Associative facilitation of word recognition as measured from a neutral prime

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It is shown that lexical decision times to strong associates with an associative strength of approximately 40% are facilitated relative to targets following a neutral prime, "blank," whereas very weak associates with an associative strength of less than 3% are neither facilitated nor inhibited. It is also shown that relative to the "blank" baseline time, a row of crosses inhibits processing of the following target. The latter finding has implications for earlier studies that have used crosses as a neutral prime. In these studies, facilitation effects have been overestimated and inhibition effects have been underestimated. Neely (1976) has proposed a predict-and-match strategy according to which subjects are assumed to predict one or more targets from the prime and to match the actual target onto the predicted targets. A part of this theory is not supported by the present data. The results are discussed in terms of the two-process theory of expectancy (Posner & Snyder, 1975). They are also considered in the light of a recent theory by Becker (1980). As an alternative interpretation of part of the reported data, a coherence assumption by the subjects about all reading materials is introduced.

Many papers have appeared recently dealing with the notion of "priming" in word recognition. "Priming" is the technical term for influencing the processes of word recognition by a preparatory stimulus, the prime. Generally, either sentence fragments (Blank & Foss, 1978; Fischler & Bloom, 1979, 1980; Forster, 1976; Schubert & Eimas, 1977; Stanovich & West, 1979; West & Stanovich, 1978) or individual words (Becker, 1979; Fischler, 1977a, 1977b; Fischler & Goodman, 1978; Meyer & Schvaneveldt, 1971; Neely, 1976, 1977; Warren, 1977) have been tested for their priming effect on the recognition of a following word, the target. In the studies reported here, we have used individual words as primes. This choice was motivated by the main question initially posed in the present series of experiments, namely, whether the strength of an associative connection between prime and target determines the amount of influence exerted by the prime on target processing. Associative strength is generally assessed from word association norms, consisting of a list of stimulus words and the response words given to each of these by the subjects participating in the free association test. The associative strength between a stimulus word and a response word is determined as the proportion of subjects producing the response word to that particular stimulus word. The immediately prior presentation of a word that evokes a particular response word in a word association task has been shown to facilitate recognition

of the latter in a number of tasks, including lexical decision (Fischler & Goodman, 1978; Meyer & Schvaneveldt, 1971; Neely, 1976), tachistoscopic recognition (Rouse & Verinis, 1962; O'Neil, Note 1), and naming (Warren, 1977). Unfortunately, the question as to whether the effect of association is all or none or varies with the degree of associative strength between prime and target has not been answered satisfactorily.

For example, O'Neil (Note 1) measured the flash duration necessary for correct recognition of a target following a priming word. He found that recognition of the target was facilitated by association, but that backward association (well-very) produced as much facilitation as forward association (very-well). In this experiment, backward associations were considered weak associations, whereas forward associations were considered strong. This study was replicated and extended by Rouse and Verinis (1962), with the same result. In a naming task, Warren (1977) found no difference between the facilitation observed in a moderately associated set of materials and that found in a high-association set. Similarly, in a lexical decision task, Fischler (1977b) failed to find a positive correlation between associative strength and amount of facilitation in a post hoc analysis of his data. Also, when Neely (1977) divided his related targets into two sets according to category dominance in the Battig and Montague (1969) category norms, he did not find that high-dominant exemplars were facilitated more by the corresponding category name than were low-dominant exemplars. It is, however, not clear to what extent association norms and category norms can be considered similar. In contrast to these studies, Warren (1974) did find an effect of associative strength in a Stroop (1935)

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task: The higher the associative strength between prime and target word, the longer it took to name the color in which the target was printed. Also, Fischler and Goodman (1978), in a post hoc analysis of the effects of associative strength, found that word targets that were strongly associatively related to a preceding prime were classified faster as words in a lexical decision task than were words that were relatively weakly related to the preceding prime. Furthermore, in a study with sentence fragments as primes, Fischler and Bloom (1979) found that lexical decisions to word targets were facilitated only when the target was a highly likely completion of the preceding sentential context (mean predictability: .92); less predictable targets were not facilitated by their sentence prime. Finally, Becker (1980) found that an effect of category typicality depends upon the relative size of facilitation and inhibition within a particular experiment: When facilitation dominates inhibition, highly typical members of a category are facilitated more than are low-typicality members, but when inhibition dominates facilitation, high- and low-typicality members are facilitated to the same degree by the prior presentation of the category word.

The reason for these inconsistent findings is unclear. Part of this inconsistency may be due to the fact that different tasks have been used. For example, Rouse and Verinis (1962) and O'Neil (Note 1) used the flash duration necessary for correct recognition of the target in tachistoscopic presentation as the measure for an effect of associative priming. The critical flash duration was equal for strong and weak associates, and the conclusion was drawn that associative facilitation is an all-or-none effect in that particular task. Rouse and Verinis explained their finding as follows: "Once the subject realizes that the words are associated, he forms a general set to respond associatively to all the fixation words [primes]. If a subject has a general associative set, the set and the fixated word together activate a large number of associates, so that the subject can *guess* the correct word when he perceives only a letter or two. The part perceptions of the flashed word raise the probability of perception of the low-strength associates, thus making strength and direction of association less powerful factors than they are in other situations" (Rouse & Verinis, 1962, p. 302). But guessing takes time, and it is quite likely that strong associates are guessed faster on the basis of part perceptions than weak associates are. This postexposure temporal factor is ignored, but it should be taken into account as well as the length of the critical flash durations.

A second reason for the inconsistency may be that the mean associative strength for groups of prime-target pairs varies considerably across different experiments. Warren (1977) compared naming times to a moderately associated set with a mean associative strength of 34% with those to a high-association set with a mean associative strength of 64% and did not find a difference

between response times (RTs) to these sets. In the experiments reported below, the mean associative strength of the strongest related set is approximately equal to that of Warren's moderately related set. Our weakly related sets have a mean associative strength of less than 3%. It may well be the case that there is a positive relationship between associative strength and size of facilitation at the lower end of the scale of associative strength, but that the function reaches asymptote at some value below a strength of 34%.

A third reason for the inconsistent results of experiments testing associative strength may be that different stimulus-onset asynchronies (SOAs) between primes and targets have been used. Associative facilitation in recognition tasks is usually, at least partly, explained in terms of activation spreading automatically from the prime word's representation in the mental lexicon to the target's representation, thus temporarily lowering the recognition thresholds for externally presented words that correspond to these internally stored targets. The "closer" the target is to the prime in the mental lexicon, or the more accessible the link between prime and target, the earlier the presence of the prime becomes effective. Warren (1977) has shown that the temporal activation patterns are different for different types of semantic relationships between prime and target. Whether or not facilitation is found for a target related to the prime depends on the SOA as well as on the relation itself. When no facilitation is found, this result may indicate only that the chosen SOA is either too long (activation has decayed already) or too short (not enough time has elapsed since prime presentation for activation to build up) to show an effect.

