words observed in a reading task in these patients led Coslett, Gonzalez-Rothi, and Heilman (1984) to propose that the processing of open- and closed-class words is mediated by distinct systems. However, Ellis, Miller, and Sin (1983) reported that the frequency rather than the word class provides a better explanation of reading performance in Wernicke's patients. When word frequency was held constant, no difference in performance on the two word classes was observed. This study shows the importance of controlling variables such as length and frequency that affect lexical access and that are confounded with word class. It is well known that closed-class words are generally shorter and more frequent than open-class words.

Gordon and Caramazza investigated differences in the processing of open- and closed-class words with normal subjects (Gordon & Caramazza, 1982) and with aphasic patients (Gordon & Caramazza, 1983). They observed similar frequency effects for open- and closed-class words for both subject populations. Segui et al. (1982) tried to replicate Bradley's results in French using normal subjects. They also obtained a frequency effect for open- and closed-class items in both homogeneous lists (made up of either open- or closed-class words) and heterogeneous lists (made up of both open- and closed-class words).

The discrepancy between the finding reported by Bradley (1983) and those of Gordon and Caramazza (1982, 1983) and Segui et al. (1982) is not yet fully understood. One possible reason for this discrepancy may be due to the fact that in Bradley's study the range over which the frequency of the two word classes overlapped was narrower than in the French study. Furthermore, the closed-class items selected by Bradley appear to be over-represented in the higher frequency range. If it is true, as Gordon and Caramazza (1982) have claimed, that there is an "inflection point" in frequency above which a reaction time floor is reached, then Bradley's choice of stimuli may have contributed to the absence of a frequency effect for closed-class words.

Since the claim of a computational distinction between vocabulary types made by Bradley and others has had a major impact on the interpretation of both normal and pathological language behaviour, it is essential to try to resolve the conflict between these results. In this paper, we re-examine the relationship between frequency and form class in lexical decision for normal subjects. We have selected experimental conditions that ought to favour the emergence of a differential sensitivity to frequency for the open- and closed-class items, while maintaining tight control over the frequency and length of the materials.

As mentioned above, the word frequency effect has been interpreted in a number of different ways. In particular, the "locus" of this effect has been attributed to different stages of processing (i.e. encoding, lexical access, and post-access verifications or decisions).

In previous experiments, Segui et al. (1982) attempted to determine whether the difference between the processing of open- and closed-class items results from lexical access and/or lexical structure by manipulating the experimental lists. Both homogeneous and heterogeneous lists were used. It was expected that subjects would be encouraged to use the specialised closed-class accessing route with a homogeneous set of closed-class items. However, the strong frequency effects obtained for both classes in the two experiments showed that the list structure did not lead to differential processing of the two word classes. In the experiments reported later, we seek to evaluate this claim further, by attempting to control the influence of early (encoding) and late (decisional) processing stages.

In Experiment I, we gave subjects feedback on the speed of their responses, hoping to accelerate RTs and thus limit the impact of post-access strategies.

In Experiment II, a masking procedure was used to limit the availability of word visual representation, which we hoped would increase subjects' reliance on the phonological code.

EXPERIMENT I

The latencies reported by Segui et al. (1982) were clearly longer than those in Bradley (1983) and Gordon and Caramazza (1982). Difference in latencies observed in experiments using different subjects, languages, and experimental set-ups must be interpreted with caution. However, longer latencies might reflect a greater reliance by French subjects on post-access strategies that may mask potential asymmetries due to the form class. In a recent paper Chumbley and Balota (1984) have shown the importance of these late processes in lexical decision and their relations to different factors like familiarity and meaningfulness. Consequently, it is important to confirm the existence of a frequency effect for open- and closed-class words in French using experimental conditions that limit the subject's reliance upon late decisional processes.

In this experiment, subjects received feedback on the speed of their responses. By speeding lexical decision latencies in this manner we hope to reduce the contribution of late decisional strategies.

Subjects

Twenty French students at Paris V University served as subjects.

Material

An experimental list of 112 items (56 words and 56 nonwords) was created including 28 words of the open class (singular nouns, infinitive verbs, and singular adjectives) and 28 of the closed class (prepositions, morphologically unmarked adverbs, conjunctions, pronouns, and possessive adjectives). Most of these words were identical to those used in experiments 1 and 2 of Segui et al. (1982). Each open-class word was matched with a closed-class word in syllable length and frequency. The frequency of occurrence of the words (Gougenheim, Michea, Rivenc, & Sauvageot, 1956) was expressed in base 10 logarithmic units ranging from 0 to 3.378[1]. The experimental materials are presented in the Appendix.

