Priming in visual word recognition : empirical studies and computational models.

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Nonword Repetition in Lexical Decision: Evidence for Two Opposing Processes

Abstract

It is well known that prior presentation enhances performance for word stimuli in lexical decision (i.e., repetition priming). In contrast, item-specific effects of repetition priming for nonword stimuli (e.g., GREACH) have seldom been systematically studied. We tested the hypothesis that repetition priming for nonwords in lexical decision is the net result of two opposing processes: (1) a facilitatory process based on the retrieval of specific episodes, and (2) an inhibitory process based on global familiarity. In four studies, we manipulated speed-stress to influence the balance between the two processes. Experiment 1 showed item-specific improvement for repeated nonwords in a subject-paced lexical decision task. Experiments 2 and 3 used 500 and 400 ms deadline procedures, respectively, and showed performance for nonwords to be unaffected by up to four prior presentations. In Experiment 4 we used a signal-to-respond procedure with variable time intervals and found negative repetition priming for repeated nonwords. These results strongly suggest that a complete account of lexical decision requires two opposing processes, one based on the activation of episodic information, and one based on global familiarity.

One of the most often used tasks in experimental psychology is the lexical decision task. In lexical decision, subjects have to decide as quickly and accurately as possible whether a presented letter string is a word (e.g., CHAIR) or a nonword (e.g., GREACH). The general assumption that underlies the use of the lexical decision task is that the speed and accuracy of responding to word stimuli indicate the efficiency with which word representations are activated or retrieved from lexical memory. Several variables are thought to reflect the speed of retrieval from lexical memory. For instance, Scarborough, Cortese, and Scarborough (1977) found that performance for high frequency words was better than performance for low frequency words. This phenomenon is known as the word frequency effect. Another extensively studied phenomenon in the lexical decision task is the effect of prior study. Performance is better for words that have been encountered previously in the experimental context than for words that have not. This repetition priming effect for words was also demonstrated by Scarborough et al. (1977).

Although the facilitatory effect of prior presentations for words is well documented, much less is known about repetition priming effects for nonwords such as GREACH. The bias toward studying repetition priming for words rather than nonwords might be due to a focus on processes that operate in lexical memory. What can we learn from nonwords when these nonwords are not represented in lexical/semantic memory? First, several recent studies have stressed the fact that lexical decision is more than just lexical activation. The important role of decisional and strategic processes is exemplified by the impact of nonword lexicality on performance for word stimuli. Stone and Van Orden

(1993) showed that illegal (e.g., BTESE) nonwords were easier to classify than legal nonwords (e.g., nonwords such as GREACH). Moreover, when the nonword stimuli looked less like words, responses to word stimuli were facilitated and the word frequency effect was attenuated. Results like this (see also Joordens, Piercey, & Mohammad, 2000; Stone & Van Orden, 1989) demonstrate that the processing of nonword stimuli is an integral part of lexical decision performance.

A second reason to study performance for nonwords in lexical decision is their theoretical relevance in the debate between abstractionist (i.e., lexical/semantic) versus episodic theories of word identification (for reviews see Bowers, 2000; Tenpenny, 1995). It has been argued that since nonwords are novel stimuli having no representation in lexical/semantic memory, any improvement in classifying nonwords as a result of prior presentation is due to an *episodic* process.[1] For instance, Logan (1988, 1990) found substantial facilitatory repetition priming effects for nonwords, and his episodic instance theory successfully fitted observed learning curves for nonwords (i.e., the increase in performance with the number of earlier presentations). Thus, the study of nonword repetition priming can potentially inform us to what extent lexical decision performance is influenced by automatic episodic retrieval.

The foregoing illustrates that repetition priming for nonwords can reveal important information about word identification. Unfortunately, empirical results on nonword repetition priming have been mixed (for a review see Tenpenny, 1995). Several researchers (e.g., Duchek & Neely, 1989; Feustel, Shiffrin, & Salasoo, 1983; McKoon & Ratcliff, 1979) have noted that when a nonword is previously presented in another task than lexical decision, no effects or slightly inhibitory effects are often observed in the later lexical decision task. However, when a nonword is previously presented in a lexical decision task, facilitatory effects are usually found (e.g., Logan, 1988, 1990). This pattern of results has led many researchers (e.g., Bodner & Masson, 1997; Feustel et al., 1983; Smith & Oscar-Berman, 1990; Tenpenny, 1995) to believe that when the previous presentation of a nonword is in the lexical decision task, the repetition priming effect is the net result of two opposing processes: (1) an inhibitory familiarity process, and (2) a facilitatory episodic process. Logan (1990) has argued that this facilitatory process "is based on underlying associations between stimuli and the interpretations given to them in the context of specific experimental tasks" (p.1).

In the following we will discuss Logan's instance theory (Logan, 1988, 1990, 1992), and the global familiarity account of lexical decision in some more detail. As was already hinted at above, the two models make opposite predictions about the nature of nonword repetition priming in lexical decision. Instance theory provides a detailed account of the rate of skill acquisition and automatization. It assumes that both encoding (i.e., storage) in memory and retrieval from memory are obligatory and unavoidable consequences of attending to a

1 *Several researchers (Bowers, 2000; Dorfman, 1994; Tenpenny, 1995) have argued that an episodic account of facilitatory nonword repetition priming is not strictly necessary. For clarity of exposition, we will evaluate the plausibility of the non-episodic accounts in a later section, and assume for now that facilitatory nonword repetition priming is at least partly caused by automatic retrieval of specific episodes.*

stimulus. In addition, instance theory assumes that every individual encounter with a stimulus is encoded and retrieved as a separate instance (i.e., an episodic memory trace). It is further assumed that people can perform tasks either by the application of an algorithm, or by retrieval of a relevant 'instance' from memory. More specifically,

"The simplest way to model the choice process is in terms of a race between memory and the algorithm – whichever finishes first controls the response. Over practice, memory comes to dominate the algorithm because more and more instances enter the race, and the more instances there are, the more likely it is that at least one of them will win the race." (Logan, 1988, p. 495).

It can be shown that the accumulation of instances (i.e., learning) results in a power-function speed-up of mean retrieval time and a power-function reduction of the standard deviation of retrieval time. When instance theory is applied to lexical decision, Logan assumes the 'algorithm' is the normal, unpracticed process by which people are usually able to decide whether a letter string is a word or not. The instances that race against the algorithm are specific episodes of earlier lexical decisions to the same stimulus. Thus, instance theory predicts that the previous interpretation given to a nonword (e.g., in lexical decision: "GREACH is a nonword") will be stored as an instance. Later automatic retrieval of such an instance will benefit performance and lead to a fast 'NONWORD' response.

In contrast to instance theory, a global familiarity account of lexical decision predicts that repetition of a nonword results in a decrease in performance (for details see Balota & Chumbley, 1984; Wagenmakers, Steyvers, Raaijmakers, Shiffrin, van Rijn, & Zeelenberg 2001). Because lexical decision requires subjects to distinguish often-encountered stimuli (i.e., words) from novel stimuli (i.e., nonwords), some familiarity or meaningfulness (FM) value could be used to arrive at a decision. According to Balota and Chumbley (1984),

"The first stage of the decision process involves a global computation of the FM value of the letter string. That is, the subject makes a quick check to determine if the stimulus is producing any meaning or is very familiar, that is, "Have I seen this stimulus frequently?" If the computed FM value exceeds the upper criterion, the subject will make a fast word response; if it fails to exceed the lower criterion, the subject will make a fast nonword response. On the other hand, if this FM value falls between the upper and lower criteria, then the subject needs more information before a decision can be made." (p. 352)

Obviously, if prior presentation of a letter string increases the familiarity of the letter string and hence biases subjects to respond 'WORD', global familiarity accounts of lexical decision predict that nonword repetition priming should be inhibitory rather than facilitatory.