In the same way that activation patterns for different types of semantic relationships are dissimilar, the time course of activation for strong and weak associates may be different. Strong associates may be considered functionally "closer" to their prime in lexical memory than are weak associates. According to this assumption, it should be possible to find facilitation for strong associates at a relatively early point in time from prime presentation, when weak associates do not yet benefit from the presence of a related prime. Another assumption, made by Collins and Loftus (1975), is that activation spreading from a prime decreases over time. If this is true, the absolute amount of facilitation for the weak associates that are finally reached by the activation wave will be smaller than that for strong associates and may even be absent due to advanced decay of activation.¹

Posner and Snyder (1975) argued that facilitation in target recognition is caused not only by automatic spreading activation, but also by a conscious attention component. According to them and others (e.g., Neely, 1976), subjects sometimes use this component to predict targets prior to their presentation. Subsequently, the predicted target(s) is (are) matched onto the actual target, and facilitation occurs when the match is successful.

When the target is unrelated to the prime, the subject is misdirected and target recognition is inhibited. Until recently, it was believed that inhibition could be caused only by the attentional system. According to this view, a conscious component is considered to be active and effective whenever inhibition is observed. Whether it is active depends on the proportion of related prime-target pairs presented to the subjects (Tweedy, Lapinski, & Schvaneveldt, 1977); whether it is effective depends on the SOA. Presumably, for attention to be effective, the SOA must be longer than the SOA at which the earliest effects of automatic spreading activation are observed, since facilitation and inhibition from conscious attention build up slower than facilitation caused by spreading activation (Neely, 1977; Posner & Snyder, 1975; but see Antos, 1979; Fischler & Bloom, 1979; Myers & Lorch, 1980). With respect to such a conscious component, we can make several predictions about recognition times of strong and weak associates: Strong associates will probably often be correctly predicted from the prime and will consequently be facilitated by conscious attention. In the experiments reported below, the association frequency to the prime of the weak associates was very low, so that these associates will only very rarely, if ever, be among the predicted ones. Therefore, we do not expect them to be facilitated by the operation of conscious attention. But if they are not predicted, others will be, so that the actual targets, the weak associates, will be inhibited.²

Considering the combined effects of spreading activation and conscious attention, we predict that, when the SOA is favorably chosen, they will both cause a certain amount of facilitation for strong associates. Weak associates are probably only facilitated by automatic spreading activation. The inhibiting effects of conscious attention may cancel out this facilitation or even cause an overall inhibition for weak associates. If this is the case, this inhibition for weak associates should be smaller than the inhibition for targets unrelated to the prime, since these are not facilitated by automatic spreading activation. In short, we would expect an overall facilitation for strong associates and an inhibition for unrelated words; for weak associates, the overall effect may be facilitatory, inhibitory, or altogether absent. But if a facilitation effect is observed for weak associates, it should be smaller than that for strong associates.

In our experiments, an SOA of 460 msec is used. This SOA is quite close to the 400-msec SOA of Neely (1977), with which he showed the automatic component of priming to be still effective and conscious attention to begin to show an effect. The choice of an SOA of 460 msec rather than 400 msec or some other SOA was made independently of Neely's result, but it was based on some preliminary priming experiments that we conducted that showed that with this SOA the overall RTs were both shorter than were those with

SOAs of 220 msec and 920 msec. The fact that with an SOA of 220 msec responses are relatively slow might indicate that the prime has not yet been completely processed by the time the target arrives. The relatively long RTs with an SOA of 920 msec may indicate that the subject's attention has drifted away from task performance when the target appears. At an SOA of 460 msec or thereabouts, the subject may be optimally ready to respond to the target (cf. Posner & Boies, 1971).

Inhibition and facilitation can be assessed only against the baseline effects of a neutral prime, which does not start conscious processing and spreading activation in the mental lexicon prior to target presentation. Following Becker (1980) and Neely (1976, 1977), we chose rows of crosses to serve as neutral primes in Experiments 1 and 4. In Experiments 2 and 3, the word "blank" was also used as a neutral prime, since, for reasons to be given below, cross primes seem to increase RTs to following targets artifactually, thus leading to an overestimation of facilitation and an underestimation of inhibition.

EXPERIMENT 1

Method

Materials. The positive trials consisted of four conditions of 16 trials each: one condition of strongly associated prime-target pairs, one of weakly associated prime-target pairs, one of unrelated prime-target pairs, and one in which the prime was always a row of crosses varying in length from three to six crosses. The mean association frequency (de Groot, 1980) to the prime for strong associates was 37.4%, with a standard error of 3.9. Fourteen of the strong associates were primary responses in the word association norms, and two were secondary responses. The mean association frequency to the prime for weak associates was 2.9%, with a standard error of .6. The position of the weak associates in the association response hierarchy varied between the 3rd and 13th. They all shared their position in these hierarchies with one or more other words. Five of the weak associates occurred only once as a response to the stimulus word in the norms. However, according to four independent judges, all of these "idiosyncratic" responses were "objective" in the sense that their relationship to the prime was obvious and could be understood without requiring an explanation from the subject. The relationships between prime and target were of various kinds, both for the strongly related pairs and for the weakly related pairs.

Prior to Experiment 1, unprimed baseline RTs for the targets in all four positive conditions were assessed in a lexical decision task in which 16 subjects participated. This was done to avoid any possible artifacts when comparing RTs between conditions. Apart from the 64 word targets to be used in Experiment 1, 98 other words and 162 pseudowords were introduced in this baseline experiment. All pseudowords were orthographically legal and easily pronounceable letter strings in Dutch. The mean baseline RTs for the four positive conditions in Experiment 1 ranged from 521 to 529 msec. The differences in mean baseline RTs between conditions were not significant ($t < 1$). The corresponding standard errors ranged from 7.4 to 11.0.

In addition to the 64 stimulus pairs with words as targets, 64 pairs were added in which the target was a pseudoword. All pseudowords were chosen from the baseline study. The proportion of word primes and cross primes in the negative

trials was equal to that in the positive trials: Forty-eight of the primes were words; 16 were rows of crosses varying in length from three to six crosses. The length of primes and targets in 16 word-pseudoword pairs was equated with the length of primes and targets in the category of crosses-pseudoword pairs. The remaining 32 word-pseudoword pairs were not strictly controlled in this manner. A second set of materials was constructed; this was the same as the first, except that the pseudoword targets from the crosses-pseudoword pairs and the 16 matched word-pseudoword pairs were swapped. This was done in order to replicate the finding from a preliminary experiment that pseudowords following word primes were responded to 43 msec faster than were pseudowords following cross primes. This finding could not be attributed to differences in processing the targets between these two negative conditions: When the targets in the word-pseudoword pairs were connected to the cross primes and vice versa, the effect did not reverse or disappear but remained equally large.

Subjects and Apparatus. Twenty students from the University of Nijmegen, all different from those who had participated in the baseline test, took part as subjects in the experiment. They were paid 6.00 guilders. Half of the subjects were given the first set of materials, and the second half were given the second set. The assignment of sets to the subjects was random. The subjects were tested in a group experiment room that allowed individual independent sessions under control of a multiprogramming computer system. Stimuli were presented in uppercase (white on gray) on individual TV monitors under program control. Individual stimulus presentation, RT collection, and feedback were performed by a program called LEXSYS (Hudson, Maarse, & Bouwhuisen, Note 2).

