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A Bias Interpretation of Facilitation in Perceptual Identification

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In a typical perceptual identification task, a word is presented for a few milliseconds and masked; then subjects are asked to report the word. It has been found that an earlier presentation of the test word will improve identification of the test word by as much as 30%. In addition, this facilitation has been shown to be preserved under amnesia. In this article we examine a fundamental question: Is the facilitation the result of bias toward the earlier presented item, an improvement in perceptual sensitivity, or both? The experiments presented here use a forced choice procedure to show that prior presentation of an item biases the subject to choose that item but does not improve discriminability. This result is obtained when the distractor items are visually similar to the target items. When distractors are dissimilar, earlier presentation affects neither bias nor discriminability. Two models of word identification are examined in light of the bias effects, and implications for understanding savings in amnesia are also examined.

The relation between performance on implicit and explicit tests of memory has become a focus for recent theoretical debate in memory research. Priming by an earlier presentation of an item in implicit memory tasks such as perceptual identification or word fragment completion is usually stochastically independent of recognition performance, an explicit test of memory (Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982; Tulving, Schacter, & Stark, 1982). This finding has led to three different proposals: first, that there are two different forms of memory, one explicit and one implicit (Graf & Schacter, 1985); second, that there are two distinct memory systems, one declarative and the other procedural (Cohen, 1984); and third, that implicit and explicit tasks use different kinds of information within a common memory system (Jacoby, 1983a, 1983b; Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982).

Additional evidence that speaks to this debate comes from the literature on amnesia. Generally, it has been found that priming effects from implicit tasks (such as perceptual identification, Cermak, Talbot, Chandler, & Wolbarst, 1985; and stem completion, Warrington & Weiskrantz, 1974) are preserved under amnesia, whereas performance on explicit tasks (recognition and recall) is impaired (for reviews see Schacter, 1987; Shimamura, 1986). In addition, priming in many implicit memory tasks shows little decay over long time delays (e.g., hours or days), in contrast to performance on explicit tasks (e.g., McKoon & Ratcliff, 1979, 1986a) that shows large decrements over seconds or minutes or with a few intervening items (see, for example, Ratcliff & McKoon, 1988).

Because the primary focus of research in this field has been concerned with memory distinctions and classifications of tasks, there has been relatively little research on examining the basic mechanisms underlying priming in implicit tasks (for example, see the arguments in McKoon, Ratcliff, & Dell, 1986; Ratcliff & McKoon, 1986; Tulving, 1986). Our aim in this article is to examine a fundamental issue that will constrain theoretical proposals concerning these mechanisms. The question is whether a prior presentation of an item produces priming in an implicit task by increasing sensitivity to the item (Jacoby & Dallas, 1981, p. 306) or by increasing bias toward reporting the item (Jacoby, 1983a, p. 36; see also Broadbent & Broadbent, 1975). The task examined is the perceptual identification task in which subjects are asked to identify a briefly presented word.

In perceptual identification (e.g., Jacoby, 1983a, 1983b; Jacoby & Dallas, 1981; Jacoby & Witherspoon, 1982), subjects are presented with material to be studied, usually a list of words, and later they are presented with a test list of words, each flashed briefly (about 10 ms) and then masked. The task is to identify (name) each test word. Typical results show that the probability of identification is greater for words previously studied than for words not previously studied. This result depends on the physical similarity between study and test items. Jacoby and Dallas (1981) showed that visually presented test items were primed by items presented visually, not auditorily. Jacoby and Hayman (1987) extended this by showing specific visual transfer between study and test in perceptual identification. This dependence on visual information leads us to use visually similar distractors in the forced choice procedure described below.

The perceptual identification task allows hypotheses about bias and sensitivity to be addressed. Experimentally, subjects can be asked to make a forced choice judgment about which of two, alternative, test stimuli was actually flashed. In other

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tasks such as fragment completion, bias and sensitivity cannot be separated because there may be only one possible answer (or no "correct" vs. "incorrect" response, as in stem completion). The specific question is whether prior presentation of an item affects a later test by producing a change in sensitivity (discriminability, d'), a change in bias (or criterion), or both. Jacoby (1983a) has considered this issue, presenting the case for both sides of the argument, and concluded in favor of a change in bias. The experiments in this article, using a forced choice procedure, provide strong support for bias in perceptual identification, with no effect of earlier presentation on sensitivity.

It is important to note here that when we talk about bias, we do not mean a strategic postperceptual response bias. Rather, any bias effects could be perceptual or semantic in nature, depending on the task, and they could be the result of unconscious information processes.

With the forced choice procedure, d' is the usual measure of sensitivity. Although d' can be easily calculated by using tables (e.g., Hacker & Ratcliff, 1979), it is subject to inaccuracy if the underlying distributions are not of equal variance and normally distributed. Both Green and Swets (1966) and McNicol (1972) recommend the use of probability correct (the average over the two choices) as the appropriate nonparametric measure of sensitivity. Thus in this article, conclusions will be based on probability correct. d' statistics (computed from tables) will also be presented for reference, with the caveat that they should be interpreted with care.