The 56 legal nonwords were created from open- and closed-class words of comparable frequency. Thus, unlike those used by Segui et al., the nonwords in this experiment were derived from both open- and closed-class words by substituting one letter (C or V) with another letter of the same category (e.g. "parfois"→ "perfois", "lequel"→"lequer"). The position of the substituted letter within the words varied from the first to the last letter. The syllabic length of both words and nonwords varied from one to two syllables.

A practice list of 20 items (5 open-class words, 5 closed-class words, 5 open-class derived nonwords and 5 closed-class derived nonwords) was also constructed.

Procedure

The items were presented one by one in the centre of a high-resolution phosphorous H-P CTR screen. Each subject received a different pseudo-random presentation with the constraint that there were never more than three successive words or nonwords. Subjects were told to judge the lexical status (word/nonword) of the letter strings by pressing one of the two keys placed in front of them. The "yes" key was associated with the subjects' dominant hand. The subject triggered the presentation of the first item of the list. Each item remained on the screen until the subject responded. The next stimulus item appeared one second after the subjects' response. When this response time exceeded 700msec. a signal ("TL", "trop lent", too slow) was presented on the screen for 300msec. This feedback procedure was used to encourage subjects to respond quickly[2]. The nature of the response as well as the reaction times (measured from the stimulus onset) were recorded by a computer.

Results

The mean reaction times (RTs) for the correct responses to each item (including RTs slower than the 700msec. feedback criterion) were obtained by using a double cutoff criterion. Individual RTs for an item were discarded when they exceeded (by two standard deviations) either that subject's mean RT for all other items or the mean RT of that item for all the other subjects. This procedure led to the elimination of less than 2% of the data.

A correlation was computed between mean RT and word frequency (log base 10) for all items. Table 1 summarises the results for the open- and closed-class words.

[1] The French frequency tables (Gougenheim et al., 1956) were established on the basis of a corpus of 312,135 words taken from 275 recordings of spoken language. The maximum frequency of occurrence of any word was 14,084. The logarithmic (base 10) frequency values given here were computed directly on the basis of this token count.

[2] We used the relatively slow criterion of 700msec. for giving subjects feedback since the principal objective of this research was to determine the existence of a correlation between frequency and RTs (and not frequency and error rate). The use of a faster criterion could well have led to an equalising of the RTs.

TABLE 1
Effects of Frequency on RT for Open- and Closed-Class Items

	Open Class	*Closed Class*
Mean RTs (msec.)	498 (661)	492 (654)
% of errors	6.6 (2.5)	10 (3.1)
Correlation coefficient	−.56 (−.57)	−.60 (.−63)
Slope of linear regression	−22 (−22)	−21 (−22)
Zero intercept	538 (704)	531 (695)

The correlations between word frequency and RTs were statistically significant ($P < 0.01$) for open- and closed-class words. While the overall pattern of the results is very similar to that obtained in Segui et al.'s experiment 1 (shown in parentheses), the mean RTs were 160msec. shorter and the percentage of errors was slightly higher for both types of words.

Table 2 presents the mean RTs and percentages of errors for the 10 most and the 10 least frequent words in each class.

TABLE 2
Mean RTs and Percentage of Errors for the 10 Most Frequent and the 10 Least Frequent Open- and Closed Class Items

	Open Class	*Closed Class*
Most frequent	490	483
% of errors	(6)	(4.5)
Least frequent	529	524
% of errors	(9)	(16.5)

A comparison using a matched pairs t-test between the mean reaction times obtained by subjects for the 10 most and the 10 least frequent words of each class (open and closed) showed a significant difference for both classes ($t[19] = 3.83$; $P < 0.01$ for open class, and $t[19] = 3.01$; $P < 0.01$ for closed class). These results are confirmed by an analysis of variance conducted on the errors. High-frequency words gave rise to fewer errors than low-frequency words ($F[1,19] = 17.5$; $P < 0.001$). There was no significant effect of the word class ($F<1$) and this factor did not interact significantly with frequency ($F[1,19] = 2.7$).

Finally, we analysed the RTs for nonwords derived from the open- and closed-class words. There were no significant differences between the RTs for the two types of nonwords: 565msec. for the open-class derived nonwords and 557msec. for the closed-class derived nonwords. The percentage of errors for these nonwords was 10% and 13%, respectively.

Discussion

In this experiment subjects were given feedback to encourage them to respond more quickly and, indeed, they provided faster RTs. However, this shortening of reaction times did not modify differentially the size of the frequency effect for the two classes of words. The overall decrease in RTs was similar for both classes of words. Further, the size of the correlations was very similar to those obtained by Segui et al. (1982). The frequency effect for open- and closed-class words observed in previous experiments using French words is therefore relatively stable regardless of the overall speed of response latencies.