Procedure. Subjects were tested in groups of one to four in a darkened room. A session lasted 35 min. Subjects were first instructed by the experimenter and were then given further instructions on their terminal screens. In the instructions, the subjects were told that pairs of character strings were going to be presented on the screen, one string after the other, and that they had to decide, as quickly and as accurately as possible, whether or not the second character string of each pair was a Dutch word. They were also told that the first character string would be either a word or a row of crosses, and they were asked neither to respond overtly to this string nor to ignore it. If the second string was a word, they were to press the positive response key on the right-hand side of the keyboard in front of them with their right forefinger. If this string was not a word, they were to press the negative response key on the left-hand side of the keyboard with their left forefinger.

Prior to every first character string of a pair, a fixation star appeared for 1 sec, slightly above and to the left of the place at which the first string, the prime, would appear. The star was immediately replaced by the prime, which remained on the screen for 440 msec. The interstring interval between prime and target was 20 msec, so that the total SOA was 460 msec. The target appeared slightly below the position where the prime had been and remained on the screen until the subject pressed one of the two response keys. Latencies and errors were recorded on-line. After every trial, one of the words "good," "slow," or "wrong" appeared. "Slow" occurred whenever a response was correct but exceeded a preset 1,000-msec deadline. When the subject failed to respond within 2,500 msec from stimulus onset, the message "too late" was shown and an error was recorded. When a subject had made three errors, the following message was displayed: "You are making too many errors; you have made three up to now." This message was repeated and updated with every other new error. The experimental trials were presented in five blocks of 24 trials each and one last block consisting of 8 trials only. After each block, the mean RT and the number of errors for that block were presented on the screen. After a minimum forced rest of 10 sec, the subject initi-

ated the presentation of a new block by pressing one of the response keys. Prior to the experimental trials, 32 practice trials were run. In the practice session, all trial types appeared in the same proportion as in the experimental session.

Results and Discussion

In the following analyses, the mean RTs within each of the six relevant prime-target categories were calculated for each subject and were treated as single observations; in the item analyses, the mean latencies for targets across subjects were treated as single scores. Latencies were calculated for correct responses only. The mean latencies and error rates are shown in Table 1 for all types of trials.

Data of the positive trials. A 4 (prime type) by 20 (subjects) ANOVA was performed on the data, with prime type as a within-subjects variable. The effect of prime type was significant [$F_s(3,57) = 11.22, p < .01$]. A second ANOVA (4 by 16), with prime type as a between-subjects variable, was performed with items as the unit of analysis. In this analysis, the effect of prime type was not significant [$F_i(3,60) = 1.80, p > .10$]. A Newman-Keuls test was performed on the difference scores from the subject analysis. The 37-msec difference between strongly related pairs and unrelated pairs, the 23-msec difference between weakly related pairs and unrelated pairs, and the 21-msec difference between strongly related pairs and crosses-word pairs were all significant at the .01 level. The 16-msec difference between unrelated-word pairs and crosses-word pairs and the 14-msec difference between strongly and weakly related pairs were both significant at the .05 level. The 7-msec difference between weakly related pairs and crosses-word pairs was not significant.

Although, on the subject analysis, we do find a difference in processing times for strong and weak associates in the predicted direction, the item analysis shows that we cannot draw a firm conclusion from it or from any of the other observed differences between conditions. It may have been the case that our independent-items design, with only 16 words in each condition, was not sensitive enough to show strong effects. In Experiment 2, below, the sensitivity of the design will be

Table 1
Mean Response Times (in Milliseconds) and Error Rates (in Percentages) of Word Targets Following Strongly Related Primes, Weakly Related Primes, Unrelated-Word Primes (URW), and Unrelated-Cross Primes (URC), and of Pseudoword Targets Following Word Primes and Following Rows of Crosses (Experiment 1)

Word Targets			Pseudoword Targets		
Prime Type	RT	Error Rate	Prime Type	RT	Error Rate
Strong	528	1.9			
Weak	542	3.1			
URW	565	5.3	Word	594	1.9
URC	549	3.8	Crosses	633	3.4

enhanced by an increase in the number of items per condition.

Data of the negative trials. Table 1 shows that pseudowords following rows of crosses had latencies that were 39 msec longer overall than RTs to pseudowords following words. This difference is about the same as the 43-msec difference found in the preliminary experiment (see "Materials"). Neely (1976) found a difference in the same direction between these two types of prime-target pairs, although in his case it was much smaller (12 msec across three different SOAs). We designed our experiment (see "Materials") such that we would be able to rule out the possibility that, for whatever reason, the particular selection of pseudoword targets following cross primes was more difficult to process than the (different) selection of pseudowords following word primes: The pseudowords that were combined with word primes for half of the subjects were paired with cross primes for the remaining subjects, and vice versa. If for both groups of subjects RTs to crosses-pseudoword pairs were relatively long, we would have to attribute this to differences in prime processing, not in target processing. A 2 (groups) by 2 (prime type) by 10 (subjects) ANOVA, with groups as a between-subjects factor and prime type as a within-subjects factor, that was performed on the data for word-pseudoword and crosses-pseudoword pairs only showed the same effect for both groups: The effect of prime type was significant [$F_s(1,18) = 42.30, p < .01$]. The 2 by 2 by 16 ANOVA that was performed with items as the unit of analysis and with both groups and prime type as between-subjects factors was also significant [$F_i(1,60) = 7.75, p < .01$]. Min F' (Clark, 1973) combining the F values from the two analyses was $\min F'(1,75) = 6.55 (p < .05)$. There was no interaction between groups and prime type. From this analysis, we must conclude either that word primes are facilitatory to processing pseudoword targets or that cross primes inhibit processing of the following pseudowords. Neely (1976), who explains his data in terms of the predict-and-match strategy (see introduction), takes the former approach. He assumes that, when the actual target does not match (one of) the target(s) predicted from the prime, the subjects tend to classify the target as a pseudoword. Therefore, pseudoword targets following word primes are facilitated, and at the same time unpredicted word targets are inhibited. On the other hand, Antos (1979) refers to the inhibitory effect of cross primes. In a pilot study, he found that subjects tended to respond to the second *linguistic* event. That is, on trials in which crosses served as the priming stimulus, the subjects seemed to regard the target as the prime and to wait for an additional letter string to appear. Antos found that this tendency artifactually increased the RTs for the baseline condition. If this artifactual inhibition does occur, it affects word targets following cross primes as well. As a consequence, facilitation effects for related targets as measured from

the cross baseline condition will be systematically overestimated and inhibition effects for unrelated targets will be underestimated.

In a second experiment, we tried to test Antos' (1979) view by adding a second but "linguistic" type of baseline prime to the cross prime in order to directly compare both their effects on target processing. If Antos' suspicion that subjects tend to wait for the second linguistic event is correct, then RTs to words and pseudowords following this linguistic prime should be shorter than RTs to targets following cross primes. Antos chose the word "neutral" as prime in the baseline condition. We preferred the word "blanco" (blank), because the word "neutraal" (neutral) is considerably longer than the mean length of the word primes in Experiment 2, below. The "blank" baseline prime has been successfully used by Myers and Lorch (1980) in a sentence-verification paradigm. The matter seems especially worthy of further investigation because the difference in processing times for word-pseudoword and crosses-pseudoword trials is the only effect in Experiment 1 that is reliable both on the subject analysis and on the item analysis. If Neely's (1976) predict-and-match interpretation of this effect is correct, would it not be reasonable, then, to expect a symmetrical result on the positive data, that is, a reliable inhibition for words following unrelated-word primes, since it has the same cause as the "facilitation" for pseudowords following word primes?

