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THE INFLUENCE OF NEAR-THRESHOLD PRIMING ON METAMEMORY AND RECALL *

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A metamemory paradigm involving the use of near-threshold visual priming is developed in which a brief flash of a previously nonrecalled answer occurs, and then the person attempts to recall the answer and/or make feeling-of-knowing judgments. The major new finding is that the feeling of knowing did not detect perceptual input from a near-threshold prime that increased the recall of otherwise nonrecallable items. This finding has two important implications: (1) The feeling of knowing is not always more sensitive than recall as an indicant of information in memory (particularly, as an indicant of small amounts of information newly deposited into memory), and (2) 'monitored' information (that the feeling of knowing would be capable of detecting, as examined in previous research) can be combined with 'nonmonitored' information (that is newly deposited into memory and that the feeling of knowing does not detect) so as to produce the successful recall of an otherwise nonrecallable item.

Hart (1965, 1967) reported findings demonstrating that a memory monitoring system he called the 'feeling of knowing' was capable of detecting the storage of nonrecalled information. Hart (1967) also presented a theoretical model postulating that the memory monitoring system is more sensitive to information in memory than is a high-threshold task like recall.

Nelson et al. (1984) reported similar findings – namely, that the feeling of knowing (FOK) predicted with significant accuracy the perceptual identification of rapidly flashed answers to previously non-

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recalled general information questions. That is, subjects identified correct answers that were flashed at speeds near or below visual threshold sooner if they had given high FOK ratings for subsequent recognition performance. One plausible explanation for this FOK-identification result is that the incremental subthreshold flashes had a priming effect on memory retrieval; that is, whatever produced the high FOK also caused the prime to have a greater effect on memory performance. These findings of Nelson et al. are in accord with Hart (1965, 1967) because items associated with high FOK ratings are also more likely to be recognized.

The above findings also suggest that correct-answer cues flashed at or near perceptual threshold may positively influence the FOK while remaining perceptually insufficient to improve recall of previously nonrecalled answers. Such a hypothesis is consistent with both the findings of Nelson et al. (1984) and those presented by Hart (1965, 1967) in which the FOK detects information not detected by the recall test. It is also in accord with a model presented by Hart that states: 'the threshold for activation of a FOK (feeling-of-knowing) signal from the MEMO (memory-monitoring) process is thought to lie between the recall and the savings thresholds' (1967: 690).

In light of the above findings and other results discussed below, it is important to understand how primes like those used in Nelson et al. (1984) contribute to metamemory and memory performance. In particular, it is important to understand when one system can be affected by a prime that does not affect the other system. The current study was designed to investigate this issue.

Our experimental methods involved the use of rapidly presented primes at durations that are near individual subjects' perceptual thresholds. It is possible that the perceptual input from such primes is sufficient to affect metamemory (a system which, according to Hart and others, is very sensitive to information in memory) even when such input does not affect the presumably less sensitive memory performance systems measured by a recall task. Experiment 1 investigated this possibility.

Experiment 1

The first experiment examined whether a single near-threshold presentation of a correct-answer prime influences the FOK for a previously nonrecalled item without influencing the probability of its recall. Such a finding would demonstrate that the FOK is in fact sensitive to perceptual input for which a supposedly high-threshold task like recall is not. Of course, it is also possible that a near-threshold presentation of an answer-prime influences memory performance without influencing the FOK.

The present paradigm is similar to the one employed by Nelson et al. (1984). However, two main differences are: (1) In the present paradigm the primes were presented *once* at a near-threshold duration, followed by a visual-pattern mask, whereas Nelson et al. repeatedly presented rapidly flashed primes at increasingly longer presentation durations; and (2) in the present paradigm, the FOK judgment occurred *after* the flashed prime. In Nelson et al., the FOK judgment was obtained *before* the prime was flashed.

Method

Subjects and design

The subjects were University of California Irvine students from undergraduate psychology courses who received partial credit for participation. They were required to be fluent in English and to have normal or corrected-to-normal vision. The design consisted of a within-subjects counterbalanced paradigm comparing the effect of two types of near-threshold visual stimuli on recall and on the FOK. The experiment consisted of two one-hour sessions, one week apart. The recall task required the subject to answer general-information questions. The FOK task consisted of judgments about whether the person believed he or she would answer questions correctly on a subsequent multiple-choice test.