As mentioned earlier, some studies have found facilitatory effects of nonword repetition whereas other studies have found inhibitory effects of nonword repetition. These different results have usually been explained by the operation of the two opposing processes mentioned above. Despite the fact that theoretical claims have been made regarding opposing processes operative in lexical decision for nonword repetition priming, few studies have systematically explored this issue. The hypothesis of two opposing processes is largely based on the comparison of results obtained across different studies, using different stimulus materials and different study and test procedures. The aim of the present study was to obtain more evidence for the operation of two opposing processes within a single study.

An additional problem in the interpretation of existing data is that in some studies nonword repetition was confounded with other variables. In the study of item-specific nonword repetition priming, it is crucial to eliminate two confounding factors: (1) time-on-task effects, and (2) criterion-shift effects. First, if the study status of a letter string is not independent of the total number of lexical decision trials that preceded the letter string, time-on-task effects could provide an alternative explanation for any observed priming effects. That is, if repeated stimuli are presented later in the lexical decision task than non-repeated stimuli, any priming effects could be due to a combination of (1) a general practice effect, causing an increase in performance for repeated stimuli, and (2) fatigue, causing a decrease in performance for repeated stimuli.

The second complicating factor is the possibility that faster responses to repeated nonword stimuli could in certain designs be due entirely to a criterion-shift. Suppose the activation or retrieval of nonwords is not influenced by prior presentations, but the activation or retrieval of words is. For instance, let us assume that repetition priming strengthens representations in semantic memory but leaves nonwords unaffected, because nonwords are not represented in semantic memory. Further assume that the decisional mechanism can be characterized as a signal-detection problem. That is the word / nonword decision might be based on a one-dimensional continuum of activation caused by the stimulus in lexical / semantic memory. Such a decisional system is illustrated in Figure 1. In general, words cause more activation in lexical / semantic memory than nonwords, and this provides the basis for the decision. Activation values to the right of the criterion lead to a 'WORD' response, and activation values to the left of the criterion lead to a 'NONWORD' response. In models of this sort, it is often assumed that the distance from the observed activation value to the response criterion is inversely related to response latency: The closer the observed activation value is to the response criterion, the longer the observed response latency (e.g., Hockley & Murdock, 1987; Ratcliff & McKoon, 1988). In the hypothetical situation described above, repeated words cause more lexical activation than non-repeated words, causing the distribution for words to shift to the right. This rightward shift of the word distribution enables a more efficient setting of the response criterion, as indicated by the dotted line. The new response criterion leads to an increase in performance for nonwords without any change in amount of activation for repeated nonwords compared to nonrepeated nonwords. Hence, facilitatory nonword repetition priming might be attributed to item-specific word repetition. Therefore, if the proportion of repeated letter strings increases over the course of an experiment and facil itatory nonword repetition priming is observed, an alternative explanation can be given to account for the results. This alternative explanation assumes that selective word repetition priming enables more efficient criterion placement that also benefits nonwords.

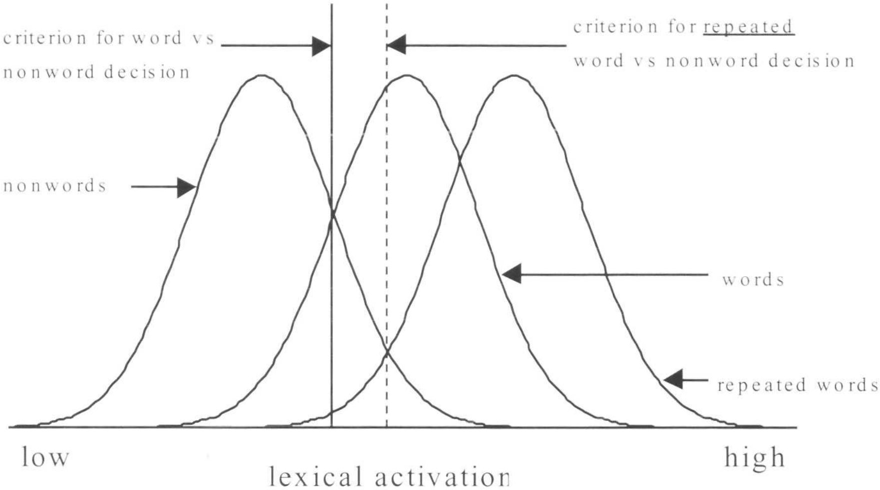

Figure 1. Selective repetition priming for words can generate repetition priming effects for nonwords. The leftmost distribution corresponds to nonword stimuli, the middle distribution correspond to non-repeated word stimuli, and the solid line indicates the criterion value on a global lexical activation dimension for making a decision between these two classes of stimuli. Previous presentations leave the nonword distribution unaffected, but shift the word distribution to the right. The new optimal response criterion, indicated by the dotted line, increases performance for nonwords.

In the experiments reported here, we have eliminated the confounding factors mentioned above by the use of a blocked design (cf. Hintzman & Curran, 1997, Experiment 2; Logan, 1988, Experiment 3; Smith & Oscar-Berman, 1990). This design is illustrated in Figure 2, and consists of a sequence of blocks. Suppose each stimulus is presented up to 5 times (as in Experiments 1-3), and each block consists of 60 trials. Consequently, each block contains 60/5 = 12 stimuli of each of the five priming conditions (1^{st}, 2^{nd}, 3^{rd}, 4^{th}, and 5^{th} presentation). Every block contains all stimuli from the previous block, except for those stimuli that were presented for the fifth time in the previous block and are replaced by a set of new stimuli. Details of this procedure are described in the Method section. Since the proportion of repeated versus non-repeated items is held constant throughout the experiment, the optimal response criterion remains fixed. The blocked design eliminates the effects of time-on-task on repetition effects, because the presentation condition of a stimulus and the total number of trials preceding the stimulus are not confounded. A final advantage of the blocked design is that the number of trials between successive repetitions is independent of the number of times the stimulus has been presented. In other words, in the blocked design there is no confounding between the time since the last presentation of the stimulus and the total number of prior presentations (Logan, 1988).

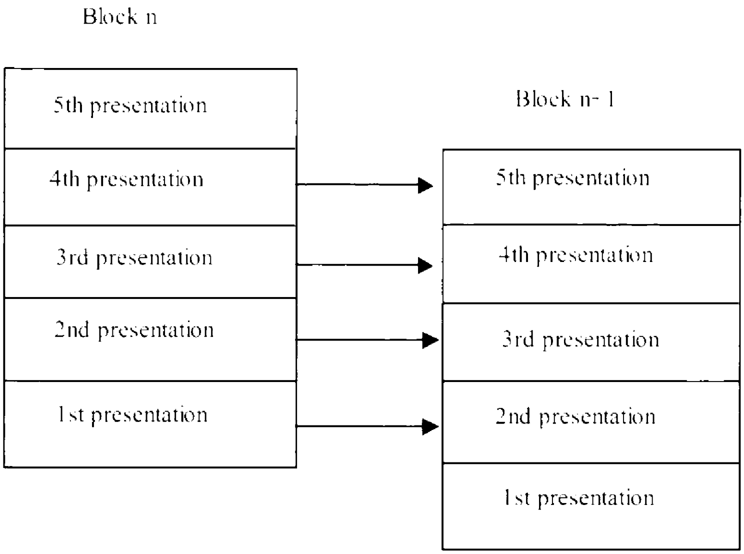

Figure 2. The blocked design used for Experiments 1-4. Stimuli are repeatedly presented in consecutive blocks. In this example, stimuli are presented up to five times. The group of stimuli that has been presented for the fifth time in block n is replaced by a group of new stimuli in block n+1.