Probabilistic Model

To illustrate the bias versus sensitivity hypotheses quantitatively, a simple probabilistic model for performance on forced choice in perceptual identification is presented in Table 1. Four cases are shown. The first is a control in which neither the test word *died* nor the test word *lied* was presented prior to the forced choice test. In the other cases, *died* was presented for earlier study. The second case illustrates the effect of a change in bias toward the previously presented item relative to the control condition, and the third shows increased sensitivity for the previously presented item relative to the control. The fourth case shows increased sensitivity to the previously presented item and also a smaller increase in sensitivity to the alternative item. This case illustrates what would happen if there were increased sensitivity on the letters in common between the alternative and the previously presented item (in the example, the letters *ied*). The parameters of the model are the probabilities that information discriminating the two alternatives is extracted from the brief presentation (one probability value for each stimulus) and the probability that one alternative is chosen, given that discriminating evidence is not obtained from the test stimulus (i.e., a guessing probability).

For the control condition, the probability that discriminating information is obtained is set to .6 for both stimuli, and the probability of a guess is set to .5, equal for both alternatives. Then the probability of reporting *died* or *lied* correctly is .6 + .5 × (1 − .6) = .8. For the bias case, the second case

Table 1
Simple Probabilistic Model for Bias and Sensitivity Changes (d') in Perceptual Identification

Case	Model prediction
Control	P(*died*) = .6, P(*lied*) = .6, P(guess *died*) = .5 Respond(*died*|*died*) = .6 + .5 × (1 − .6) = .8 Respond(*lied*|*lied*) = .6 + .5 × (1 − .6) = .8 P(correct) = (.8 + .8)/2 = .8, d' = 1.19
Bias on *died*	P(*died*) = .6, P(*lied*) = .6, P(guess *died*) = .8 Respond(*died*|*died*) = .6 + .8 × (1 − .6) = .92 Respond(*lied*|*lied*) = .6 + .2 × (1 − .6) = .68 P(correct) = (.92 + .68)/2 = .8, d' = 1.19
Enhanced processing on *died*	P(*died*) = .9, P(*lied*) = .6, P(guess *died*) = .5 Respond(*died*|*died*) = .9 + .5 × (1 − .9) = .95 Respond(*lied*|*lied*) = .6 + .5 × (1 − .6) = .8 P(correct) = (.95 + .8)/2 = .875, d' = 1.63
Enhanced processing on *died* and *lied*	P(*died*) = .9, P(*lied*) = .7, P(guess *died*) = .5 Respond(*died*|*died*) = .9 + .5 × (1 − .9) = .95 Respond(*lied*|*lied*) = .7 + .5 × (1 − .7) = .85 P(correct) = (.95 + .85)/2 = .9, d' = 1.81

Note. It is assumed that the forced choice is between two visually similar words (our example is *died* and *lied*). In Cases 2, 3, and 4, the word *died* is presented in an earlier study phase. P(*died*) is the probability that information that will provide an unambiguous identification of *died* (when presented with *died* as a choice) is extracted from the stimulus *died*.

in Table 1, the probability of a guess of the previously presented alternative is set to .8, so that the overall probability of a correct response is .8, with a bias toward reporting the previously presented item (*died*) and a resulting trade-off against reporting the alternative (*lied*). For the third case in Table 1 in which sensitivity for the previously presented alternative is enhanced, the probability that discriminating information is obtained for that alternative is set to .9, while the probability for the other alternative remains at .6. The overall probability correct in this case is .875, which shows enhancement over the first two cases. Finally, in the fourth case, the probability of obtaining discriminating evidence is set to .9 for the previously presented item and .7 for the alternative. The overall probability correct is .9, again enhanced over the other cases.

This simple model is designed to illustrate the difference between bias and enhanced perceptual sensitivity within the forced choice paradigm. Overall, probability correct improves only when there is a change in sensitivity, not when there is a change in bias. With the naming paradigm, under the bias assumption, if the subject has partial information, he or she may choose whether to respond or not. Thus it is possible that there will not be a perfect trade-off; the bias may show up as a large increment in the correct response rate to *died* when *died* was presented earlier, in conjunction with a smaller increment to the intrusion rate to *lied* (i.e., *died* responses) when *died* was presented earlier.

Besides the general implications for processes underlying word identification and more generally other implicit tasks, the results of the experiments in this article have implications for specific current theories. In the framework of Morton's (1969, 1970, 1979) logogen model, increased identification should be attributed to bias in the logogen. In McClelland

and Rumelhart's (1981) model for word identification, either bias or sensitivity could be responsible for improvement in identification. The implications for these models, as well as generalizations to other tasks that show similar patterns of facilitation, will be outlined in the discussion section at the end of the article.

A secondary aim of the experiments was to examine predictive inference by using the perceptual identification task. Jacoby (1983b) examined the effects of "top-down" and "bottom-up" processing in perceptual identification by using study conditions in which the target word (*cold*) was presented in isolation, presented with a high associate (*hot*), or required to be generated from the high associate (of course, if the target was not generated, the trial was discarded). Results showed that perceptual identification was highest in the isolation condition, next in the study condition, and lowest in the generate condition. For predictive inferences in text processing, we used materials from McKoon and Ratcliff (1986b). Table 2 shows the conditions with examples of the materials. In our experiments, target words were paired with sentences rather than single words as in Jacoby's experiments. Thus, where the target word *cold* was associated with *hot* in Jacoby's (1983b) study, the target word *died* was associated with a sentence that predicted *death* in our experiments. The first two sentences in Table 2 explicitly mention the word to be used as a target. In the second case, the sentence would predict an event represented by the target word even if the target word was not explicitly stated. The third and fourth sentences do not mention the target word explicitly, although the third sentence predicts *death*.