Apparatus and materials

All stimuli were presented on a NEC monitor controlled by an IBM PC1 computer. This apparatus presented stimuli at the durations described in the appendix.

A list of nouns was constructed from the Thorndike–Lorge (1944) norms for use in determining the presentation durations to be used in session 2. The nouns had frequencies of occurrence of 100 or more per million words. Nouns beginning with every letter of the alphabet were represented. A list of 100 questions was selected from the Nelson–Narens (1980a) norms such that the correct answers were words of either 5, 6 or 7 letters. An example is: 'What is the name of the north star?' (answer = Polaris). The list of 100 questions consisted of a set of questions having a normatively varied probability of recall (i.e., not all normatively easy questions and not all normatively difficult questions). An additional 22 questions with their corresponding answers were selected from the Nelson–Narens norms to be used in catch-trial segments that are discussed below.

For each of the 100 question stimuli, one of two types of near-threshold primes was used in session 2. The first was the correct answer to the question. The second was a 'nonsense word', selected from a list created by a linguist (E. Matthei) and designed to conform to the orthographic and phonological structure of real words. Nonsense words of 5, 6 and 7 letters were randomly assigned to each of the 100 individual stimulus items, with the exception of a few instances in which the randomly assigned nonsense word closely resembled the answer prime (e.g. beginning with the same letter) in which a new nonsense word was assigned, usually the next nonsense word from the list.

A fixation point consisting of a rectangular outline with a dot in its center was presented prior to the flashing of the near-threshold stimuli.

Immediately following the presentation of the near-threshold stimuli, a visual-pattern mask was presented for approximately 150 msec to prevent possible visual persistence of the prime (see appendix). The visual-pattern mask, which randomly varied from trial to trial, consisted of randomly overlapping letters, upper and lower case, and additional keyboard symbols (e.g., $, @, %, etc.).

Procedure

In session 1, 100 general-information questions were presented in a pre-randomized order, which randomly varied from subject to subject. Subjects were required both to recall the answer to each question and to rate their FOK for each question. Both tasks were self-paced. Session 1 served to isolate a subset of questions for which the subject did not recall the correct answers.

Session 2 consisted of two segments: The first established two different presentation durations at which the primes would be presented during the second segment. The second segment involved the presentation of nonrecalled questions from session 1 and the presentation of near-threshold primes. Practice trials were incorporated into both sessions.

Session 1

Subjects were told that the experiment would investigate their knowledge about general information. Questions were presented individually on the monitor, and responses were typed into the computer keyboard. Subjects were instructed to try to answer each question and to guess whenever possible, even if unsure of the answer. If they had no guess, they typed the word 'next'. In determining a correct response, the computer was programmed to check for correct spelling of the first three letters of the answer (this was also true for the recall task in session 2), as in Nelson and Narens (1980a).

After each recall response, subjects rated – on a scale from '1' (lowest) to '9' (highest) – their FOK for that question. The ratings were described to the subject as judgments about his or her likelihood of recognizing the correct answer from a list of possible answers. Subjects were allowed to change their response (if they made a typing error) before proceeding to the next question.

Session 2

Session 2 consisted of (1) a preliminary phase during which subjects' individual presentation durations for the primes were determined; and (2) a test phase in which nonrecalled questions and near-threshold primes were presented, and responses to recall and FOK tasks were collected.

Preliminary phase. Due to a large amount of variability in subjects' perceptual thresholds (Marcel 1983) it was necessary to establish individual presentation durations. Two presentation durations were used. The first duration – called the 'near-threshold duration' – was determined by a staircase-like algorithm (see appendix). This algorithm yielded a duration at which subjects tended to perceive the stimuli as being present but not identifiable.

The second presentation duration – called the 'catch-trial duration' and abbreviated CT – was 120% of the near-threshold duration. The CT duration had the property that subjects were able to identify the stimuli presented during the duration setting procedure.