Overview of the Experiments

To evaluate the possibility that two opposing processes (i.e., retrieval of episodic instances versus global familiarity) mediate repetition priming for nonwords, a variable is needed that affects the balance between these opposing processes. In this study, we opted to manipulate speed-stress. We assumed that high speed-stress will increase the subject's reliance on familiarity and at the same time reduce the contribution of retrieval of specific episodic traces (cf. Balota & Chumbly, 1984).[2] If an inhibitory familiarity component is operative for repeated nonwords in lexical decision, reduction of the opposing episodic component by enhancing speed-stress should result in the elimination and perhaps even in the reversal of the priming effect for nonwords.

In all experiments reported here, we repeated word and nonword stimuli in lexical decision using the blocked design mentioned above. Experiments 1-3 used exactly the same stimulus materials. In Experiment 1-3, each stimulus was presented up to five times. In Experiment 1, we used a regular lexical decision procedure and instructed subjects to respond as quickly and accurately as possible. This experiment showed a facilitatory repetition effect for both words

2 *Smith and Oscar-Berman (1990) used a dual-task paradigm to "minimize the contribution of episodic memory to task performance" (p. 1033). Their results are consistent with ours and we will discuss their study in the General Discussion.*

and nonwords. In Experiment 2, we used a deadline procedure and instructed subjects to respond within a time frame of 500 ms. In this experiment, the presence or absence of feedback concerning the correctness of the response was added as a between-subject variable. Experiment 2 showed no effect of nonword repetition priming, whereas repetition priming effects for words were substantial. Experiment 2 also indicated that feedback did not affect repetition priming effects. Experiment 3 was identical to Experiment 2 except for the fact that a deadline of 400 ms was used and feedback concerning the correctness of the response was always present. Again, no effect of nonword repetition priming was found (more specifically, a nonsignificant tendency toward an inhibitory effect was observed), despite substantial positive effects of repetition priming for words. The finding that nonwords did not show facilitatory repetition priming effects is remarkable, given that each nonword was presented as much as five times, and the task requirements remained the same throughout the experiment.

Experiment 4 used variable deadlines to increase the speed-stress of the lexical decision task even further. In addition, we used only two presentations of each stimulus. This experiment showed an inhibitory effect for repeated nonwords. In sum, over the four experiments reported here speed-stress was gradually increased and this resulted in a reversal of the nonword repetition priming effect.

Experiment 1

In Experiment 1, subjects performed a regular (i.e., subject-paced) lexical decision task. As in all experiments reported here, we used three classes of stimuli: HF words, LF words, and pronounceable nonwords (i.e., nonwords such as GREACH).

Method

Participants. Thirty-five students of the University of Amsterdam participated for course credit. All participants were native speakers of Dutch and reported normal or corrected-to-normal vision.

Stimulus Materials. The experimental stimuli consisted of 48 high frequency (HF) words, 48 low frequency (LF) words and 96 pronounceable nonwords. Nonwords were created by changing one letter of an existing Dutch word. Frequency counts were obtained from the CELEX norms (Baayen, Piepenbrock, & Van Rijn, 1993). The frequency of occurrence for all HF words was higher than 30 per million (mean frequency 189 per million). The frequency of occurrence for the LF words ranged between 1 and 5 per million (mean frequency 2.2 per million). For each stimulus class (i.e., LF words, HF words and nonwords) one-third of the stimuli were four letters long, one-third were five letters long and one-third were six letters long. In addition to the experimental stimuli there were 48 fillers, consisting of 12 HF words, 12 LF words and 24 nonwords. The filler stimuli had the same general characteristics as the experimental stimuli.

Design. The experiment consisted of a total of 960 lexical decision trials. The stimuli were presented for up to five presentations over the course of the experiment. The experiment was designed in such a way that the presentation condition (i.e., 1st, 2nd, 3rd, 4th, or 5th presentation) of a stimulus and the total number of trials preceding the stimulus were not confounded. Therefore, any change in performance over the number presentations of a stimulus is due to a stimulus specific repetition effect and can not be ascribed to some general practice effect, skill learning, or fatigue.

The experiment consisted of 16 'blocks' of 60 trials each. The transition from one block to another block was not marked in any way and from the point of view of the participants the experiment consisted of one long sequence of trials. The 16 blocks consisted of four 'filler' blocks at the beginning of the experiment followed by 12 experimental blocks. The first four filler blocks were needed to arrive at a design in which each block of 60 trials consisted of 12 trials for each presentation condition. These 12 trials always consisted of three trials on which a HF word was presented, three trials on which a LF word was presented and six trials on which a nonword was presented.

Table 1 gives an overview of the presentation scheme of the stimuli. As can be seen in Table 1, in the first block of 60 trials all stimuli were presented for the first time. The 60 trials of the first block consisted of 48 filler stimuli and 12 experimental stimuli. In the second block, 12 new stimuli were introduced and 48 stimuli were presented for the second time. The 12 new stimuli presented for the first time were all experimental stimuli. Of the 48 stimuli that were presented for the second time, 12 were experimental stimuli and 36 stimuli were fillers. Thus, 12 of the 48 fillers that were presented in block 1 were not presented in block 2. In this manner, 12 old stimuli (either fillers or experimental stimuli, depending on the block) were deleted in each block and 12 new experimental stimuli were added. From block 5 on each block consisted of only experimental stimuli, 12 for each of the five presentation conditions.

Table 1
Number of Presentations as a Function of Stimulus (Experimental vs. Filler) and Number of Repetitions

	Stimulus			Presentation				
Block	Total	Filler	Exp	1	2	3	4	5
1	60	48	12	60	0	0	0	0
2	60	32	24	12	48	0	0	0
3	60	24	32	12	12	36	0	0
4	60	12	48	12	12	12	24	0
5	60	0	60	12	12	12	12	12
6	60	0	60	12	12	12	12	12
:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:
16	60	0	60	12	12	12	12	12

Note. Exp = Experimental.

All trials (i.e., both filler and experimental stimuli) from block 1 to block 4 were excluded from the data-analyses, thus including only trials from block 5 to block 16. This was done to assure that trial number and presentation condition were uncorrelated. Thus, for each subject a total of 720 experimental trials (12 blocks of 60 trials) was presented. For the LF words and HF words there were 36 observations for each presentation condition. For the nonwords there were 72 observations for each presentation condition.

Procedure. Subjects received spoken and written instructions explaining the lexical decision task. Subjects were instructed to respond as quickly and accurately as possible. Each trial started with the 1000 ms presentation of a trial marker (##). Next, the trial marker was replaced by the stimulus. The stimulus remained visible in the center of the screen until the subject responded or 1500 ms had elapsed. Subjects gave a 'NONWORD' response by pressing the 'z' key of the keyboard with the left index finger and a 'WORD' response by pressing the '?/' key with the right index finger. When the subject made an error, the message 'FOUT' (Dutch for 'error') was presented for 1500 ms. When no response was given after 1500 ms, the message 'TE LAAT' (Dutch for 'too late') was presented for 1500 ms. The next trial immediately followed the previous one. For each subject the order of the trials was randomly determined (within the constraints of the presentation scheme of the experiment). Participants were allowed a short break after 480 trials.