For perceptual identification, in which subjects name the test word, probability of correct identification of the target word (*died*) in the four conditions can be predicted from Jacoby's results. Identification should be easiest when the target word was studied prior to testing, in a context in which it was unexpected (Condition 1). Identification should be most difficult when the target word was not studied prior to testing and when the context did not allow the subject to infer the target word (Condition 4). These results were confirmed in the first experiment. We thought that the predicting context in Condition 2 might allow the subjects to infer the target word before they actually read it and so might minimize the benefit of prior study to later perceptual identification. We also thought that subjects might infer the target word in Condition 3 even though it was not actually presented and that this inference might lead to some benefit to later perceptual identification. Neither of these latter two hypotheses was confirmed: the predicting-explicit condition behaved just like the nonpredicting-explicit condition (Experiment 1), and the predicting-control condition just like the nonpredicting-control condition (Experiment 3).

Five experiments are presented. The first demonstrates enhancement on naming in perceptual identification with our materials. In the second experiment, the procedure was changed from naming to forced choice: Instead of naming aloud the test word that was flashed, subjects had to choose which of two words presented after the test word was the same as the test word. As explained above, the forced choice procedure was used to allow bias to be measured separately from sensitivity. Experiments 3 and 4 were designed to provide additional controls—Experiment 3 by using an additional class of materials, and Experiment 4 by mixing postcued identification and forced choice procedures in the same experiment to ensure that the results of Experiments 1 and 2 did not reflect different encoding strategies due to the different tasks. Experiment 5 used forced choice with visually dissimilar alternatives to examine the case in which the choices were less likely to allow bias.

In all five experiments, subjects were presented with a series of study–test trials. On each trial, they studied several sentences, and then they were given a list of test items. Each test item was made up of a warning signal, the test word flashed briefly, and a mask. If the task was perceptual identification, a signal to name the test word followed the mask. If the task was forced choice, the two choice words were displayed after the mask, and the subjects indicated their choice by pressing a key. Test words were related to studied sentences according to the conditions shown in Table 2.

Experiment 1

The task in this experiment was perceptual identification. Subjects studied sentences representing the first three conditions in Table 2, and test words for the sentences were presented in test lists for naming. The experiment was intended to show that subjects would be more likely to name the target in the explicit conditions than in the control condition; this would replicate Jacoby's perceptual identification findings with our materials.

Method

Subjects. The subjects were 30 Northwestern undergraduates who participated to receive credit for an introductory psychology course.

Table 2
Examples of Materials Used in Experiments 1–4

Condition	Sentence
Nonpredicting explicit	The director jumped on the cameraman, demanding that he get a close-up of the actress when all of a sudden she fell and died.
Predicing explicit	The director and cameraman were ready to shoot close-ups when suddenly the actress fell from the 14th story and died.
Predicting control	The director and cameraman were ready to shoot close-ups when suddenly the actress fell from the 14th story.
Nonpredicting control	The director jumped on the cameraman, demanding that he get a close-up of the actress when all of a sudden she fell.

Note. Target word = *died*; control word = *lied.*

Materials. There were 42 sets of sentences, with three sentences in each set: one nonpredicting explicit, one predicting explicit, and one predicting control. The two predicting sentences predicted an event that could be summarized by one word, the target word. They had exactly the same wording except for the addition of the target word in the predicting-explicit sentences. The nonpredicting-explicit sentence did not predict the target word prior to its mention but used as many as possible of the same words as the predicting sentences. Twenty-three of the sets of sentences were the same as those used by McKoon and Ratcliff (1986b), shown in the appendix of that article. The mean lengths of the sentences were 25.8 words in the nonpredicting-explicit condition, 24.0 words in the predicting-explicit condition, and 19.4 words in the predicting-control condition.

Each set of three sentences was associated with a target word and a control word. The target word expressed the predicted event, and the control word had exactly the same number of letters as the target word, differing by one letter in 38 cases and by two letters in 4 cases. The mean frequency of the target words was 56.2 and of the control words, 56.4 (Kučera & Francis, 1967). The words varied in length from 3 to 9 letters, with a mean of 5.0 letters.

For practice test items and filler test items during the experiment proper, another set of 97 word pairs was formed in which the second word of each pair differed from the first by one or two letters.

Procedure. The materials were presented on a Hewlett-Packard 1345A digital display module, controlled by a microcomputer. Subjects' responses were collected on a video terminal keyboard placed in front of the display screen.

Each subject was tested individually in one 30-min session. The first part of the session was used to select the display time for the test words in the remaining parts of the experiment and to give the subject practice in perceptual identification. In this practice, the subject was presented with 55 test items. Each item was initiated by the subject's pressing the space bar on the CRT keyboard when a "press space bar" message appeared on the digital display screen. Then four dashes appeared on the screen for 400 ms to indicate where the test word would be presented. Immediately after the offset of the dashes, the test word was displayed—for 100 ms on the first 5 items and then for either 10 or 15 ms on the remaining items, a randomly chosen half of the items at each display duration. After the test word, a mask of nine "@" signs appeared in the same position on the screen as the test word for 300 ms. The "@" signs were slightly larger than the letters of the test word and covered the whole area in which the test word had been presented. The mask was replaced by a row of question marks, presented for 3 s, which cued the subject to name the test word aloud. The experimenter was seated in the room to record responses. Subjects were encouraged to guess if they were unsure about what the test word had been. They were given no feedback about their accuracy. After the 3 s, the message to press the space bar for the next test item appeared on the screen.