Test phase. During the test phase, the following sequence of stages, initiated by a key press, occurred: (1) question stimulus, (2) frame and dot, (3) prime (at a near-threshold duration or CT), (4) visual-pattern mask, (5) recall task, (6) FOK task, and (7) subjective detection task. These stages (respectively) consisted of:

(1) When a question appeared on the monitor, the subject read the question aloud and then pressed a key after he or she understood the question.
(2) The subject fixed his or her gaze on the dot when it appeared and waited (approximately 2 seconds) for the flashed word.
(3) One of three possible stimuli was presented to the subject: (a) the correct-answer prime at the near-threshold duration; (b) a nonsense-word prime at the near threshold duration; or (c) the correct-answer prime at the catch-trial duration. [1]
(4) Immediately after the prime, a visual-pattern mask was presented for approximately 150 msec. The mask was generated by the computer on each trial and covered the entire area formerly within the frame, thus masking the prime as well as the region surrounding it.
(5) Following the mask, the question appeared again and the subject typed his or her response into the computer. As in session 1, subjects were encouraged to guess when unsure about the correct answer, or if unable to make a guess, to type the word 'next'.
(6) The subject rated his or her FOK, using the same scale as in session 1.
(7) Finally, the subject indicated whether he or she subjectively saw the prime, by answering the question 'Did you see a word flashed?' If they answered 'yes', they were then asked, 'Did you see the answer to the question flashed?'

Every question the subject failed to answer correctly during session 1 was presented. The type of prime appearing after these questions was assigned randomly, with the constraint that half of the primes were correct answers presented at the near-threshold duration and half were nonsense words at the near-threshold duration (hereafter, the condition of correct-answer prime is referred to as the 'answer condition', and the condition of nonsense-word prime is called the 'nonsense condition').

[1] Additional questions and primes (representing both answer and nonsense conditions) equal in the number to those presented at the near-threshold duration, were presented at 90% of that duration. A detailed analysis of the data from this briefer duration is not presented here. Suffice it to say that no effect of prime type on either the FOK or recall performance was observed.

Table 1
Mean probability of recall, mean of individuals' median FOK rating, and FOK accuracy gamma from session 2 of experiments 1 and 2.

N	Measure	Kind of prime	
		Correct answer	Nonsense word
Experiment 1			
34	P (recall)	0.28	0.10
34	FOK rating	5.4	5.2
23	Gamma for FOK & recall	+0.53	+0.76
Experiment 2			
30	FOK rating	6.1	6.1

Note: *N* is the number of subjects upon which the measure is based.

Catch trials were included to motivate the subjects to attend to the briefer presentations. These consisted of randomly selected questions that the subject had correctly answered in session 1, with the primes being the correct answers presented at the CT duration. One catch trial occurred randomly in every block of eight questions.

Results and Discussion

The mean number of questions incorrectly answered in session 1 (and therefore presented in session 2) was 47 ($SD = 14$). The mean near-threshold duration, which was computed [2] via the algorithm in the appendix, was 32.27 msec ($SD = 5.57$). The primary results are from session 2 and are reported in table 1; they are described next.

Recall during session 2

To determine if recall was influenced by the near-threshold primes, the probability of correct recall – designated P(recall)–for questions in the answer condition was compared with that for questions in the nonsense condition (the latter is a measure of reminiscence – cf. Nelson et al. 1984, and Gruneberg et al. 1973). As indicated in table 1, the mean P (recall) was greater after the answer prime than after the nonsense prime, $t(33) = 5.74$, $p < 0.001$.

Feeling of knowing during session 2

FOK ratings in the answer condition were compared with those in the nonsense condition. To avoid making any assumptions beyond ordinal for the FOK ratings, we examined each subject's median FOK ratings rather than his or her mean ratings (in

[2] We refer to this as a computation rather than as an estimate of the presentation duration because (due to the apparatus) the amount of time that the item was on the screen was not completely determined by the near-threshold duration but instead took on one of two values, as described in the appendix.

accord with Nelson and Narens 1980b: 78). Of the 34 subjects, 20 had a median FOK greater in the answer condition than in the nonsense condition, vice versa for 9 subjects, and 5 subjects had ties. A sign test, examining the hypothesis that the FOK should be greater (versus less than or equal) following the answer prime than following the nonsense prime, indicated no significant difference between these two conditions ($Z = 0.857$, $p > 0.10$). [Note: The mean of the individual subjects' median FOK ratings, reported in table 1, also did not differ significantly following the answer prime versus the nonsense prime, $t(33) = 1.0$, $p > 0.10$.]