Results

The results of Experiment 1 are presented in Table 2. ANOVAs were performed on the mean latencies of correct responses and on error percentages. In all experiments reported here, the topic of interest is whether performance decreases or increases monotonically with the number of prior presentations. The corresponding statistical analysis is given by a linear trend analysis, which we report throughout this paper. One participant was excluded from the analysis because his error rate exceeded that of the average of the other participants by more than 2.5 standard deviations.

Table 2
Mean Reaction Times (in Milliseconds) and Error Rates (in Percentages) in Experiment 1 as a Function of Target Word Status and the Number of Presentations.

	Number of Presentations				
Target	1	2	3	4	5
HF	583 (4.9)	555 (2.7)	542 (3.0)	543 (2.4)	546 (1.8)
LF	685 (27.6)	610 (8.9)	597 (5.1)	593 (4.4)	583 (3.0)
NW	628 (3.7)	620 (3.7)	607 (3.2)	600 (3.9)	601 (3.5)

Note. HF: high frequency words, LF: low frequency words, NW: nonwords.

Facilitatory effects of repetition priming were observed for HF, LF, and nonword stimuli. More specifically, HF words were responded to faster, $F(1, 33) = 27.7$, $MSE = 863$, $p < .001$, and more accurately, $F(1, 33) = 12.0$, $MSE = 12$, $p < .01$, as the number of presentations increased from 1 to 5. LF stimuli were also responded to faster, $F(1, 33) = 130.7$, $MSE = 1273$, $p < .001$, and more accurately, $F(1, 33) = 145.0$, $MSE = 68$, $p < .001$, as the number of presentations increased from 1 to 5. Most importantly, nonwords were responded to faster as the number of presentations increased from 1 to 5, $F(1, 33) = 21.1$, $MSE = 863$, $p < .001$. No effect of nonword repetition priming was apparent from the error rates, $F < 1$.

Discussion

The results from Experiment 1 are straightforward: All types of stimuli (i.e., HF words, LF words, and nonwords) profited from previous presentations. The repetition priming effect was especially pronounced for LF words, particularly from the first presentation to the second. For nonwords, the overall 27 ms facilitatory repetition priming effect was highly reliable. In this experiment, the repetition priming effect for nonwords (27 ms) amounted to about 73% of the repetition priming effect for HF words (37 ms). We will postpone a theoretical discussion on the mechanisms underlying facilitatory nonword repetition priming until the General Discussion. For now, we would like to point out that the finding of facilitatory nonword repetition priming is consistent with earlier findings by Logan (1988, 1990). Logan obtained larger effects of nonword repetition priming than observed in this experiment, perhaps because Logan used few intervening trials between successive repetitions (an average of 12 or 24 intervening items) and a more limited set of stimuli.

Experiment 2

Experiment 2 was identical to Experiment 1, except for the application of a response deadline. Subjects were instructed to respond before 500 ms, and to encourage timely responding we included a series of tones and provided visual feedback on response latency. To study whether explicit episodic information on the lexical status of the stimuli has any effect on subsequent performance, we manipulated the presence of feedback on the accuracy of the response as a between-subjects variable.

Method

Participants. Sixty-two students of the University of Amsterdam participated for course credit. All participants were native speakers of Dutch and reported normal or corrected-to-normal vision.

Stimulus Materials and Design. The stimulus materials were identical to those of Experiment 1. The design was also identical to that of Experiment 1, with one important exception: The presence or absence of feedback on the correctness of the response was added to the design as a between-subjects variable. Thirty subjects received no feedback on the correctness of their response, and 32 subjects did receive feedback on the correctness of their response.

Procedure. The procedure was identical to that of Experiment 1, with two important exceptions related to the deadline-procedure. First, during the 1000 ms presentation of the trial marker (i.e., ##), two 1000 Hz tones were presented for 10 ms on every trial. The first tone was presented 500 ms after the onset of the trial marker, and the second tone was presented 500 ms after the onset of the first tone, immediately preceding the presentation of the stimulus. Subjects were told were instructed to respond before the third imaginary tone. Schouten and Bekker (1967) used a similar procedure, with the exception that Schouten and Bekker also actually presented the third tone. One of the reasons for not presenting the third tone during stimulus processing was that we wanted to approximate the situation in Experiment 1 as closely as possible. In order to emphasize the importance of timely responding even further, we used the time-band method (e.g., Wickelgren, 1977) illustrated in Figure 3. For subjects that did not receive feedback on the correctness of their response, the time-band feedback was presented for 1500 ms regardless of response accuracy. For subjects that did receive feedback on the correctness of their response, an error message identical to the one from Experiment 1 was presented instead of the time-band feedback. When subjects did not respond after 800 ms, the appropriate feedback (i.e., 'too late' in Dutch) was presented for 1500 ms.

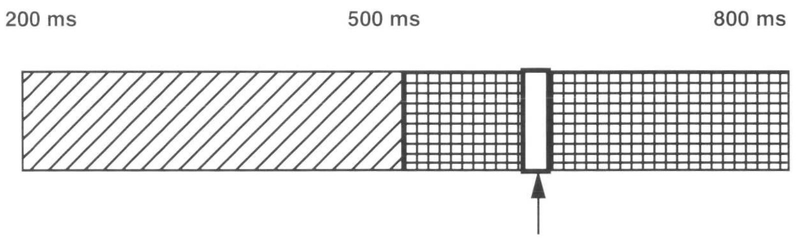

Figure 3. The time-band feedback method used in Experiment 2. The shaded area to the left of the middle was colored green, and the checkerboard-patterned area to the right of the middle was colored red. The arrow beneath the bar and the small white rectangle on the bar indicated the observed response time of the participant. In this example, the participant exceeded the temporal deadline of 500 ms and responded about 600 ms after stimulus onset.

Results

The results of Experiment 2 are shown in Table 3. An ANOVA with feedback as a between-subjects variable and repetition as a within-subjects variable showed no main effects of feedback or interaction effects with the repetition priming effects (all p's $> .15$). Therefore, the data were collapsed over this between-subjects variable. ANOVAs were performed on the mean latencies of correct responses and on error percentages.

Facilitatory effects of repetition priming were again observed for HF and LF stimuli. More specifically, HF words were responded to more accurately as the number of presentations increased from 1 to 5, $F(1, 61) = 14.3$, $MSE = 78$, $p < .001$. HF words were also classified correctly faster as the number of presentations increased from 1 to 5, $F(1, 61) = 35.8$, $MSE = 509$, $p < .001$. LF words were responded to more accurately as the number of presentations increased from 1 to 5, $F(1, 61) = 190.6$, $MSE = 176$, $p < .001$. LF words were also classified correctly faster as the number of presentations increased from 1 to 5, $F(1, 61) = 47.6$, $MSE = 898$, $p < .001$. Most importantly, in contrast to Experiment 1 nonwords showed no effect of the number of presentations, neither on accuracy nor on response latency (both F's < 1).

Table 3
Error Rates (in Percentages) and Mean Reaction Times (in Milliseconds) in Experiment 2 as a Function of Target Word Status and the Number of Presentations.

	Number of Presentations				
Target	1	2	3	4	5
HF	16.8 (482)	11.2 (459)	11.0 (459)	9.1 (455)	11.2 (457)
LF	51.8 (523)	36.9 (509)	24.9 (491)	24.4 (498)	21.3 (487)
NW	17.7 (507)	19.2 (510)	18.4 (505)	18.7 (509)	18.7 (508)

Note. HF: high frequency words, LF: low frequency words, NW: nonwords.