In Experiment 2, the question is also asked whether with a new and larger set of materials the recognition of strong associates is affected more by a prime than is the recognition of weak associates.

EXPERIMENT 2

Method

Materials. The baseline RTs for all targets used in this experiment were taken from the baseline study described in the Materials section in Experiment 1. The positive trials consisted of five conditions of 24 trials each: one condition of strongly associated prime-target pairs, one of weakly associated prime-target pairs, one of unrelated prime-target pairs, one condition in which the prime was always the word "blank," and the last condition, in which the prime was a row of crosses varying from three to six. The mean baseline RT was similar for all conditions, namely, 525 msec. The corresponding standard errors ranged from 6.0 to 7.2. The mean association frequency (de Groot, 1980) to the prime for strong associates was 37.4%, with a standard error of 2.9. Twenty of the strong associates were primary responses in the word association norms, and four were secondary responses. The mean association frequency to the prime for weak associates was 1.9%, with a standard error of .2. The position of the weak associates in the association response hierarchy varied between the 3rd and the 16th. They all shared their position in this hierarchy with one or more other words. Ten of the 24 weak associates occurred only once as a response to the corresponding stimulus word in the norms. As in Experiment 1, care was taken that all weak associates be "objectively" related to the prime. The relationships between prime and target were of various kinds, both for the

strongly related pairs and for the weakly related pairs. None of the targets in the unrelated-word/word pairs appeared as a response to the prime in the association norms.

The negative trials also consisted of five conditions of 24 trials each. Three conditions were the same; they consisted of word-pseudoword pairs. The fourth consisted of "blank"-pseudoword pairs, and the last consisted of crosses-pseudoword pairs. Again, the mean baseline RTs of the targets were similar for all conditions, namely, 587 msec. The corresponding standard errors ranged from 6.6 to 8.4.

Subjects, Apparatus, and Procedure. Twenty students from the University of Nijmegen, none of whom had participated in the baseline test or in Experiment 1, took part in this experiment. Each was paid 7.50 guilders for participation.

The apparatus and procedure were the same as those in Experiment 1. The only difference was that, this time, the "good-slow" deadline was set at 800 msec rather than at 1,000 msec. Fifty practice trials were presented prior to the experimental trials. In the practice session, all trial types appeared in the same proportion as in the experimental session. The experiment lasted about 55 min.

Results and Discussion

In the following analyses, the mean RTs within each of the relevant prime-target categories were calculated for each subject and were treated as single observations; in the item analyses, the mean latencies for words across subjects were treated as single observations. Latencies were calculated for correct responses only. Table 2 shows the mean latency and error rates for all types of positive and negative trials.

Data of the positive trials. From Table 2, we see that targets following "blank" primes were processed faster than were targets following cross primes. This supports Antos' (1979) notion that subjects wait for the second linguistic event. If we accept the RT to the targets following "blank" as a baseline for measuring facilitation and inhibition, strong associates were facilitated 19 msec, whereas unrelated words were inhibited 22 msec. RTs to weak associates were approximately similar to the baseline times. However, if we accept the RTs to the targets following crosses as the baseline, strong associates were facilitated 35 msec, weak associates were facilitated 19 msec, and unrelated words had RTs similar to the baseline. The ANOVAs performed on the positive data with prime type as the only factor (five levels) were significant [$F_5(4,76) = 14.39, p < .01$;

$F_4(4,115) = 6.12, p < .01$; $\min F'(4,183) = 4.30, p < .01$]. Subsequently, a Newman-Keuls test was performed on the difference scores from the subject analysis. The strong associates were significantly faster than all other targets at the .01 level. The weak associates were significantly faster than the targets following unrelated words and cross primes, both at the .01 level. The targets following "blank" primes were significantly faster than those following unrelated words ($p < .01$) and than targets following cross primes ($p < .05$).

The different processing times for words following the neutral cross prime on the one hand and following the neutral "blank" prime on the other support Antos' (1979) view that cross primes inhibit processing of the following targets. For this reason, we will no longer consider crosses as a proper neutral prime.

Above, we presented two ways of viewing the present data: Measured from the "blank" baseline, strong associates are facilitated, whereas RTs to weak associates are approximately similar to baseline times; measured from the "crosses" baseline, a relatively large facilitation can be observed for strong associates, together with a small facilitatory effect for weak associates. Since inhibition has been shown to occur on crosses-word trials, we prefer the former view.

The inhibition of targets following unrelated words has been explained by Neely (1976) in terms of a predict-and-match strategy (see introduction). Such a strategy on its own, however, cannot explain the response pattern to weak associates that occurs in our experiment. When it is applied, word targets are either facilitated or inhibited, depending on whether or not they occur among the predicted words, but they never escape an influence from the prime. However, our weak associates have RTs similar to targets following the "blank" baseline prime and cannot be said to be facilitated or inhibited. The predict-and-match strategy is likely to cause inhibition for weak associates: All weak associates had very low association frequencies to the prime and would certainly not have been among the predicted targets to be matched with the actual targets; therefore, they should have been inhibited. There is, however, a way to reconcile this lack of inhibition for weak associates with the matching model if we assume that facilitation can be caused in two ways, namely, by activation spreading automatically from the prime and by an attentional system of limited capacity. The latter is presumably involved in the predict-and-match strategy and is likely to cause inhibition for weak associates. The former may have reached the lexical entries corresponding to the weak associates by the time the targets were presented and may thus have brought these entries above threshold value, causing a certain amount of response facilitation. The facilitation caused by automatic spreading activation and the inhibition caused by the attentional strategy may have canceled each other's effects, resulting in baseline times. This explanation is

Table 2
Mean Response Times (in Milliseconds) and Error Rates (in Percentages) of Targets in All Prime-Target Pairs
(Experiment 2)

Word Targets			Pseudoword Targets		
Prime Type	RT	Error Rate	Prime Type	RT	Error Rate
Strong	517	1.3	Word	584	.4
Weak	533	1.7	Word	582	1.7
URW	558	4.8	Word	582	1.9
Blank	536	1.9	Blank	588	4.0
Crosses	552	2.3	Crosses	598	2.9

Note—URW = unrelated word.

a reasonable one, since it is known (Neely, 1977) that with an SOA of 460 msec, as used here, automatic spreading activation is still effective and conscious attention is just beginning to cause an effect.

For strong associates, the predict-and-match model correctly predicts a net facilitation effect: Because most of the strong associates have a reasonably high association frequency to the prime, the actual target will often be among the predicted targets. The overall effect for the conscious attention component will therefore be facilitatory, even when not all of the strong associates are correctly predicted. The activation spreading automatically from the prime will, if anything, only add to this effect.³

Data of the negative trials. Table 2 shows that the mean RTs to the three categories of word-pseudoword trials were very similar (584, 582, and 582 msec). Because the primes were words for all three categories and the mean baseline RTs for the targets were the same (see Materials section), this is what one would expect. The "blank"-pseudoword trials were 5 msec slower than the word-pseudoword trials. Crosses-pseudoword pairs were responded to 15 msec slower than were word-pseudoword pairs. This difference is 24 msec smaller than the corresponding difference in Experiment 1, but it comes very close to that found by Neely (1976): In his experiment, word-pseudoword pairs were 12 msec faster than crosses-pseudoword pairs across three different SOAs. RTs to crosses-pseudoword trials were 10 msec longer than were RTs to "blank"-pseudoword trials. The ANOVAs performed on the negative data with prime type as the only factor (five levels) showed that prime type was not quite significant on the subject analysis [$F_4(4,76) = 2.43$, $.05 < p < .10$] and was non-significant on the item analysis. Therefore, no further analyses were performed on the pseudoword data.