After the 55 practice items, subjects' performance was examined. If the number of correct responses (on the last 50 items) was between 40 and 50, the display duration for the test word in the remainder of the experiment was set at 6 ms; between 30 and 39 responses, 7 ms; between 20 and 29, 8 ms; between 10 and 19, 10 ms; between 5 and 9, 12 ms; and if less than 5, 15 ms. The mean display duration across subjects was 9.6 ms.

In the second part of the experimental session, there was a series of study–test trials. On each trial, there was a list of sentences for study, and then a series of perceptual identification test items. On the practice trial, there were 3 study sentences and 6 test items. On the remaining 3 trials, there were 14 sentences to study and 28 test items. The study sentences were presented word by word, with each word on the screen for 250 ms and each word presented in the same position on the screen. Subjects were instructed to read the sentences because they might be helpful on the subsequent perceptual identification tests. After each sentence, a row of asterisks was presented for 2,500 ms. The perceptual identification test items had the same format as in the practice (dashes, the test word, mask, and question marks). Of the 28 test items on a given trial, 14 were fillers, 7 had the target word for one of the studied sentences as the test word, and 7 had the control word for one of the studied sentences as the test word.

Design. There were six experimental conditions—the three types of sentences (nonpredicting explicit, predicting explicit, and predicting control) crossed with two test words (target and control). These were crossed with six groups of subjects (5 per group) and six sets of sentences (seven per set) in a Latin-square design. Sentences and test items were presented in a different random order for each subject.

Results

We expected that subjects would be more likely to identify the test word when they had studied it prior to perceptual identification, and this is what the data in Table 3 show: Probability of naming the targets is higher in the explicit conditions than in the control condition.

By analysis of variance, this interaction between type of sentence and test word was significant, $F(2, 58) = 12.2$ with subjects as a random variable, and $F(2, 82) = 12.3$ with sentence sets as a random variable ($p < .05$ throughout this article). Post hoc tests showed that subjects were more likely to name target words in the explicit conditions than in the control condition, $F(1, 58) = 32.8$ and $F(1, 82) = 32.8$, but this was not the case for the control test words. The MS_e on the interaction was 1.6, with subjects as the random variable and 1.1 with sentences sets as the random variable. The main effect of sentence type was significant, $F(2, 58) = 5.7$ and $F(2, 82) = 5.8$, as was the main effect of test word ($Fs > 69$).

In the explicit conditions with the control test word (*lied*), subjects sometimes named the target word in error. There were 27 of these intrusions in the nonpredicting-explicit condition (out of 90 total responses in that condition) and 29 (out of 102 responses) in the predicting-explicit condition. The numbers of correct responses in the target test word conditions were corrected by using these intrusion rates to estimate guessing, but such an analysis did not significantly change the pattern of the data nor the results of the analyses. There were no other kinds of intrusion errors.

Experiment 2

The high number of intrusions of *died* for the test word *lied* leads to the question of whether there is bias in processing and whether bias is responsible for the advantage in perceptual identification. To address this, we used the forced choice procedure.

Table 3
Results From Experiment 1: Probabilities of Correct Responses

Condition	Test word: Target (*died*)	Test word: Control (*lied*)
Nonpredicting explicit	.80	.30
Predicting explicit	.77	.35
Predicting control	.55	.37

Method

Experiment 2 differed from Experiment 1 mainly in the task required of the subjects: forced choice instead of perceptual identification. The practice and study–test trials had the same materials, procedure, and design as Experiment 1, except that after the mask following each test word, two words appeared on the screen for forced choice. For test words corresponding to studied sentences, one of the words was the target and one was the control. For filler test items, one of the choice words was the presented test word, and the other was the word that differed by only one or two letters. The two choice words remained on the screen until the subject made a response, pressing the "/" key on the keyboard if the right-hand word was the same as the test word, and the "Z" key if the left-hand word was the same as the test word. The position of the correct response, right or left, was randomized. If the correct response was made, the message to press the space bar for the next test item appeared on the screen. If the response was an error, the word ERROR appeared for 2 s before the "press space bar" message. In all other details, the experiment was the same as Experiment 1. Eighteen subjects participated in the experiment to receive credit in an introductory psychology course. The average display duration was 11.7 ms.

Results

Table 4 shows the probabilities of correct responses. When the target was presented as the test word (and so it was the correct response), probability correct is shown in column 1, and when the control was presented as the test word, probability correct is shown in column 2. The third column contains the average probability correct (i.e., the average of columns 1 and 2).

To the extent that subjects are biased to choose the target word over the control word by prior presentation of the target word, they should be more likely to report the target and less likely to report the control word. This is the pattern shown in the probabilities of correct responses. When a target word was presented explicitly in a studied sentence, subjects were more likely to choose the target and less likely to choose the control than when the target word was not stated in the studied sentences. At the same time, there was little difference in the average probability correct across study conditions.

The interaction between sentence type and test word in the probabilities of correct responses was verified statistically, $F(2, 34) = 4.9$ with subjects as the random variable, and $F(2, 82) = 7.3$ with sets of sentences as the random variable. Post hoc tests showed that when the target was the correct response, performance was better in the explicit conditions than the control conditions, $F(1, 34) = 5.2$ and $F(1, 82) = 7.7$. But when the control word was the correct response, performance in the control condition was better than in the explicit conditions, $F(1, 34) = 5.2$ and $F(1, 82) = 6.6$. The MS_e for the interaction was 1.3 in the subjects analysis and 0.4 in the materials analysis. There was also a significant main effect of test word, $F(1, 17) = 56.6$ and $F(1, 41) = 26.4$. The main effect of sentence type was not significant (Fs < 1).