Changes in FOK ratings across sessions

In another attempt to detect any influence of primes on FOK, an additional analysis was conducted that might have even greater sensitivity. This analysis is based upon nonparametrically comparing, between the two conditions, the change in FOK from session 1 to session 2 for each subject and each question.

For any two questions, let the subscript 'J' designate a question in the answer condition and 'K' designate a question in the nonsense condition, and let 'fok1' represent a question's FOK rating during session 1 and 'fok2' represent its FOK rating during session 2. Then for a dyad of items J and K, the following are called 'positive reversals' in FOK due to the correct-answer prime:

(i) $\text{fok1}_J = \text{fok1}_K$ AND $\text{fok2}_J > \text{fok2}_K$,
(ii) $\text{fok1}_J < \text{fok1}_K$ AND $\text{fok2}_J = \text{fok2}_K$,
(iii) $\text{fok1}_J < \text{fok1}_K$ AND $\text{fok2}_J > \text{fok2}_K$.

The rationale is that instances of (i), (ii) and (iii) indicate that the correct-answer prime produced a positive effect on the FOK for item J, as compared with the effect of the nonsense-word prime on the FOK for item K. In the analogous way 'negative reversals' were also defined. The remaining cases were called 'nonreversals' because they provide no information as to the effectiveness or noneffectiveness of the primes on FOK; e.g., $\text{fok1}_J = \text{fok1}_K$ AND $\text{fok2}_J = \text{fok2}_K$.

The notion that positive reversals will be observed more often than negative reversals was tested by a within-subject comparison, with the result being that 19 subjects had more positive reversals than negative reversals, vice versa for 14 subjects, and one subject had an equal number of each, which yielded no significant difference (sign test, $p > 0.10$). This result, consistent with the one discussed above, shows no evidence of an effect of perceptual input on FOK.

Conclusion about relative sensitivity of FOK to perceptual input

The above results do not support the hypothesis discussed earlier. That is, at the outset the FOK was hypothesized to monitor information contributed to the memory system by a near-threshold prime even though the contributed information might not be sufficient to increase recall performance (i.e., FOK more sensitive than recall at monitoring incoming information). Instead, however, the results from the previous three sections suggest that at least under some conditions–such as those examined here–the FOK is *less* sensitive than recall as an indicant of new information contributed via perceptual input to the memory system. The ramifications of this conclusion are discussed below.

FOK accuracy

We also examined the relationship between subject's FOK in session 2 and recall performance in session 2. The subject's FOK ratings under both the answer condition and the nonsense condition proved to be reliably correlated with previous recall performance. The Goodman–Kruskal gamma correlation for each condition was computed for each subject. The rationale for using the gamma correlation is given in Nelson (1984, 1986). Mean gammas were then computed for each condition using the individual gammas of the 23 subjects whose recall performance differed across their range of FOK judgments and who therefore had determinate FOK-recall gammas in both conditions. The mean FOK-recall gamma (see table 1) was significantly greater for the nonsense condition than for the answer condition, $t(22) = 1.77$, $p < 0.025$. This difference between the FOK-recall gammas reflects a relative loss of predictive (or perhaps more appropriately, postdictive) power for those FOK judgments following the correct-answer prime.

Experiment 2

Experiment 2 was performed to extend the finding of experiment 1 that the improvement in recall attributable to the prime did not produce a corresponding improvement in FOK. Experiment 2 reexamined the FOK in a situation similar to experiment 1, with the main change being that the recall phase of session 2 was eliminated. The logic for this change is that the FOK ratings might be more sensitive to the effects of the prime when they are reported immediately after the prime rather than after the delay caused by an intervening recall task.

Method

Thirty new subjects (from the same population described above) participated in a procedure identical to that of experiment 1, except that the recall task in session 2 was omitted. Aside from this, the materials and procedure of experiment 2 were identical to those of experiment 1.