Discussion

As in Experiment 1, HF words and LF words were facilitated by previous presentations. These effects of repetition priming for words were substantial and appeared in both response latency and response accuracy. Again, these facilitatory effects were most pronounced for the first couple of presentations. In contrast to the word stimuli, nonword stimuli did not benefit from previous presentations. In our opinion, it is a remarkable finding that no repetition priming is found for a stimulus that is presented up to five times in exactly the same task. In sum, speed-stress eliminated the facilitatory nonword repetition priming effect observed in Experiment 1, but left the repetition priming effect for words intact. This result is consistent with the notion that increasing speed-stress reduces the contribution of episodic processes to performance, and perhaps increases the contribution of a familiarity-based process. If two opposing processes are involved in nonword repetition priming, increasing speed-stress even further might reveal inhibitory nonword repetition effects.

Experiment 3

Experiment 3 served to replicate and extend the findings obtained in Experiment 2. Experiment 3 was identical to Experiment 2, with two exceptions. First, the deadline was reduced from 500 ms to 400 ms in order to increase speed-stress. Second, since feedback on the correctness of the response had no effect in Experiment 2, we omitted this between-subjects variable in Experiment 3. All subjects received feedback on the correctness of their response.

Method

Participants. Thirty-six students of the University of Amsterdam participated for course credit. All participants were native speakers of Dutch and reported normal or corrected-to-normal vision.

Stimulus Materials, Design, and Procedure. The stimulus materials and design were identical to those of Experiment 1 and 2. The procedure was identical to that of Experiment 2, except that the response deadline was shortened with 100 ms (i.e., subjects had to respond within 400 ms of stimulus onset). The time-band feedback was of course adjusted accordingly. In addition, all subjects received feedback on the correctness of their response.

Results

The results of Experiment 3 are presented in Table 4. ANOVAs were performed on the mean latencies of correct responses and on error percentages. Two participants were excluded from the analysis because their response latencies or error rates exceeded that of the average of the other participants by more than 2.5 standard deviations.

Table 4
Error Rates (in Percentages) and Mean Reaction Times (in Milliseconds) in Experiment 3 as a Function of Target Word Status and the Number of Presentations.

	Number of Presentations				
Target	1	2	3	4	5
HF	26.4 (456)	17.4 (438)	17.4 (432)	17.3 (427)	18.5 (436)
LF	50.7 (482)	33.8 (460)	30.2 (464)	27.7 (453)	26.7 (462)
NW	25.4 (477)	28.5 (480)	25.7 (480)	27.9 (478)	29.3 (485)

Note. HF: high frequency words, LF: low frequency words, NW: nonwords.

As in Experiment 1 and 2, facilitatory effects of repetition priming were observed for both HF stimuli and LF stimuli. More specifically, HF words were responded to more accurately as the number of presentations increased from one to five, $F(1, 33) = 7.1$, $MSE = 120$, $p < .05$. HF words were also classified correctly faster as the number of presentations increased from one to five, $F(1, 33) = 13.2$, $MSE = 658$, $p < .01$. LF words were responded to more accurately as the number of presentations increased from one to five, $F(1, 33) = 40.9$, $MSE = 245$, $p < .001$. LF words were also classified correctly faster as the number of presentations increased from one to five, $F(1, 33) = 7.2$, $MSE = 1081$, $p < .05$.

As in Experiment 2, nonwords did not show repetition priming effects. Response latencies for correct nonword classification were not affected by previous presentations, $F(1,33) = 1.1$, $MSE = 611$, $p > .30$. As can be seen in Table 4, nonwords were classified most accurately on their first presentation, and least accurately on the final fifth presentation. However, the overall trend toward an inhibitory effect of repetition priming for nonwords was not significant, $F(1, 33) = 1.9$, $MSE = 89$, $p > .15$.

Discussion

The results from Experiment 3 replicate those of Experiment 2. For words, facilitatory repetition priming was reliably found. In contrast, no repetition priming was found for nonwords, even after four previous presentations. This differential effect of speed-stress on word versus nonword repetition priming can be taken as evidence for the important role of episodic retrieval in nonword repetition priming. However, in order to conclude that apart from a facilitatory episodic process a concurrent familiarity process is involved in nonword repetition priming, we need to observe inhibitory repetition priming effects for nonwords.

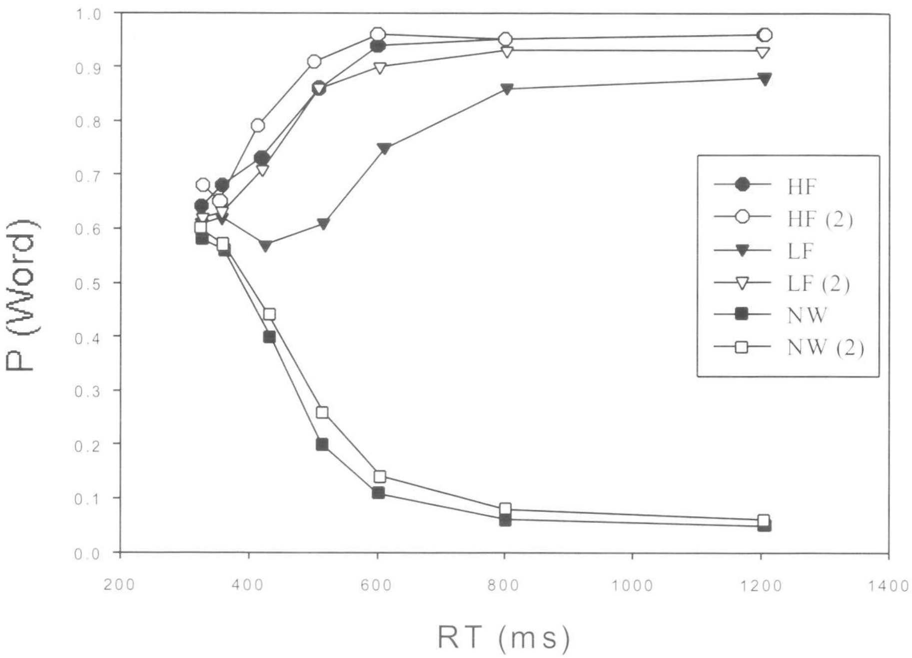

Figure 4. Re-plotted data from Hintzman & Curran (1997, Experiment 2, Figure 9). As is apparent from the figure, repeated nonwords are responded to less accurately than novel nonwords. P(Word): probability of responding 'WORD', HF: high frequency words, LF: low frequency words, NW: nonwords. The digit 2 in brackets indicates the second presentation.

A study by Hintzman and Curran (1997) demonstrated that inhibitory nonword repetition priming can be observed when nonwords are repeated in lexical decision. In Experiment 2 of Hintzman and Curran, subjects were instructed to respond immediately after presentation of a tone (i.e., the signal-to-respond). The tone could be presented at variable times after stimulus onset. The seven deadlines used by Hintzman and Curran were 75, 125, 200, 300, 400, 600, and 1000 ms. In addition, Hintzman and Curran used four kinds of stimuli: HF words, LF words, nonwords derived by changing a letter from an HF word, and nonwords derived by changing a letter from an LF word. All stimuli were presented twice. The results showed no difference between the two sets of nonwords. However, the finding of an inhibitory nonword repetition priming effect was not the focus of the Hintzman & Curran paper, and the repetition priming effects for nonwords are difficult to evaluate because of clutter (Hintzman & Curran, 1997, Figure 9).[3] We re-plotted the results of Hintzman and Curran, collapsing the two types of nonwords. Figure 4 shows that the probability of erroneously classifying nonword stimuli as words is higher on the second presentation than on the first presentation (i.e., inhibitory nonword repetition priming). The results also show the usual facilitatory repetition priming effects for HF and LF words.