Table 4 also shows d' values, which differ little across conditions. Values of d' were calculated from the proportions correct shown in the table and also from the average probability of a correct response for each subject. Because the number of responses is small for each condition (e.g., 7), d's for individual subjects are grainy and may be inaccurately estimating true d's because equal steps on the scale of probability lead to unequal steps in d', with the d' steps getting larger as d' increases. In addition, for perfect scores, when all the responses are correct, d' could range up to infinity. In practice, the estimate of d' for a score of 7/7 was set to be $d'_6 + (d'_6 - d'_5)$, and this value will be an inaccurate estimate if the true value of probability correct is high.

Table 4
Results From Experiment 2: Probabilities of Correct (PC) Responses and d' Values

	Test word			d'	
Condition	Target (*died*)	Control (*lied*)	*PC*	Straight	Average
Nonpred. ex.	.94	.68	.81	1.24	1.23
Pred. ex.	.94	.70	.82	1.29	1.34
Pred. con.	.83	.79	.81	1.24	1.40

Note. Nonpred. ex. = nonpredicting explicit; Pred. ex. = predicting explicit; pred. con. = predicting control. The first d' value is calculated straight from the probability correct shown in the table, and the other d' value is calculated from each individual subject's d' average.

Experiment 3

The predicting-control condition used in Experiments 1 and 2 might be thought to lead to an inference involving the concept expressed by the target word. That is, when subjects read the sentence about the actress falling off the 14th story roof, they may make the inference that the actress died. If they did make such an inference, then the conditions in Experiment 2 might all be showing constant facilitation because all involved a common inference (or explicit statement) of the test word. Although the hypothesized inference has not found strong empirical support (McKoon & Ratcliff, 1986b, in press) with other paradigms, we wanted to provide a test with perceptual identification procedure. Thus, the nonpredicting-control was used in Experiment 3 instead of the predicting control used in Experiments 1 and 2. The nonpredicting-control sentences did not relate in any way to the target word, but they did include as many as possible of the same words as the nonpredicting explicit sentences.

Method

In every other respect, Experiment 3 was the same as Experiment 2. The 30 subjects participated in the experiment for extra credit in an introductory psychology course.

Results

The probabilities correct and d's shown in Table 5 parallel the results from Experiment 2. When the target word was presented in a studied sentence prior to the forced choice test, then subjects were more likely to give the target word as a response and less likely to give the control word as a response than when the target word had not been presented previously. But prior presentation of the target word did not affect overall probability correct.

Table 5
Results From Experiment 3: Probabilities of Correct Responses (PC) and d' values

Condition	Test word: Target (*died*)	Test word: Control (*lied*)	*PC*	*d'*: Straight	*d'*: Average
Nonpred. ex.	.89	.65	.77	1.05	1.19
Pred. con.	.81	.76	.78	1.12	1.27
Nonpred. con.	.80	.73	.76	1.03	1.09

Note. Nonpred. ex. = nonpredicting explicit; Pred. con. = predicting control; Nonpred. con. = nonpredicting control. The first *d'* value is calculated straight from the probability correct shown in the table, and the other *d'* value is calculated from each individual subject's *d'* averaged.

For probabilities of correct responses, the interaction between test word and type of studied sentence was significant with subjects as the random variable, $F(2, 58) = 4.34$, and with materials as the random variable, $F(2, 82) = 6.76$. There was a significant main effect of test word, $F(2, 58) = 21.1$ and $F(2, 82) = 13.6$, but not of sentence type ($Fs < 1.0$). The MS_e for the interaction was 0.24 in the subjects analysis and 0.43 in the materials analysis. Thus the hypothesis that there was constant facilitation across the explicit and control study conditions in Experiment 2 can be ruled out.

Experiment 4

The results of Experiments 2 and 3 indicate that the reason subjects are more likely to be correct on a target word that has been presented previously is an increased bias to report that word, not an improved ability to detect the word. A change in bias would also explain the results of Experiment 1, in which the perceptual identification paradigm was used, although in that paradigm bias cannot be measured directly, independently of sensitivity. To extend the bias interpretation to perceptual identification, therefore, requires the assumption that the same processes are operating in the two tasks, identification (naming) and forced choice. Experiment 4 was designed to test that assumption by mixing the two tasks in one experiment with the same subjects.

Subjects studied sentences just as in the previous experiments and then were presented with a series of test items. Half of the test items were presented for identification, and half for forced choice. The task was indicated only after the test word had been flashed, when question marks were presented to cue a naming response or when two words were presented for forced choice. Thus, processing of sentences and test words should be the same with the two tasks up to the point at which the test cue is presented.

Method

Twenty-four Northwestern University undergraduates participated in the experiment in exchange for $5.

Only two sentence types were used in this experiment: nonpredicting explicit and predicting control. These sentence types were crossed with two types of test words (target and control) and two test conditions (naming and forced choice) to make eight experimental conditions. These conditions were combined in a Latin-square design with eight sets of sentences (five per set, chosen from Experiment 1) and eight groups of subjects (3 per group). Order of presentation of sentences and test items was randomized differently for each subject. The procedure was the same as in the previous experiments, except that the task, naming or forced choice, was not known to the subject until the question marks or the pairs of choice words were presented after the test word and mask. The mean presentation time for the test words was 9.8 ms.