Results and Discussion

The primary results are reported in the bottom of table 1. Each subject's FOK ratings following the answer prime were compared with those following the nonsense prime. Of the 30 subjects, 14 had a median FOK that was greater after the answer prime than after the nonsense prime, 11 had a median FOK that was greater after the nonsense prime than after the answer prime, and 5 had ties. As in experiment 1, a sign test showed that this difference was not significant, $Z = 0.182$, $p > 0.10$. [Note: The mean of the individual subjects' median FOK ratings also did not differ significantly following the answer prime versus the nonsense prime, $t(29) = 0.03$, $p > 0.10$; as indicated in table 1, the two means were the same.]

Thus, as in experiment 1, there is no significant effect of the correct-answer versus nonsense conditions on the FOK that follows those conditions. However, the important point of our article is not so much that the FOK is completely unaffected (e.g., perhaps more subjects would eventually yield a reliable effect) but rather is this: A set of conditions – namely, input of small amounts of new information into memory – can produce an effect on subsequent recall without affecting the FOK.

General discussion

An increase in recall performance occurred following a near-threshold answer prime as compared to a near-threshold nonsense prime (experiment 1), but no effect of prime type on FOK was found (experiments 1 and 2). This pattern of results disconfirms the usual assumption (e.g., Hart 1967, and many others) that the FOK is always more sensitive than recall at detecting information in memory. Rather, the FOK is not always the most sensitive memory monitoring device, and, in particular, it is not as good as recall at detecting the perceptual input from a near-threshold prime.

This finding implies that the metamemory system does not have access to all aspects of the information in memory that are utilized by the recall process, which may be somewhat surprising because previous investigations have shown the FOK to be a good predictor of subjects' *subsequent* performance in a wide variety of memory tasks, including recognition, cued recall, lexical decision-making, relearning, reminiscence, and perceptual identification (for a review, see Nelson 1988).

The present findings also imply that there are at least two distinct memory processes involved in facilitating recall, consistent with models that conceptualize memory as a composite-of-associates structure (e.g., Murdock 1982), as well as with models that divide memory into multiple components (e.g., Bower 1967). For example, an item in memory that is below the retrieval threshold may have a subthreshold amount of information in memory that is accessed by the FOK. Then, if useful information (e.g., semantically related prime, contextual information, etc.) about the item is contributed to the system, by way of the perceptual input that is not monitored by the metamemory system, these two kinds of information – one detected by the metamemory system, the other not – can combine to raise the item above the retrieval threshold so that it becomes recalled. Although this notion of combining information across memory processes is not new to the literature, the present findings are of some importance because they provide empirical evidence for the notion offered here that 'unmonitored' information can be psychologically combined with 'monitored' information to produce the retrieval of a previously nonrecalled item.

Our findings also bear upon the existing literature from related areas. A brief discussion of the relevance of these findings is given next.

Relevance to other findings

Amnesia and the feeling of knowing

The present findings are consistent with results concerning amnesic patients obtained by Shimamura and Squire.

Shimamura and Squire (1986) found that Korsakoff patients have a severe metacognitive impairment in their ability to predict their memory performance on subsequent recognition tests for previously nonrecalled questions and for newly learned information, which both normal subjects and temporal lobe amnesics are able to predict accurately. They concluded that this 'demonstrates(s) that memory and metamemory are not inextricably linked: impaired FOK is not an obligatory component of anterograde amnesia'. This is consistent with conclusions drawn earlier in this paper stating that there are some processes in memory that are accessible to recall but that are not accurately monitored by the FOK.

Moreover, Shimamura and Squire (1984) and Shimamura (1986) report that both Korsakoff patients and temporal lobe amnesics exhibit priming influences on subsequent memory tasks, which implies that priming can input information to memory in both types of amnesia. This finding is consistent with the notion discussed above that information about a given item in memory may be distributed across several distinct memory processes and can likely be combined across memory processes to facilitate retrieval. This suggests that for the abovementioned amnesic patients the portion of memory influenced by priming is not the portion monitored by the metamemory system.

Insight problems and the feeling of knowing

The inability of judgments similar to FOK to monitor accurately a different kind of cognitive process was reported by Metcalfe (1986).