The absence of a significant difference, both on the subject analysis and on the item analysis, between word-pseudoword and crosses-pseudoword trials is inconsistent with the preliminary experiment and with Experiment 1. The following two factors may have been responsible for this inconsistency: First, the total number of cross primes both in Experiment 1 and in the preliminary experiment was considerably smaller than that in Experiment 2, namely, 32 vs. 48. Therefore, the subjects in Experiment 2 may have become more familiar with the cross primes; consequently, the tendency to consider the primes to be some sort of alerting signal preceding two linguistic events may have diminished. Second, the proportion of baseline trials in Experiment 1 and the preliminary experiment was considerably smaller than that in Experiment 2 (25% vs. 40%). These two possibilities will be investigated further in Experiment 4. With respect to the question posed prior to this experiment, namely, whether the difference between word-pseudoword and crosses-pseudoword pairs in Experiment 1 had to be interpreted in terms of a

facilitation for pseudowords following word primes (Neely's, 1976, view) or in terms of an inhibition of pseudowords following cross primes (Antos', 1979, view), the positive data of this experiment provide compelling evidence in favor of the second view: Although both are "neutral" primes, word targets following "blank" primes are processed significantly faster than are those following cross primes. This provides direct evidence that cross primes inhibit processing of the following targets and runs counter to Neely's conception that word primes facilitate pseudoword recognition due to a "no" response bias when the target predicted from the prime does not match the actual target.

If it could be shown that RTs to crosses-pseudoword pairs are longer than RTs to word-pseudoword pairs in a condition in which all word targets are unrelated to the word prime, this would be additional evidence for the inhibiting effect of cross primes and against the idea that the inhibition is caused by a bias toward responding "no" when the actual target does not match one of the predicted targets: When the prime word and the target word are never related, it is not likely that the subject will apply a predict-and-match strategy. Without this strategy, a "no" response bias in case of a mismatch will also be absent.

In the following experiment, RTs to word and pseudoword targets are measured following unrelated-word primes, "blank" primes, cross primes, and following the word "ready." The last served as a neutral prime, along with "blank" and cross primes. "Ready" was included as a neutral prime since the overall mean for "blank"-pseudoword trials in Experiment 2 was a little higher than that for word-pseudoword trials, although not significantly so. It may have been the case that some of the subjects were inhibited by "blank" for a reason other than the second-linguistic-event inhibition. The fact that a prime is repeatedly presented may cause the subject to suspect that the word itself has some special meaning. Of course, if this were the case, part of the inhibition by crosses would have to be attributed to the same phenomenon. The repeated "ready" prime should also be negatively influenced by this effect, but this inhibition may perhaps be compensated for by the fact that the word "ready" (in contrast to the word "blank") explicitly draws the subject's attention to the task.

EXPERIMENT 3

Method

Materials. The baseline RTs for all targets used in this experiment were taken from the baseline study described in Experiment 1. The positive trials consisted of five conditions of 28 trials each: two conditions of unrelated-word/word pairs (identical conditions with different materials), one condition in which the prime was always the word "blank," one in which the prime was a row of crosses varying from three to six crosses, and a last condition, in which the prime was always the word

"ready" followed by an exclamation mark. The mean baseline RTs of the targets were the same for all conditions, namely, 535 msec. The corresponding standard errors ranged from 7.0 to 7.4.

The negative trials also consisted of five conditions of 28 trials each: two conditions of word-pseudoword pairs (different materials), one of "blank"-pseudoword pairs, one of crosses-pseudoword pairs, and one of "ready"-pseudoword pairs. The mean baseline RTs ranged from 584 to 586 msec. The corresponding standard errors ranged from 5.8 to 7.4 msec. These stimulus materials were organized in five different ways, such that the targets of all conditions, words and pseudowords, were connected with the primes of each of the five conditions. Thus five sets of materials were generated, each consisting of 280 primes and 280 targets, but combined in different ways. For example, the word targets connected to the word primes in the first condition of unrelated-word/word pairs in Set 1 were linked with the word primes in the second condition of unrelated-word/word pairs in Set 2, with the "blank" primes in Set 3, with the cross primes in Set 4, and with the "ready" primes in Set 5. In the same manner, the pseudoword targets from every condition were connected to each of the five types of primes. The rationale behind this was to ensure that RT differences across the different types of positive and negative prime-target pairs were due to differences in prime processing, not target processing.

Subjects, Apparatus, and Procedure. Forty students from the University of Nijmegen, all different from those who had participated in the baseline test and in Experiments 1 and 2, took part in this experiment. They were paid 7.50 guilders for participation. Each subject was randomly assigned to one of five groups. A group consisted of eight subjects who were presented the same stimulus set.

The apparatus and procedure were the same as in Experiments 1 and 2. As in Experiment 2, the "good-slow" deadline was set at 800 msec. Fifty practice trials were presented prior to the experimental trials. In the practice session, all trial types appeared in the same proportion as in the experimental session. The experiment lasted about 1 h.

Results and Discussion

In the following analyses, the mean RTs within each of the prime-target categories were calculated for each subject and were treated as single scores. Latencies were calculated for correct responses only. Table 3 shows the mean latency and error rate for all types of positive and negative trials.

With both the word and the pseudoword data, the RTs to targets following "blank" primes were approximately equal to those following "ready" primes. The "ready" prime did not compensate for a possible effect caused by repeated presentation of primes. In fact,

Table 3
Mean Response Times (in Milliseconds) and Error Rates
(in Percentages) of Targets in All Prime-Target Pairs
(Experiment 3)

Word Targets			Pseudoword Targets		
Prime Type	RT	Error Rate	Prime Type	RT	Error Rate
URW	582	4.2	Word	629	2.1
URW	588	5.4	Word	633	2.3
Blank	571	3.1	Blank	638	3.4
Crosses	583	3.2	Crosses	649	3.5
Ready	576	3.2	Ready	639	2.9

Note—URW = unrelated word.

some subjects mentioned that they were inhibited by the "ready" prime in a way similar to the one we have assumed for cross primes: The target was interpreted as being the prime, since "ready" rather than the preceding fixation star was interpreted as the alerting signal.

Data of the positive trials. A 5 (groups) by 5 (prime type) by 8 (subjects) ANOVA was performed on the subjects' means for the positive conditions. The effect of prime type was significant [$F_4(4,140) = 3.75$, $p < .01$]. The main effect of groups was not significant, nor was the interaction between subject groups and prime type. This indicates that the effect of prime type was not confounded with differences in target processing demands across the different conditions of prime-target pairs within each set of material. It also indicates that the effect can be generalized to at least five different sets of materials. Therefore, no item analyses were performed on the data and no min F' values were calculated. A Newman-Keuls test was performed on the difference scores from the subject analysis. The RTs to words following "blank" primes were significantly shorter ($p < .01$) than were those to targets in the second condition of word-word pairs. None of the other differences between means was significant. The finding that in this experiment, in which it is unlikely that subjects predicted the targets prior to presentation, the targets in one of the conditions of unrelated-word/word pairs were responded to significantly slower than the "blank"-word trials, was unexpected. This finding will be discussed below. The 11-msec difference between the RTs to "blank"-word trials and to targets in the first condition of word-word pairs was not significant ($Q = 3.24$; the critical value for the .05 level is 3.36), nor was the 12-msec difference between RTs to "blank"-word trials and crosses-word trials ($Q = 3.40$; the critical value for the .05 level is 3.69).