Results

Mixing the two tasks together did not change the results on either task. The data for identification look much like the data from Experiment 1, and the data for forced choice look like the data from Experiments 2 and 3. Probabilities of correct responses and *d'* values are shown in Table 6.

Independently of whether the task was identification or forced choice, previous study of the target word led to more accurate responses when the target word was tested but did not improve performance when the control word was tested. This interaction was significant with subjects as the random variable, $F(1, 23) = 12.6$, and with sentence sets as the random variable, $F(1, 39) = 10.6$. The MS_e on the interaction was 1.0 with subjects as the random variable, and 0.7 with sentence sets. There were also main effects of task, $F(1, 23) = 55.4$ and $F(1, 39) = 70.9$; sentence type, $F(1, 23) = 7.3$ and $F(1, 39) = 5.2$; and test word, $F(1, 23) = 33.4$ and $F(1, 39) = 12.6$. There were also interactions between task and sentence type, $F(1, 23) = 10.8$ and $F(1, 39) = 5.8$, and between task and test word, $F(1, 23) = 4.2$ and $F(1, 39) = 4.8$. The triple interaction was not significant ($Fs < 1.0$).

There were a large number of intrusions in the identification task, intrusions in which the target word was given as the response when the test word was the control word. In the explicit condition, there were 25 intrusions of the target (out

Table 6
Results From Experiment 4: Probabilities of Correct Responses (PC) and d' Values

Condition	Id. test word: Target (*died*)	Id. test word: Control (*lied*)	FC test word: Target (*died*)	FC test word: Control (*lied*)	*PC*	*d'*: Straight	*d'*: Average
Nonpred. ex.	.77	.48	.93	.70	.82	1.27	1.35
Pred. con.	.55	.41	.81	.84	.83	1.31	1.48

Note. Nonpred. ex. = nonpredicting explicit; Pred. con. = predicting control; Id. = identification; FC = forced choice. The first *d'* value is calculated straight from the probability correct shown in the table, and the other *d'* value is calculated from each individual subject's *d'* averaged.

of a total of 83 responses when the control word was presented) and 92 correct responses on the target. In the control condition, there were 11 intrusions of the target (out of 60 responses) and 66 correct responses on the target. If correct responses on the target are corrected for guessing by simply subtracting the intrusions, then probability correct on the target becomes .56 in the explicit conditions and .46 in the control condition. Analysis of variance on the corrected data for the identification task alone showed no significant effects, Fs < 3.1 for the effect of sentence type, and all other Fs < 1.8.

Experiment 5

One concern about these results is that the bias effect arises from the nature of the distractors. It is possible that visually similar distractors constrain the subject to decisions on the visual dimension and produce bias effects that might be replaced by sensitivity effects if the decision dimension were unconstrained. To address this potential problem, distractors with minimal visual similarity to targets were used in Experiment 5.

Method

Experiment 5 was exactly the same as Experiment 2 in design and procedure, but the alternatives for the forced choice test were different. For each item, subjects read either the nonpredicting-explicit, the predicting-explicit, or the predicting-control sentence (as in Experiment 2). At test, the briefly flashed word was either the target used in all the other experiments (e.g., *died*) or a new control word. The words presented for the forced choice decision were the target and this new control word. The new control words had the same number of letters as the targets and the same average word frequency, but otherwise were as different as possible: There were no letters in common between the two words, and the overall shape of the words was different. For example, the new control for *died* was *sofa*, for *bend* it was *spot*, for *lift* it was *away*, and so on. The filler materials were the same as those used in the other experiments, and the two filler test words differed by one or two letters. Thus, subjects were unable to use the simple strategy of responding when they identified one letter in the briefly flashed word.

There were 18 subjects who participated in the experiment for credit in an introductory psychology course. For 4 of the subjects, the test item duration was 9 ms, and for the remainder of the subjects, the test item duration was 8 ms. (These durations were reduced relative to earlier experiments because the two choices were visually dissimilar in this experiment, leading to an easier decision relative to the visually similar distractors used in the earlier experiments.)

Results

The data were analyzed as in Experiment 2, and the results are shown in Table 7.

The data show no effects of study condition on performance. The only significant differences on probability correct were between target and control words, $F(1, 17) = 7.8$ with subjects as the random variable, and $F(1, 41) = 8.6$ with test words as the random variable. All other Fs were less than 1.24. The MS_e for the interaction was 1.9 in the subjects analysis and 0.8 in the materials analysis.

Table 7
Results From Experiment 5: Probabilities of Correct Responses (PC) and d′ Values

	Test word			d'	
Condition	Target (*died*)	Control (*sofa*)	*PC*	Straight	Average
Nonpred. ex.	.89	.76	.83	1.35	1.47
Pred. ex.	.88	.77	.83	1.35	1.52
Pred. con.	.83	.74	.79	1.14	1.27

Note. Nonpred. ex. = nonpredicting explicit; Pred. ex. = predicting explicit; Pred. con. = predicting control. The first d' value is calculated straight from the probability correct shown in the table, and the other d' value is calculated from each individual subject's d' averaged.

These results show no evidence of any bias effects as a function of prior presentation of the test word and only a small nonsignificant increase in the probability correct from the predicting control to the explicit conditions. The interpretation of these results is clear: If the forced choice alternatives are visually dissimilar, then almost any information will discriminate them, and there is little chance of bias toward the incorrect alternative. The lack of change in overall probability correct as a function of prior presentation replicates the lack of change in probability correct in the earlier experiments that did produce a bias effect.