Metcalfe found, as did previous researchers, that the FOK has predictive value for performance on a subsequent recognition test. However, she also found that subjects were not reliable at predicting subsequent performance on problem solving tasks involving 'insight problems'. These are problems whose solutions are perceived by subjects as being spontaneous and non-incremental, unlike other types of problems involving solutions that are perceived by subjects as systematically and incrementally derived. It is plausible that solutions to insight problems involve mental processes that are beyond conscious manipulation, not unlike the mental processes involved in priming. Metcalfe showed that subjects' judgments concerning whether a correct insight would appear were invalid, thus demonstrating subjects' inability to monitor whatever underlies such solutions.

Perceptual identification and the feeling of knowing

The findings of Nelson et al. (1984) are also consistent with our findings when viewed from our perspective of combining two different kinds of information. That is, Nelson et al.'s finding that high FOK predicted better performance on a *subsequent* perceptual identification task can be interpreted as follows: Suppose a subject reports a high FOK for the subsequent recognition of a nonrecalled item, which in theory indicates an awareness of relevant information in memory that does not exceed the retrieval threshold. Further suppose that the perceptual input from a prime contributes some amount of information, which in itself is not sufficient to produce identification. Then, according to the 'combining notion', it is possible for these two amounts of information to combine to surpass the identification threshold (perhaps by surpassing the retrieval threshold), and as a result, perceptual identification is facilitated for items previously given a high FOK. An analogous explanation can be made for the failure of items given low FOK ratings to be identified.

The present study illustrates that high FOK ratings need not be directly related to the effect of primes on memory performance. Rather, it seems that a high FOK rating indicates that a lesser amount of additional information is needed to produce memory retrieval (or in the case of Nelson et al., perceptual identification) and that a low FOK rating indicates that a greater amount of additional information needs to be input into memory to produce retrieval.

Conclusions

The present findings suggest that the FOK does not monitor all aspects of memory. Specifically, the FOK does not monitor the perceptual input to the memory system that is contributed from near-threshold priming. As a consequence, FOK accuracy can be reduced for items that are primed with near-threshold stimuli. In addition, our results confirm the idea from multiple-process models of memory that information from different aspects of memory are capable of combining to facilitate performance on a recall task.

Appendix

Due to the nature of the equipment, not all of the items presented to a given subject were displayed for the same duration. This is because a 60 Hz monitor does not put items on the screen instantaneously; instead, it draws them line by line. Because the subject initiated the instruction to put an item on the screen, each item received one of two presentation times, depending upon which line on the screen was currently being drawn. These two presentation times were 'K multiplied by 16.67 msec' and '$K-1$ multiplied by 16.67 msec', where K was a fixed positive integer for each each subject (with K varying from subject to subject). The following algorithm was used to determine K for a given subject.

Let the *Duration Parameter* (DP) of T msec be defined as the T msec that elapsed between the computer-driven instruction to display the item and the computer-driven instruction to display the mask.

One DP – called the 'near-threshold duration' – was established by presenting nouns for brief durations. A dot within a frame appeared for a few seconds on the video screen, followed by a flashed word. The subject was instructed to fix his or her gaze on the dot and to identify the word when it appeared. Initially the word was presented for DP = 49.8 msec (the 'start time', abbreviated ST). If the subject successfully identified the prime, then the ST became the 'first estimated presentation time', abbreviated FEPT. However, if the subject failed to identify the prime at ST, then ST was increased by an increment of 5.31 msec. This process continued until the subject identified the prime, thereby yielding the FEPT.

Next the FEPT was decremented by 5.31 msec until a short enough DP was found for which the subject would incorrectly identify 8 successive stimuli. This was called the 'second estimated presentation time' or SEPT.

The computer continued by presenting stimuli at increments half the magnitude of the previous decrement from the SEPT as long as the subject continued to fail to identify 8 successive primes for each of the incremented DPs, but never equalling or exceeding the FEPT. If the subject correctly identified a single prime then the DP was shortened by a decrement half that of the previous increment duration, and so on. This staircase procedure continued until the increment/decrement was reduced to 0.66 msec *and* a DP shorter than FEPT was determined at which the subject failed to identify 8 successive primes. This DP was called the 'near-threshold duration', and it determines K above as the unique integral solution to the inequality,

$$((K-1)\times 16.67) < \text{near-threshold duration} < (K\times 16.67).$$

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