The results of Hintzman and Curran (1997) hint at the possibility that a design with variable, mostly very short deadlines could produce inhibitory nonword repetition priming. Experiment 4 was done to test this hypothesis.

Experiment 4

In Experiment 4, subjects were instructed to respond exactly at various, randomly intermixed time intervals after stimulus onset (i.e., 350, 400, 450, 500, 550, and 600 ms). We used the same general procedure as in Experiment 2 and 3 to encourage timely responding (i.e., a series of tones and time-band feedback). We anticipated this task to be very difficult and therefore provided extensive training. In addition to HF words, LF words, and nonwords that differed from an existing word in one letter (e.g., GREACH), we included a set of pronounceable nonwords that were created by changing two letters from an existing word (e.g., ANSU).[4] All stimuli were presented twice in a blocked design.

Method

Participants. Forty-three students of Indiana University participated for monetary reward. All participants were native speakers of English and reported normal or corrected-to-normal vision.

Stimulus Materials. We used four types of experimental stimuli: (1) 168 HF English words, each occurring more than 30 times per million according to the CELEX lexical database (Baayen, Piepenbrock, & Van Rijn, 1993), (2) 168 LF English words, each occurring one or two times per million, (3) 168 pronounceable nonwords created by replacing one letter of an existing word (e.g., GREACH derived from PREACH), (4) 168 pronounceable nonwords differing by at least two letters from any word (e.g., ANSU). The first three stimulus categories were matched on neighborhood structure (i.e., a neighbor is a word differing from another word in one letter, so TIED is a neighbor of LIED): These categories had roughly the same summed logarithmic word frequency of the neighbors. All stimuli were four, five, six, or seven letters long, occurring in the respective proportions 2:2:2:1. In addition to the experimental stimuli there

3 *Hintzman and Curran do state that "(...) subjects tended to respond more positively on the second than on the first presentation, regardless of the lexical status of the test item (...)" (p. 236).*

4 *Due to a programming error, some nonwords that were created by changing two letters from a 'parent' word only differed by one letter from yet another word. Despite this inaccuracy, the data showed substantial differences between the two types of nonwords.*

were 72 fillers and 72 lexical decision practice stimuli, each group consisting of 18 HF words, 18 LF words, 18 'one-letter replaced' nonwords, and 18 'two-letters replaced' nonwords. Both fillers and lexical decision practice stimuli had the same general characteristics as the experimental stimuli. Finally, the stimuli ">" and "<" were used as stimuli to familiarize the subjects with the variable speeded-response procedure.

Design. The experiment consisted of three phases: (1) a general, non-lexical practice phase during which subjects were familiarized with the variable speeded-response procedure. To this aim, we required subjects to classify arrows (">" and "<"). Throughout the experiment, subjects were required to respond at one of six times after the onset of the target stimulus (i.e., deadlines): 350, 400, 450, 500, 550, and 600 ms. The general practice phase consisted of 300 trials. (2) a lexical decision practice phase. In this phase, subjects had to make 96 lexical decisions to 72 different stimuli (i.e., one block of 48 new stimuli followed by a block of 24 new stimuli and 24 stimuli from the first block). (3) the experimental phase. This phase consisted of 30 blocks of 48 trials each, resulting in a total of 1440 trials. In each block except the first, half of the stimuli were new, and half of the stimuli had been presented in the previous block (i.e., the blocked design was used). As in the previous experiments, the transition from one block to another block was not marked in any way and from the point of view of the participants the experiment consisted of one long sequence of trials. The first block consisted of 48 filler stimuli. In the final block, the remaining 24 filler stimuli were added to 24 experimental stimuli that had been presented in the previous block. Each block consisted of an equal number of word and nonword stimuli, and each of the six deadlines occurred eight times in one block. Only responses to experimental stimuli were analyzed. The experimental stimuli were assigned to each of the six deadlines in a counterbalanced design. The order of the trials was randomly determined for each subject. Participants were allowed two short breaks, one after 480 trials in the experimental phase, and one after 960 trials in the experimental phase.

Procedure. The procedure was identical to the procedure of Experiment 3, with the following exceptions. First, the time-band feedback method was adjusted (see Figure 5). Instead of requiring subjects to respond before a deadline, as in Experiments 2 and 3, subjects were now required to respond within one of six specific time windows. Each time window was 50 ms wide and centered on the desired response time. To help subjects give a timely response, we used three tones instead of two. The first tone was presented 500 ms after presentation of the trial marker (##), and the time between the three successive tones was constant and equaled the desired response time (i.e., one of the six deadlines). The last tone immediately preceded the presentation of the stimulus, and subjects were instructed to respond at the fourth imaginary tone.

Results

The results of Experiment 4 are presented in Figure 6 and Table 5. Figure 6 shows the accuracy data and Table 5 shows the response latencies. ANOVAs were performed on the mean latencies of correct responses and on error percentages. The data of 14 subjects were excluded from the analysis, either because of excess error rate (i.e., an overall logarithmic d′ lower than 1.0) or because of bad timing (i.e., an average of more than 50 ms off the goal RT). One participant failed to comply with the task instructions completely.[5] Of the remaining 29 subjects, only data within a 200 ms window centered around the goal RT were analyzed. This resulted in the exclusion of 16.1% of the data. Other methods of analysis (e.g., binning the data or using different window-sizes) yielded similar results.

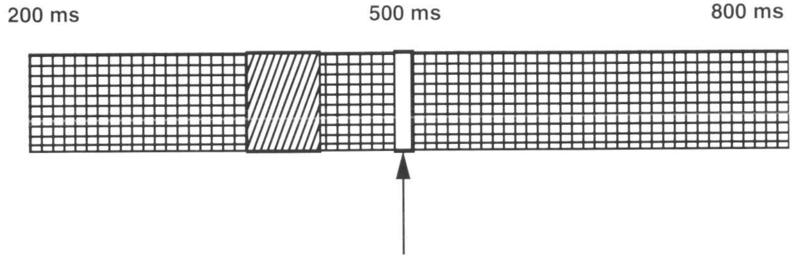

Figure 5. The time-band feedback method used in Experiment 3. The shaded area in the middle was the 50 ms wide target area and was colored green. The checkerboard-patterned areas on either side of the target area were colored red. The arrow beneath the bar and the small white rectangle on the bar indicated the observed response time of the participant. In this example, the participant missed the target area and responded at about 500 ms after stimulus onset, whereas perfect timing would have resulted in a response time of 400 ms.

As in the previous experiments, facilitatory effects of repetition priming were observed for both HF stimuli and LF stimuli. More specifically, both HF words and LF words were responded to more accurately on their second presentation than on their first presentation, $F(1, 28) = 26.3$, $MSE = 71$, $p < .001$, and $F(1, 28) = 101.2$, $MSE = 149$, $p < .001$, respectively. HF words and LF words were also classified correctly faster on their second presentation than on their first presentation, $F(1, 28) = 18.1$, $MSE = 63$, $p < .001$, and $F(1, 28) = 14.2$, $MSE = 79$, $p < .01$, respectively.