Data of the negative trials. A 5 (groups) by 5 (prime type) by 8 (subjects) ANOVA was performed on the subjects' means for the negative conditions. Only the effect of prime type was significant [$F_4(4,140) = 5.93$, $p < .01$]. Subsequently, a Newman-Keuls test was performed on the difference scores. The RTs to pseudowords following cross primes were significantly longer than were those following both sets of word primes ($p < .01$) and those following "blank" primes and "ready" primes ($p < .05$). RTs to targets following "ready" and "blank" primes did not differ significantly from those following either set of word primes.

These data provide evidence against Neely's (1976) view that pseudowords following word primes are facilitated due to a "no" response bias that is present as a side effect of the subject's strategy to generate the target and to match this generated target onto the actual target. When a mismatch is encountered, the subject would, according to this interpretation, be inclined to press the "no" button. Since the "no" response is appropriate when the target is a pseudoword, this tendency

would be facilitatory to the processing of pseudowords following words. But even when none of the targets is related to the prime, and, consequently, such a predict-and-match strategy will most likely be absent, pseudowords that follow word primes are processed faster than are those following cross primes.

The 18-msec difference between lexical decision times for pseudowords following cross primes and those following word primes (631 msec for the combined word-pseudoword conditions) was about the same as the nonsignificant 15-msec difference between the same conditions in Experiment 2, but considerably smaller than the 39-msec and 43-msec differences between those conditions in the preliminary experiment and in Experiment 1. In discussing the results of Experiment 2, we proposed two possible causes for this diminishing effect: first, the increasing absolute number of cross primes from 32 (16 preceding word targets and 16 preceding pseudoword targets) in the preliminary experiment and Experiment 1 to 48 and 56 in Experiments 2 and 3, respectively, and, second, the increasing proportion of baseline trials from 25% in the preliminary experiment and in Experiment 1 to 40% in Experiment 2 and 60% in Experiment 3. These two possibilities will be investigated in Experiment 4.

EXPERIMENT 4

Method

Materials. The materials were the same as those used in Experiment 2, except that all "blank" primes were replaced by rows of crosses varying in length from three to six crosses. These substitutions of crosses for "blank" primes are distinguished in subsequent analyses from the original "crosses" condition of Experiment 2 because the target items differ. The total number of cross primes in this experiment was 96, 48 preceding a word target and 48 preceding a pseudoword target. By this manipulation, the probability of baseline trials did not change but remained .40, as it was in Experiment 2. If the familiarity with the cross prime determines the size of inhibition of the following target, we may expect this inhibition to diminish even further or disappear altogether in this experiment. On the other hand, if the probability of baseline trials determines the size of inhibition, Experiments 2 and 4 should produce equal amounts of inhibition for targets following a cross prime.

Subjects, Apparatus, and Procedure. Twenty students from the University of Nijmegen, all different from those who had participated in the baseline test and in Experiments 1-3, participated as subjects in this experiment. They were paid 7.50 guilders.

The apparatus and procedure were the same as those in Experiments 1-3.

Results and Discussion

In the following analyses, the mean RTs within each of the prime-target categories were calculated for each subject and were treated as single scores; in the item analyses, the mean latencies for words across subjects were treated as single observations. Latencies were calculated for correct responses only. Table 4 shows

Table 4
Mean Response Times (in Milliseconds) and Error Rates (in Percentages) of Targets in All Prime-Target Pairs (Experiment 4)

Word Targets			Pseudoword Targets		
Prime Type	RT	Error Rate	Prime Type	RT	Error Rate
Strong	522	1.0	Word	599	2.5
Weak	540	1.5	Word	601	2.7
URW	572	7.9	Word	611	3.5
Crosses	565	2.9	Crosses	624	2.1
Crosses	557	5.0	Crosses	632	3.3

Note—URW = unrelated word.

the mean latency and error rates for all types of positive and negative trials.

Data of the positive trials. A 5 (prime type) by 20 (subjects) ANOVA was performed on the positive data, with prime type as a within-subjects variable. In this analysis, the effect of prime type was significant [$F_s(4,76) = 17.30, p < .01$]. On the corresponding 5 by 24 item analysis with prime type as a between-subjects variable, the effect of prime type was also significant [$F_t(4,115) = 7.82, p < .01$]. Clark's (1973) min F' combining the F values from both analyses was also significant [min $F'(4,185) = 5.39, p < .001$]. Subsequently, a Newman-Keuls test was performed on the difference scores from the subject analysis. The strong associates were significantly faster than both conditions of cross baseline trials and than the targets following unrelated words, at the .01 level; they were significantly faster than the weak associates at the .05 level. The weak associates were significantly faster than the unrelated-word/word pairs and the first condition of cross baseline trials at the .01 level, and they were significantly faster than the second condition of cross baseline trials at the .05 level. The 8-msec difference between the two conditions of baseline trials and the 7-msec and 15-msec differences between the unrelated-word pairs on the one hand and the two baseline conditions on the other were not significant. This pattern of results is an exact replication of the pattern obtained in Experiment 2 and, therefore, strengthens the conclusions drawn there: Relative to unrelated-word pairs and cross baseline trials, both strong and weak associates are facilitated, but strong associates benefit more from the presence of their prime than do weak associates. The 18-msec difference between the facilitation effects for strong and weak associates is significant, as was the 16-msec difference between those two conditions in Experiment 2. Relative to cross baseline trials, unrelated-word pairs were slightly inhibited, but not significantly so.

Data of the negative trials. A 5 (prime type) by 20 (subjects) ANOVA was performed on the negative data, with prime type as a within-subjects variable; also, a 5 by 24 (items) ANOVA was performed on the data, with prime type as a between-subjects variable. On

both analyses, as well as on the min F' , the effect of prime type was significant [$F_s(4,76) = 10.14$, $p < .01$; $F_i(4,115) = 4.27$, $p < .01$; min $F'(4,183) = 3.00$, $p < .05$]. The Newman-Keuls test that was subsequently performed on the difference scores from the subject analysis showed that the three conditions of word-pseudoword trials were not significantly different from each other; neither were the two conditions of crosses-pseudoword trials. The first and second conditions of word-pseudoword trials were significantly different from both conditions of crosses-pseudoword trials, all at the .01 level. The third condition of word-pseudoword trials was significantly different from the second condition of crosses-pseudoword trials at the .01 level. The 13-msec difference between the third condition of word-pseudoword trials and the first condition of crosses-pseudoword trials was not significant. Although the last finding is not in accordance with the remaining results (but had the difference between these means been .5 msec larger, it would have reached significance on the Newman-Keuls), the whole pattern again strongly suggests that crosses-pseudoword trials are processed relatively slowly.