General Discussion

The main result of these studies is that the improvement in perceptual identification as a function of earlier presentation of an item is the result of a bias to select the earlier presented item and not the result of a change in perceptual sensitivity. It is important to note that this does *not* mean that the effect is an uninteresting response bias that occurs consciously at the response stage. Rather, the bias may well arise early in perceptual processing and should be labeled *perceptual* bias to distinguish it from a postperceptual response bias. The perceptual bias interpretation is the one that we favor for two reasons: First, subjects report that a previously presented word "jumps" out of the display, and this suggests a perceptual basis for the effect. Second, response times are in the range of 700–900 ms, indicating that there is not significant postchoice (slow strategic) processing.

A simple probablistic model was presented in Table 1 to illustrate the difference between bias and sensitivity effects in the forced choice task. The parameters of the model are the probabilities of selecting an alternative, given discriminating information and guessing probability. If the guessing probability is changed as a result of an earlier presentation, then the patterns of results for forced choice found in Experiments 2, 3, and 4 are obtained.

A similar bias effect has been obtained by Brunn (1986). She used a small set of letters as stimuli and found that the probability of reporting a letter correctly increased when it was preceded by the same letter as a prime. But this benefit was smaller than the increase in errors when the prime letter was different from the target letter. Calculations using Luce's choice model (Luce, 1959) showed that a matching prime actually decreased sensitivity while giving a strong bias toward the prime letter. Thus, like the results in the experiments presented here, sensitivity was not increased. The fact that it was decreased rather than unchanged (as in the current experiments) may be the result of differences in procedure and differences in the nature of the stimuli (a small set of four letters vs. words from paragraphs).

A secondary aim of the experiments in this article was to examine predictive inference using perceptual identification. The results showed no difference between predictive and nonpredictive sentences when the predicted word was not presented. These results fail to replicate Jacoby's (1983b, Experiments 2 and 3) results when subjects were required to explicitly generate an item to be tested later. The reason for this failure to replicate is that the inferences in our experiments were not as compelling as the high associates generated in Jacoby's experiments (see McKoon & Ratcliff, 1986b).

Evaluation of Word Recognition Models

Logogen model. Morton's (1969, 1970, 1979) logogen model has many features in common with the bias hypothesis described here. In fact, it is one way to implement the probabilistic model with bias shown in the second case in Table 1. The logogen model was designed to account for word identification. Words are represented as individual logogens, each with a set of defining features. Words input to the processing system are assumed to be decomposed into basic auditory, visual, and semantic features. When an input feature is a member of the defining set for a logogen, then the counter for the logogen is incremented. The response of the system is determined by the logogen for which the count first exceeds a critical threshold value. The critical value is not the same for all logogens and is determined by a several factors including word frequency. Thus effects of word frequency are explained as bias effects, and Morton (1970, p. 207) argues that these effects should produce a slow decay of the threshold back to resting levels, or else the system would become unstable. Because Morton does not specify what is meant by "slow," we do not know whether this will account for the slow decay of facilitation in perceptual identification (e.g., Jacoby & Dallas, 1981; but contrast with Jacoby's arguments, 1983a, 1983b).

Interactive activation model. Another model that has the properties necessary to provide a bias interpretation of performance in perceptual identification is McClelland and Rumelhart's (1981) interactive activation model. In their model, there are three levels of analysis: letter-feature nodes, letter nodes, and word nodes, with facilitatory connections between levels and inhibitory connections within levels. Input to the system, in the form of features, gives rise to activation, which is transmitted up through the network. At the output level, Luce's choice rule is used to determine which word is chosen as matching the input. In this framework, it is possible to account for bias effects by assuming that an earlier presentation of a word leaves the word node in a state with higher than baseline activation. We implemented a simple version of the interactive activation model (using a restricted set of words) with the parameter values presented in McClelland and Rumelhart (1981). A change in baseline activation was found to produce a bias effect, with little change in discriminability d'.

One reservation that should be noted about the interactive activation model is that there is no reason to expect word activation to be long lasting. Experimental results (e.g., Jacoby, 1983a; Jacoby & Dallas, 1981) show slow decay, whereas the parameter values selected by McClelland and Rumelhart (1981) provide quite rapid decay. McClelland and Rumelhart (1981) do set resting levels of words as a function of word frequency, but these are fixed and not subject to slow decay or to alteration as a function of earlier presentation. What is needed to account for the current results is the addition of another, slower component of decay, although this would be ad hoc unless further justification were provided.

Both of these models have been criticized by Jacoby (1983a, 1983b) because they assume that the record of an earlier presentation is context independent. He argues that a considerable body of data supports the notion that performance on the perceptual identification task is context dependent, and so models should allow performance to be dependent on the prior context (and even surface form) of the stimulus (e.g., Jacoby & Hayman, 1987). Although our results do not speak specifically to this issue, we have sympathy for that view. For example, Ratcliff (1978) has developed a retrieval model that assumes that the representation of each item in memory is kept separate and that the comparison between a test item and items in memory is carried out in parallel. The quality of match between the test item and each item in memory is dependent on many factors such as various kinds of similarities including semantic, acoustic, visual, and so forth. This model is compatible with the instance-based view of memory. In another vein, Ratcliff, Hockley, and McKoon (1985) showed that in a continuous recognition memory/lexical decision task, there was long-term facilitation in lexical decision, but the size of the effect depended on whether item recognition or lexical decision was used on the first presentation of the item. Thus they argued that context in terms of previous task or response processes also can affect long-term memory (cf. Jacoby, 1983b).