Figure 6 shows that for nonwords differing in only one letter from an existing word (i.e., 'one letter replaced' nonwords), sizeable inhibitory effects of repetition priming were observed. More specifically, 'one letter replaced' nonwords were responded to less accurately on their second presentation than on their first presentation, $F(1, 28) = 43.1$, $MSE = 66$, $p < .001$. Nonwords differing in two letters from any existing word (i.e., 'two-letters replaced nonwords') were also responded to less accurately on their second presentation than on their first presentation, thus showing an inhibitory repetition priming effect, $F(1, 28) = 12.2$, $MSE = 35$, $p < .01$. The response latencies for both 'one letter replaced' nonwords and 'two letters replaced' nonwords were not affected by prior presentation, $F(1, 28) = 2.3$, $MSE = 66$, $p > .10$, and $F(1, 28) = 1.4$, $MSE = 93$, $p > .20$, respectively.

5 *The difficulty of the variable speeded-response procedure is also witnessed by the fact that Hintzman and Curran (1997, Experiment 2) had to exclude 6 out of their initial 25 participants, either because of low accuracy or because of bad timing.*

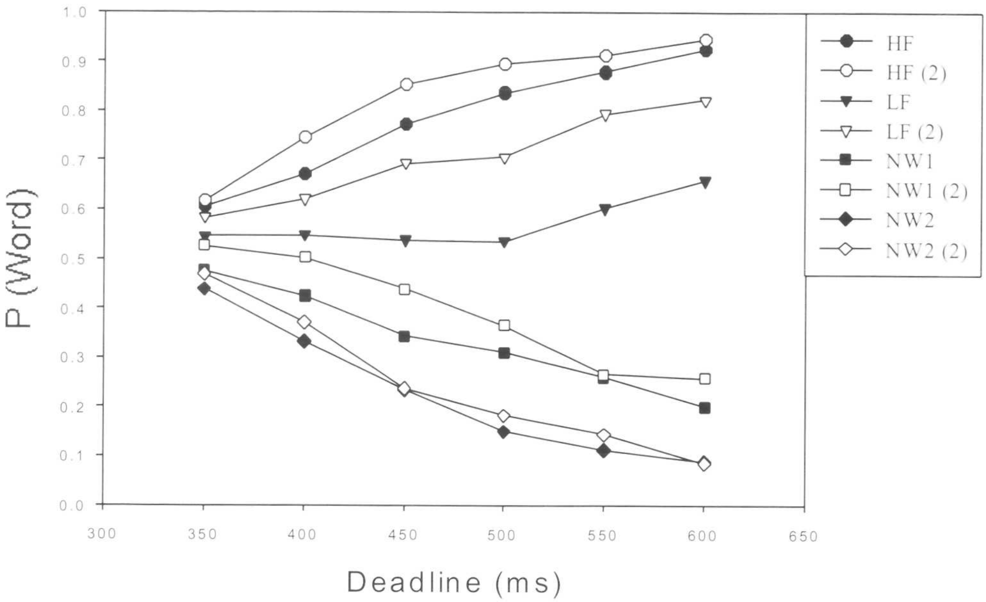

Figure 6. Results from Experiment 4. Repeated nonwords are responded to less accurately than novel nonwords. P(Word): probability of responding 'WORD', HF: high frequency words, LF: low frequency words, NW1: 'one letter replaced' nonwords, NW2: 'two-letters replaced' nonwords. The digit 2 in brackets indicates the second presentation.

Table 5
Mean Reaction Times (in Milliseconds) for First Presentations and Second Presentations (in Brackets) in Experiment 4 as a Function of Target Word Status and Deadline.

	Deadline (ms)					
Target	350	400	450	500	550	600
HF	363 (364)	411 (409)	455 (449)	494 (488)	533 (528)	579 (576)
LF	366 (363)	416 (412)	462 (460)	500 (501)	545 (541)	595 (584)
NW1	367 (364)	417 (417)	463 (464)	504 (500)	546 (544)	586 (587)
NW2	365 (368)	417 (420)	462 (462)	501 (500)	536 (537	579 (582)

Note. HF: high frequency words, LF: low frequency words, NW1: 'one letter replaced' nonwords, NW2: 'two letters replaced' nonwords.

Discussion

The main result of Experiment 4 is that nonword stimuli were responded to less accurately on their second presentation than on their first presentation: Subjects tended to erroneously classify nonword stimuli as words on their second presentation. Thus, using a speeded-response procedure with variable short deadlines, inhibitory nonword repetition priming can be reliably obtained. In contrast to the nonword stimuli, word stimuli showed positive effects of repetition priming. The inhibitory effect of repetition priming for nonwords observed in Experiment 4 strongly suggests that a process of global familiarity can influence lexical decisions for repeated nonwords. More specific accounts of inhibitory nonword repetition priming will be discussed in the next section.

General Discussion

In four experiments, we systematically studied the effects of prior presentations on performance for word and nonword stimuli in lexical decision. The focus of these experiments was to demonstrate that two opposing processes influence lexical decision performance for nonwords. First, automatic retrieval of episodic information (e.g., "GREACH is a nonword") can facilitate performance for nonwords repeatedly presented in lexical decision, as predicted by instance theory (e.g., Logan, 1988; 1990). Second, an increased sense of familiarity can harm performance for repeated nonwords (e.g., Bodner & Masson, 1997). To influence the balance between the facilitatory episodic process and the inhibitory familiarity process we manipulated speed-stress. Increasing speed-stress should enhance the role of the inhibitory familiarity process (e.g., Balota & Chumbley, 1984), while simultaneously decreasing the role of the facilitatory episodic process. In complete agreement with this hypothesis, we found that a gradual increase in speed-stress from Experiment 1 to Experiment 4 reversed the effect of nonword repetition priming: With low speed-stress (i.e., Experiment 1), previous presentation increased performance for nonwords, but with high speed-stress (i.e., Experiment 4), previous presentation decreased performance for nonwords. In Experiment 2 and 3, even four previous presentations did not affect performance for nonword stimuli. In contrast to nonword stimuli, the qualitative pattern of results for word stimuli was unaffected by speed-stress: In all four experiments, previous presentation facilitated performance for words. This facilitatory repetition priming effect was more pronounced for LF words than for HF words (cf. Scarborough et al., 1977; Wagenmakers, Zeelenberg, & Raaijmakers, 2000).[6]

In a study by Smith and Oscar-Berman (1990; for a conceptually related study on short-term masked repetition priming for nonwords see Bodner & Masson, 1997) additional evidence for the existence of two opposing processes in nonword repetition priming was obtained. Smith and Oscar-Berman (1990; Experiment 1) used a dual-task paradigm to reduce the contribution of episodic memory to lexical decision performance. Word stimuli showed reliable facilitatory repetition priming effects in both the single-task condition and the dual-task condition. For nonword stimuli in the single-task condition, performance was substantially facilitated by a previous presentation. However, this facilitatory nonword repetition priming effect was eliminated in the dual-task setting. This result mirrors the findings obtained in Experiment 1, 2

6 *Up to now, we focussed on the effects that are of primary interest for the present argument, and hence omitted the statistical results on the attenuation of the word frequency effect for repeated words. In all four experiments, repetition priming was larger for LF words than for HF words with respect to both accuracy and response latency, all p's smaller than or equal to .01. Two exceptions were the lack of an attenuation of the word frequency effect for repeated words with respect to response latencies in Experiment 3 and 4, both F's < 1.*

and 3 here, in which speed-stress eliminated the facilitatory repetition priming effect for nonwords but left the facilitatory repetition priming effect for words intact. In another experiment, Smith and Oscar-Berman (1990; Experiment 2) found that in a regular, subject-paced lexical decision task, both normal subjects and amnesic subjects performed better for repeated words than for non-repeated words (i.e., facilitatory repetition priming for words). However, normal subjects performed better for repeated nonwords than for novel nonwords, but amnesic subjects showed just the opposite pattern: Amnesics performed worse for repeated nonwords than for novel nonwords! That is, normal subjects showed facilitatory nonword repetition priming, whereas amnesics showed inhibitory nonword repetition priming. We believe this result supports the notion that repetition priming for nonwords in lexical decision is the net result of (1) an inhibitory familiarity process, operative in both amnesics and normal subjects, and (2) a facilitatory episodic process that is dysfunctional in amnesics but that is able to support performance for repeated nonwords in normal subjects.