The putative difference in frequency sensitivity of the two word classes may have its origins at the encoding stage rather than at decisional stages. McCusker et al. (1981) have suggested that high-frequency words are accessed "directly" on the basis of a visual representation, whereas low-frequency words are accessed preferentially by means of phonological encoding. A related view was adopted by Seidenberg (1985). Furthermore, some neurolinguistic data (Coltheart, 1980a, 1980b) suggest that the encoding process depends not only on word frequency but also on form class. Recently, Gordon and Caramazza (1985) speculated that "...access to closed-class representations might depend on phonological recoding first".

If open- and closed-class words are accessed by different codes, experimental manipulations might differentially affect their processing and consequently the size of the observed frequency effect for these two word classes. We reasoned that the use of a pattern mask procedure would serve to modify encoding processes by limiting the availability of the visual stimulus representation. As a consequence, subjects should rely more heavily upon the phonological route leading to differences in processing of the two word classes if, as proposed, these two word classes are accessed by means of different encoding routes.

In the next experiment, the presentation duration of the stimuli was varied and a pattern mask was used to limit the amount of sensory information subjects receive. To establish the appropriate presentation duration in Experiment II, we used a technique which allowed us to adjust the presentation duration of stimuli to the identification threshold of each subject.

EXPERIMENT II

Subjects

Twenty-five French students at Paris V University served as subjects.

Materials

The experimental list was the same as that used in Experiment I. A second list of 80 items (21 words of the open class, 21 words of the closed class, 19 nonwords derived from open-class words, 19 nonwords derived from closed-class words) was prepared to determine a stimulus presentation duration for each subject.

Procedure

The experimental procedure was similar to that used in the first experiment. However, in an initial phase, presentation durations were determined for each subject. Subjects were instructed that they would have to decide whether presented letter strings were French words or not by pressing a "yes" or a "no" key. They were informed that during the initial part of the experiment, stimulus items would be presented for very short durations. First, a fixation point was displayed for 250msec., and then the stimulus was presented. When the stimulus disappeared, a pattern mask, made up of a series of "%" signs, appeared in exactly the same position as the stimulus. A constant one-second interval separated the subject's response from the presentation of the next fixation point. The nature of the response as well as its latency were recorded by computer. Subjects were warned that, since the stimuli were presented for only a short time, they should respond as quickly as possible.

In the initial part of the experiment, 4 blocks of 5 items, followed by 6 more blocks of 10 items, were presented. During each one of the first 4 blocks, if subjects made more or less than 2 errors (out of 5), the presentation duration was increased or decreased respectively by 10msec., starting from an initial 20msec. presentation duration.

The presentation duration achieved at the end of the first blocks was taken for the first block of the following six. If the number of errors made in any of these remaining 6 blocks of 10 items was less than or equal to 1, the presentation duration was decreased by 2msec. for the next block of 10 items. If the number of errors was greater than 3, the presentation duration was increased by 2msec. The presentation duration was not changed if there was more than 1 error or less than 3 errors. This procedure allowed us to determine for each subject a presentation duration resulting in about 75% overall correct responses for all words and nonwords items. This presentation duration was used throughout the second part of the experiment.

Results

The individual presentation durations used in the experimental session varied from 26msec. to 76msec., with a mean presentation duration of 48msec. The procedure for analysing reaction times was the same as that used in Experiment I, and less than 2% of the data were discarded. Table 3 presents the experimental results obtained.

TABLE 3
Effects of Frequency on RTs for Open- and Closed-Class Items

	Open Class	*Closed Class*
Mean RTs (msec.)	480	458
% of errors	6	8
Correlation coefficient	−.58	−.60
Slope of linear regression	−33	−26
Zero intercept	541	506

The difference in RTs between open- and closed-class words (480 vs. 458msec.) was not significant ($t[23] = 1.69$). As in previous experiments, the frequency effect for open- and closed-class words was roughly the same in size. The correlations between frequency and RT for open- and closed-class items were both significant ($P < 0.01$). Table 4 presents the mean RTs and percentages of errors for the 10 most frequent and the 10 least frequent words of the two classes.