On the basis of these results, we conclude that the relative familiarity with the cross prime in Experiments 2 and 3 was not responsible for the relatively small difference between mean RTs to word-pseudoword and crosses-pseudoword pairs: When the number of cross primes is increased, the inhibition for pseudowords following cross primes does not diminish further. In fact, the 24-msec difference between the overall mean for the word-pseudoword conditions (604 msec) and the overall mean for the cross-pseudoword conditions (628 msec) is larger than those in Experiment 2 (15 msec) and in Experiment 3 (18 msec), but it is still 15 msec smaller than that in Experiment 1 and 19 msec smaller than that in the preliminary experiment. Therefore, of the two suggested causes of the relatively slow responses to cross baseline trials, only the one concerning the probability of the baseline trials remains.

GENERAL DISCUSSION

The word data of Experiment 2 summarize the results of the present series of experiments. First, lexical decision times to strong associates of a preceding prime are relatively short, while (very) weak associates are neither facilitated nor inhibited by their primes. Second, the processing of words unrelated to a preceding word prime is inhibited. Third, rows of crosses inhibit processing of the following target. The first two results are intrinsically interesting, and the third shows the importance of an adequate neutral prime. Without such a prime, facilitation and inhibition effects cannot be assessed correctly. For example, when rows of crosses are used as the neutral prime, the size of facilitation effects will generally be overestimated and inhibition

effects will be underestimated. Becker's (1980) and Neely's (1976, 1977) findings must be reconsidered in this light.

We have interpreted the facilitation observed for strong associates and the lack of any effect for weak associates within the framework of Posner and Snyder's (1975) two-process theory of expectancy. According to this theory, facilitation in primed lexical decision can be caused by two different processes: by lexical activation spreading automatically from the prime to nearby memory locations in the mental lexicon, thus lowering the recognition thresholds for the words that correspond to these locations, and by attentional expectation patterns and response strategies developed by the subjects when they discover the fact that some of the prime-target pairs are related. Posner and Snyder assume that inhibition can be caused only by the attentional component. In Experiment 2, word targets following unrelated words were inhibited (22 msec). We have therefore assumed that, apart from spreading activation, conscious attention was operative. It is impossible to tell how much of the (19-msec) facilitation for strong associates was caused by spreading activation and how much by conscious attention, since the facilitatory effects of the two were confounded in our experiments. This is also a flaw in most other studies that investigate facilitation and inhibition effects by priming. Only Neely (1977) used a design in which the two types of facilitation were separated. The lack of an effect for very weak associates was explained by assuming that a facilitatory effect of spreading activation had been canceled by an inhibiting effect of conscious attention.

Recently, the assumption that inhibition can be caused only by the attentional component has been questioned. Posner and Snyder (1975) considered the effects of this component to develop slowly, to be under the control of the subjects, and to require capacity within an attentional system of limited capacity. The third property was held responsible for the inhibiting effects caused by the attentional component. Some recent studies (Antos, 1979; Fischler & Bloom, 1980; Myers & Lorch, 1980), however, show that inhibition is found with SOAs as small as 200 msec and that it is sometimes difficult to avoid. Both findings suggest that inhibition can be produced by "automatic" processes as well.

Automatic inhibition may be caused by an implicit assumption of fluent readers that reading material is always meaningfully related, or, in other words, that there is a coherence between words and the context in which they appear. When these fluent readers participate as subjects in a laboratory experiment in which word targets are preceded by sentence fragments, this assumption may cause them to expect targets that complete these fragments into meaningful sentences. When primes and targets are both single words, it may lead

subjects to expect words that are somehow related to the prime, for example, words that are word associations to the prime. This expectation may be particularly strong when the assumption is confirmed in a number of cases, that is, when some of the prime-target combinations are associatively related, but it may also be present when none of the prime-target pairs are related. It is possible that such an assumption produces a tendency in the subjects always to look for a meaningful relationship between word prime and word target before they indicate that they have classified the target as a word. This tendency will inhibit responding to all word pairs, but it will be especially inhibitory to unrelated-word pairs, since no relationship will be discovered to stop the search for coherence. When an unrelated-word pair is encountered, some deadline will have to be exceeded before the subject can quit the search. This inhibition may be called "automatic," insofar as the subjects engage themselves involuntarily in the activity of relating word meanings. It is, however, far less specific than the inhibition caused by interference from a list of one or more expected words, as was assumed in the predict-and-match model, since no word in particular is expected, but just any related word, irrespective of which one it is. Another difference between the predict-and-match model and the coherence assumption proposed here is that the former is usually assumed to affect a processing stage that precedes target recognition, thereby facilitating or inhibiting the recognition process, whereas the latter operates upon the meanings of prime and target after both have been recognized. This property may explain the fact that inhibition can be observed with very small SOAs: The only requirement for the coherence search is that two word meanings be available. As long as the SOA is long enough for the prime word to be consciously perceived, this requirement is fulfilled. However, when the prime is masked by the target or some other signal so that it cannot be recognized, the search cannot take place, and, consequently, inhibition for unrelated targets should disappear. This view implies that the critical variable is not the SOA, but whether or not the prime, as well as the target, can enter consciousness.

Some evidence supporting this idea of automatic inhibition comes from the word data in Experiment 3. In this experiment, none of the prime-target pairs were related, and therefore it was assumed that the subjects would not apply a predict-and-match strategy. Yet we found that the targets in at least one of the two conditions of word-word pairs were inhibited relative to the word targets following the neutral prime "blank." If the assumption is correct that the above strategy was indeed not used by the subjects, what else could have caused the inhibition within the unrelated-word pairs? The coherence assumption may provide a reasonably satisfactory answer to this question. Although the effect goes in the predicted direction also with the targets in

the second condition of word-word pairs, the difference between the "blank" baseline and this condition is too small to reach significance. The model also explains the fact that in Experiment 3 (and in Experiment 2) pseudowords following word primes are not inhibited relative to pseudowords following "blank" primes: The search for coherence can take place only when two word meanings are available.

Because the assumption that all reading material is meaningfully related postpones the lexical decisions to primed targets until a relation between prime and target has been found or some deadline has been exceeded, it can explain only (part of) the inhibition observed in the present series of experiments. Posner and Snyder's (1975) component of automatic spreading activation in the mental lexicon must be maintained in order to explain the net facilitation for strong associates and the baseline times for weak associates as measured from the "blank" baseline trials. Their conscious attention component need no longer provide the sole explanation for inhibition, although it is likely to operate under certain circumstances (e.g., when the probability of related trials is high and the SOA is very long).