In the next section, we will discuss the implications of our findings for global familiarity accounts of lexical decision and instance theory and elaborate on the specific lexical/semantic and episodic mechanisms that might contribute to repetition priming for nonwords.

Theoretical Implications and Alternative Explanations

Throughout this paper, we have assumed that an increase in performance for repeated nonwords in lexical decision is due to retrieval of episodic information (i.e., "GREACH is a nonword"). This assertion is consistent both with the result of Experiment 1 and with the results of Smith and Oscar-Berman (1990, Experiment 2) mentioned above, who found that amnesics showed inhibitory rather than facilitatory repetition priming effects for nonwords. Also, an explanation of facilitatory nonword repetition priming in terms of the retrieval of episodic information has a firm theoretical background in instance theory (e.g., Logan, 1988).

Dorfman (1994; see also Bowers, 2000) has contradicted the claim that facilitatory nonword repetition priming is necessarily due to the use of episodic information. Dorfman pointed out that nonwords used in standard lexical decision experiments usually bear a close resemblance to real words and that repeated nonwords might therefore show a performance benefit due to the activation of preexisting abstract sublexical codes. That is, any comparison process between a presented nonword and various word representations in memory could arguably be facilitated when it involves sublexical codes that have already been activated by prior exposure. We do not believe this explanation can provide a complete account of facilitatory nonword repetition priming. As mentioned in the Introduction, facilitatory nonword priming in lexical decision is usually found only when the study task requires subjects to make lexical decisions (e.g., Tenpenny, 1995). Additional and specific evidence for this assumption is provided by Logan (1990, Experiment 3 and 4). If facilitatory nonword repetition priming was solely mediated by the activation of abstract sublexical codes, facilitatory priming effects would be expected to occur regardless of the nature of the study task. It seems implausible to us that a study task such as lexical decision would lead to activation of specific sublexical codes that would not be activated by other word recognition tasks such as naming, pronunciation decision (e.g., Logan, 1990), or recognition memory (e.g., McKoon & Ratcliff, 1979). In addition, facilitatory priming for nonwords is also found for nonwords that are random letter strings (e.g., Bowers, 1994; Stark & McClelland, 2000). Finally, the fact that long-term priming of orthographically similar words (i.e., neighbor priming such as HOUSE priming MOUSE) is absent or small (Bowers, 2000) renders the sublexical activation account of facilitatory nonword priming less plausible.

Bowers (2000) mentioned that a benefit of previous presentation for nonwords could be the result of the activation of orthographically related words. Bowers did not elaborate on how the activation of orthographically similar words could facilitate performance for nonword stimuli specifically. One suggestion would be that the benefit occurs because highly activated word representations can be compared to a nonword stimulus sooner and more accurately than less highly activated word representations. However, facilitatory repetition priming for nonwords can be as large as that of words (e.g., Logan, 1988, 1990), an unlikely outcome for a mediated effect. Further, as mentioned above, priming for nonwords is also found for random letter strings (e.g., Bowers, 1994) who do not have similar word representations to activate. Finally, if nonwords are assumed to activate similar words in any standard word recognition task, as seems plausible, the activation-of-similar-words account would falsely predict that facilitatory nonword priming effects should be observed regardless of the nature of the study task, as explicated above.[7] In sum, the retrieval-of-episodic-information account provides the most plausible explanation of facilitatory nonword repetition priming in lexical decision and is consistent with the result of Experiment 1.

As outlined in the Introduction, familiarity-based accounts of lexical decision (e.g., Balota & Chumbley, 1984) predict inhibitory repetition priming for nonwords (e.g., Logan, 1990). A familiarity-based account of lexical decision would generally assume that (1) prior presentation of a nonword stimulus increases its familiarity value, and (2) the process of making lexical decisions is influenced by the initial feeling of familiarity that the stimulus evokes, such that high familiarity values bias the subject toward the "WORD" response and low familiarity values bias the subject toward the "NONWORD" response. Therefore, previous presentations of a nonword stimulus will bias the subject toward the erroneous "WORD" response, and thus result in inhibitory repetition priming.

7 *Bowers (2000) argues that facilitatory repetition priming for nonwords is due to perceptual learning, possibly mediated by specific brain regions in the right hemisphere (for a comparison between word and nonword repetition priming using the perceptual identification task see Bowers, 1996). The impact of a perceptual component is difficult to evaluate in the lexical decision task. Again, the fact that facilitatory repetition priming for nonwords in lexical decision only occurs when the study task is also lexical decision strongly suggest that perceptual learning cannot give a complete account of facilitatory nonword priming in lexical decision. A discussion on the similarities between a perceptual learning account and an episodic account is beyond the scope of this paper.*

The inhibitory effect of nonword repetition priming was observed in Experiment 4 and provides support for a familiarity-based account of lexical decision. The increase in familiarity due to prior presentation could be due to several factors. For instance, prior presentation of a nonword might leave an episodic trace that is automatically activated upon re-presentation of the same nonword. This activated episodic trace may then heighten the overall familiarity value of the primed nonword stimulus. Another possibility is that the previous presentation of a nonword might activate orthographically similar words. The increased activation of the orthographically similar words would also result in a higher familiarity value of the primed nonword stimulus. At present, we do not know of any empirical results that falsify either of the two mechanisms.

In sum, although an episodic account such as provided by Logan's instance theory can readily explain the facilitation for repeated nonwords as obtained in Experiment 1, it has no explicit mechanism to explain the inhibitory nonword repetition effects as observed in Experiment 4. In complete opposition, the familiarity-based account of lexical decision (e.g., Balota & Chumbley, 1984) can readily explain the inhibitory nonword repetition priming effects from Experiment 4, but it has no explicit mechanism to explain the facilitatory effects of nonword repetition priming from Experiment 1. Therefore, a complete model of lexical decision might need both a facilitatory episodic component and a global familiarity process. For instance, an instance-like model might base a lexical decision for nonwords either on a retrieved instance (i.e., the facilitatory component), or on the total number of instances that race to be retrieved (i.e., the inhibitory familiarity component). Likewise, familiarity-based accounts of lexical decision would have to be adjusted to also activate specific episodic information. A quite general explanation of both facilitatory and inhibitory nonword repetition priming would assume that (1) facilitation comes about through the retrieval of specific information contained in an episodic trace, whereas (2) inhibition is caused by the mere activation of the episodic trace as a whole or by the activation of orthographically similar word traces in lexical/semantic memory.

Author Note

We would like to thank Douglas Hintzman for sending us the data from Hintzman & Curran (1997, Experiment 2), and Jeff Bowers for comments on an earlier draft of this paper. We also thank Jordy Zandwijk and Charissa de Ruijter for their help in testing participants.