TABLE 4
Mean RTs and Percentage of Errors for the 10 Most Frequent and 10 Least Frequent Open- and Closed-Class Items

	Open Class	*Closed Class*
Most frequent	454	446
% of errors	(4.4)	(6.4)
Least frequent	494	473
% of errors	(6.8)	(10)

A comparison using a matched pairs t-test between the mean RTs obtained by subjects for the 10 most frequent and the 10 least frequent words of each class showed a significant difference for both classes ($t[23] = 2.77$; $P < 0.05$ for the open-class words, and $t[23] = 2.26$; $P < 0.05$ for the closed-class words). An analysis of variance on the error data indicated a marginal effect of frequency ($F[1,24] = 2.14$; $P < 0.10$) but no effect of word class. There was also no significant interaction between these two factors. The RTs and error rate for the nonwords derived from open-class words (743msec. and 22%) and closed-class words (726msec. and 26%) were high. These results for the nonwords in Experiment II are strikingly different from those obtained in Experiment I. The difference in RTs between words and nonwords increased dramatically from Experiment I (66msec.) to Experiment II (265msec.). A similar pattern was obtained for the error rates in the two experiments (3% vs. 17%). This increase in both RTs and errors reflects the strong impact of the stimulus masking procedure used in the second experiment on the subjects' processing of the input. As is well known, pattern masks affect nonword decision times more than those for words (e.g. Dobbs, Friedman, & Lloyd, 1985). However, in the present experiment the effect upon nonwords derived from open- and closed-class words was roughly the same in magnitude for both lexical decision latencies and errors.

GENERAL DISCUSSION

The results obtained in the two experiments presented here confirm the previously established frequency effect for closed-class words. The magnitude of this effect is comparable to the one observed with open-class words even when experimental conditions encourage fast responses (Experiment I) or when there is a time degradation of the stimuli (Experiment II). As noted earlier, these manipulations presumably affect late or early stages of processing. Nonetheless, they do not alter differentially the correlation between lexical decision latencies and word frequency for the two classes.

In recent work, Gordon and Caramazza (1985) also used stimulus masking and speeded responses. They were interested in teasing out any possible asymmetry between word classes by minimising floor effects thought to be responsible for the absence of frequency effects for very high-frequency words — in particular, closed-class words. No frequency effect for very high-frequency open- and closed-class words were obtained despite the experimental manipulations used. However, they did obtain a difference in the frequency effect between open- and closed-class words whose frequency was less than log 2.6. This asymmetry went in the direction of that obtained by Bradley. Gordon and Caramazza attribute the absence of the frequency effect for closed-class words to the small number of items used and to non-controlled properties of these words. While these confounding factors will need to be examined further, our results for French show no asymmetry between word classes using experimental procedures and frequency ranges which are similar to Gordon and Caramazza's. Indeed, both studies presented here globally show that the experimental manipulations involving stimulus masking and speeded responses did not differentially affect the subjects' performance on open- and closed-class items.

In summary, our results demonstrate a strong frequency effect for both open- and closed-class in French. This result is at odds with the hypothesis of a computational distinction based upon a difference in frequency sensitivity between the two word classes. However, there are still other experimental results obtained with normal subjects that point to a difference in

retrieval systems for the two word classes. These include the differential interference effect obtained for open- and closed-class items (Bradley, 1983, but see Kolk and Blomert, 1985, for some contradictory results) and the differences in recognition between open- and closed-class words as a function of the visual hemisphere to which they are presented.

It remains unclear why the two classes behave differently under some manipulations and not under others, and future research may clarify the differential status of these classes. Nevertheless, the attempt to explain the behaviour of Broca's aphasics in terms of selective damage of a frequency-insensitive route seems difficult to justify since no evidence of such a route arises from the study of normal subjects.

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APPENDIX

Open-Class Words (words log10 freq.)		*Closed-Class Words (words log10 freq.)*	
tortue	0.000	sitot	0.000
laitue	0.301	lors	0.301
savon	0.477	selon	0.477
vice	0.602	mien	0.602
arme	0.778	hors	0.778
boule	1.041	guère	1.041
dent	1.176	soit	1.176
lapin	1.255	parmi	1.255
arbre	1.431	voici	1.431
huile	1.518	ainsi	1.255
hiver	1.707	ceci	1.707
haut	1.763	celle	1.763
peine	1.812	cela	1.812
dame	1.838	dont	1.838
dieu	1.869	ceux	1.869
drole	1.949	chaque	1.919
prix	2.033	quoi	2.041
rendre	2.204	depuis	2.212
beau	2.359	sans	2.396
soir	2.403	donc	2.396
partir	2.484	violà	2.482
vingt	2.525	moins	2.507
grand	2.631	après	2.628
parler	2.650	aussi	2.657
petit	2.936	meme	2.908
voir	3.158	comme	3.196
aller	3.273	dans	3.315
dire	3.378	pour	3.317