Apart from considering the present experiments in light of Posner and Snyder's (1975) theory, we must also discuss them in terms of the theory that is proposed in a recent paper by Becker (1980) and that is partly related to the predict-and-match strategy set forth above. In this theory, a specific prediction strategy is distinguished from a general expectancy strategy. Depending on the distribution of relationship strengths between the words in the related-word pairs, the subjects performing a lexical decision task choose one of these two strategies. If most of the connections within the related-word pairs of a stimulus list are about equally strong, the response pattern will be determined primarily by the prediction strategy. On the other hand, if the strength of these connections varies considerably, the subjects will use the expectancy strategy. The former strategy produces facilitation dominance, that is, much facilitation for prime-related targets accompanied by a negligible amount of inhibition for targets unrelated to the prime; the latter strategy results in inhibition dominance, that is, little facilitation for related targets together with a large inhibitory effect for targets unrelated to the prime. Only when facilitation is dominant does a category name produce more facilitation with highly typical category members than with low-typicality members (see Experiment 5 in Becker, 1980). Becker used a string of five crosses as a neutral prime. Therefore, in comparing our results with those of Becker, we will consider the "cross" prime condition rather than the "blank" prime condition as the baseline. In doing so, we can readily see that in Experiments 2 and 4 the mean facilitation effect for the related conditions (27 msec in Experiment 2 and 30 msec in Experiment 4; in Experiment 4, the mean RT for both cross

prime conditions was taken as the baseline RT) is larger than the inhibition for the unrelated condition (6 msec in Experiment 2 and 11 msec in Experiment 4). Experiment 1 is not considered in this comparison because its data were not reliable, and Experiment 3 is omitted because no related-word pairs were included in its stimulus list. Under these facilitation-dominant circumstances, Becker's model predicts a difference between strong and weak associates with respect to the size of facilitation. In Experiments 2 and 4, we do indeed find more facilitation for strong associates (35 msec and 39 msec, respectively) than for weak associates (19 msec and 21 msec, respectively). However, an unsatisfactory aspect of an analysis of our data in terms of Becker's theory is that it departs from the assumption that strings of crosses are truly "neutral" primes. This assumption was challenged in the present series of experiments. In our Experiment 2, the pattern of facilitation dominance disappears if priming effects are measured from the "blank" baseline condition.

Summarizing the results of this series of experiments, we conclude that strong associates are facilitated when primed by a stimulus word from the association norms. The size of this facilitation, however, is smaller than has previously been assumed, since in earlier studies the "neutral" prime, a string of crosses, seems to have inhibited target processing. Contrary to this overestimation of facilitation, the inhibition for word targets preceded by unrelated words has been underestimated. As measured from the "blank" baseline prime, very weak associates do not seem to be positively or negatively influenced by their primes. The current data indicate that the probability of the baseline trials within a list of stimuli determines to what extent the priming pattern is distorted by the cross prime: If this probability is .40 or more, the inhibition of targets preceded by cross primes is about 15 msec and is sometimes unreliable (see the pseudoword data of Experiment 2). Nevertheless, *all* inhibition caused by cross primes, the unreliable as well as the reliable, produces a distortion if facilitation and inhibition are calculated from this baseline condition.

One final remark about the baseline nature of the "blank" prime remains to be made: Because, unlike word primes, the "blank" prime is repeatedly presented during the course of the experiment, it is more redundant than the word primes are. Thus, although it is a "linguistic" prime and, as such, preferable to the cross prime, it may still provide a systematic bias in the data. Furthermore, since it is presented so often, the meaning of the word "blank" will no longer be experienced by the subjects (this is, in fact, a prerequisite for any baseline prime). Therefore, relatively little appeal is made to the subjects' memory when such a baseline trial is presented. Also, only if two word meanings are presented can an inhibiting search for coherence, as described above, take place. Ultimately, the conclusion may be

drawn that baseline primes, in order to be truly "fair," should be both meaningful and varying in form; that is, they should be different words for different trials. By definition, such words can never be neutral, since they are either related or unrelated to the target. This would lead us into an awkward dilemma, to which as yet no obvious solution is available.

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- decisions to words that are presented for a second time are relatively fast, even when there is a lag of 2 days between the first and second occurrences of the repeated words.
2. If a subject predicts only one target from the prime, a strong associate with an association frequency to the prime of less than 50% will, in the same way as weak associates, more often be inhibited than facilitated on the basis of the conscious component. We will, however, assume that several targets are predicted from the prime. Neely (1977) takes a similar, although somewhat more abstract, approach. He assumes that subjects generate an expectancy consisting of a set of semantic features rather than a set of words. Facilitation occurs when the semantic features of the generated expectancy and of the presented target have sufficient overlap.
3. We have assumed that the relatively small number of trials per condition in Experiment 1 was responsible for the fact that, unlike in Experiment 2, the difference between strong and weak associates was not reliable on the item analysis. The difference in associative strength as measured from the association norms was about the same in Experiments 1 and 2. This measure of associative strength is based on production data: The subjects in a free association test generate one (or more) response word(s) to each of the presented stimulus words. A measure of associative strength based on more "receptive" data is obtained when subjects are asked to judge the relative strength between two words that are both presented. It is possible that the difference between the strong and weak associates of Experiment 1 as determined from such a receptive measure of associative strength is smaller than that in Experiment 2. This would provide an alternative interpretation of the inconsistency between Experiments 1 and 2. In order to test this possibility, the strongly and weakly related pairs, as well as the unrelated-word pairs of Experiment 1, 16 of each, were presented in written form to 12 subjects; the strongly and weakly related pairs and the unrelated-word pairs of Experiment 2, 24 of each, were presented to a second group of 12 subjects. Twelve filler word pairs were added to both lists. Four of these were strongly related, four were weakly related, and the remaining four were unrelated. All filler pairs were the same for both lists. The total number of word pairs in List 1 was 60; the second list consisted of 84 word pairs. The order in which the word pairs were printed was different for all subjects within a group. The subjects of both groups were asked to indicate on a 7-point scale how often thinking of the first word within a pair evoked the thought of the second word. They were to mark the 1 on the scale if this seldom happened; if it happened relatively often, they were to mark the 7. The results of this experiment show that the difference between the receptive associative strengths of strong and weak associates was small but reliable, and about the same for both lists ($p < .0001$ in both cases). Therefore, the inconsistency between Experiments 1 and 2 cannot be attributed to a relatively small difference in receptive associative strength between the strong and weak associates in Experiment 1. In List 1 (Experiment 1), the mean receptive associative strength for the 16 strong associates was 5.91, with a standard error of .15; the mean receptive associative strength for the 16 weak associates was 4.74, with a standard error of .19. The corresponding data for List 2 (Experiment 2) were 5.75 (SE = .13) and 4.73 (SE = .18). The mean receptive associative strength of the unrelated-word pairs was 1.36 (SE = .11) in List 1 and 1.31 (SE = .06) in List 2. The same values were attached to the filler items in Lists 1 and 2 ($t < 1$). The last finding allows us to consider the data of both groups of subjects as a whole.

NOTES

1. The lowered recognition thresholds of memory locations encountered by the activation wave will, of course, rise again over time. Let us assume that thresholds for strong associates to the prime are lowered 200 msec after prime onset and those for weak associates are lowered 400 msec after prime onset. When strong associates are presented at a 200-msec SOA, their recognition thresholds will be lowest and facilitation will be maximal. However, when they are presented at a 400-msec SOA, the thresholds will have risen again and facilitation will be past its maximum. Weak associates presented at this SOA will be maximally facilitated. If threshold rising takes place at the same rate at which spreading activation from the prime decays, the observed facilitation for strong and weak associates presented at a 400-msec SOA may be the same. We will, however, assume that the rate of decay of spreading activation will be more rapid than the process of threshold rising and that, therefore, differences between strong and weak associates will be observed in favor of the speed of recognition of the former. Evidence that thresholds of recognized words rise very slowly comes from a series of experiments by Scarborough, Cortese, and Scarborough (1977), in which it was shown that lexical

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