Generalizations to Other Tasks

The simple criterion model (Table 1) gives useful constraints for understanding differences between the perceptual identification and item recognition tasks. We propose that some other tasks that show long-term facilitation and preserved performance under amnesia produce facilitation in the same way as perceptual identification, namely a shift in criterion.

Tasks such as perceptual identification and word fragment completion require the subject to produce alternative candidates to match to impoverished stimuli. In fragment completion, for example, the subject has to generate candidates for checking against the fragment. This process could be affected by prior presentations through bias of the alternatives chosen for checking. In contrast, tasks such as recognition require specific knowledge of previous presentation; this knowledge is reflected not in changes in bias but in changes in d', and decay of this information is short-term relative to perceptual identification and fragment completion.

There is no guarantee that decay of the bias effect will be the same for different tasks. For example, the decay of the long-term component of facilitation in fragment completion may be different from the decay function for facilitation in perceptual identification. We would interpret such results as reflecting different but possibly overlapping kinds of information for different tasks (again, consistent with an instance based view, see Jacoby, 1983a, 1983b). For example, in perceptual identification, letters (and features) are impoverished at test so that partial information about features and letters is used to match candidates for words, whereas in lexical decision, the whole word is available and can be used to match lexical representations. These different kinds of information could contact different pieces of information in the lexicon, leading to different behaviors in the tasks. Thus one might find a range of effects from dependence to complete independence between tasks.

Although we have discussed bias as resulting from changes in only one criterion, it is not necessary to make such a unitary assumption. The results we have presented are equally consistent with the view that there are many places in the processing system where bias could occur. For example, in the interactive activation model (McClelland & Rumelhart, 1981), it could be assumed that all the nodes involved in recognizing a word have their baseline activation raised. Then, to the extent that processing a subsequent stimulus overlaps with processing of a prior stimulus, one would expect a bias toward an alternative choice most consistent with the processing of the prior stimulus. Thus the bias interpretation of facilitation could be extended to other classes of stimuli such as pictures (Weldon & Roediger, 1987) that may not have simple lexical entries. Bias for these stimuli would be interpreted as biases in the subprocesses involved in identification. However, it should be stressed that the results presented here provide no evidence as to whether biases occur in subprocesses or at the thresholds of lexical entries.

Implications for Savings in Amnesia

If long-term priming effects (in lexical decision, fragment completion, perceptual identification, etc.) can be assigned to the operation of a bias mechanism, then it becomes possible to understand why these effects might be preserved in amnesia. The reasoning is that bias operates on the same kind of information that is used in lexical processing (or the equivalent processes for pictures, for example), and this kind of information appears to be preserved in amnesics. Amnesics appear to have relatively normal language interactions (compared with their memory deficits) in that they can select appropriate words to express ideas, so the system that maintains the relative criteria of words in the lexical system should be preserved. If the long-term effects in tasks such as perceptual identification are the result of bias in the lexical system, then it follows that these effects would be spared in amensics. Again, generalizing this argument from a purely lexical system to perceptual/lexical subprocesses may suggest the range of materials and tasks that might be spared in amnesia.

Even if savings on a range of tasks are the result of bias of some kind (perceptual in perceptual identification, semantic in free association, Shimamura, 1986) and even if priming on all these tasks is preserved under amnesia, this does not mean that the tasks will behave the same way under all conditions. As mentioned above, the tasks may depend on different kinds of information, and biases may operate on different subprocesses of the tasks. For example, Shimamura (1986; see also Schacter, 1987) has noted that facilitation in stem completion decays within hours, whereas facilitation in perceptual identification and fragment completion lasts for days.

Furthermore, even if the savings that result from bias are always preserved under amnesia, this does not mean that performance on the tasks that show savings will always be statistically independent of performance on tasks that are not preserved. Tulving et al. (1982) have found one case in which there is such independence, between performance on recognition and priming effects in word fragment completion (see discussion in Tulving, 1983, and McKoon et al., 1986). However, Jacoby and Witherspoon (1982) found that recognition and priming in perceptual identification were not independent for pseudoword stimuli (although they were independent for words). This result suggests that the kinds of performance preserved under amnesia are not always statistically independent of the kinds of performance that are not preserved. In addition, there is also sometimes statistical independence between two tasks that are both preserved. Witherspoon and Moscovitch (1988) found independence between performance on word fragment completion and performance on perceptual identification. This suggests that the criteria of preservation under amnesia and statistical independence do not coincide (see also Jacoby & Witherspoon, 1982, and Mandler, Graf, & Kraft, 1986, for related arguments). A reasonable way of viewing these results is that that degree of statistical dependence, like other aspects of performance, reflects the degree of use of common processes or information (Jacoby & Witherspoon, 1982).

Our conclusion is that the bias interpretation of priming in perceptual identification, which derives from the experiments presented in this article, can be generalized to other implicit memory tasks. In a perceptual task (such as perceptual identification), perceptual processes will be biased, whereas in a task that shows semantic priming effects (free association), part of the bias will result from semantic processes. Thus, although the bias explanation may generalize across a range of implicit priming tasks, it does not constrain the kinds of information or processes used in the tasks. Thus the bias interpretation does not constrain decay rates to be equal, nor does it require statistical dependence between performance on the different implicit tasks. Rather, what is provided is one specific proposal to constrain models of priming to affect bias and not sensitivity in these implicit tasks.

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