LEXICAL-CONTEXT EFFECTS IN VISUAL WORD RECOGNITION

A.M.B. de Groot

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Promotor: Prof. Dr. A.J.W.M. Thomassen

Co-referent: Dr. P.T.W. Hudson

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Aan Remmert
die er altijd in geloofde
en aan mijn ouders
die er nooit aan twijfelden

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CONTENTS

SUMMARY

The research reported in this thesis investigates the effect of a visually presented context stimulus on the recognition and further processing of a subsequent stimulus that is also presented visually. In all but one of the reported experiments, the so called 'lexical-decision' experiments, the context stimuli (primes) were followed by letter strings (targets) for which the subjects had to decide whether they were words or nonwords. The remaining experiment consisted of two sub-experiments. One of them was again a lexical-decision experiment; the second was a 'naming' experiment in which the subjects had to read the targets aloud. In the naming sub-experiment all targets were words. It is often found that in both these types of experiments responses are made faster when prime and target are words that are associatively related to one another (e.g., *foal-horse*) than when the target word is preceded by some neutral prime. Furthermore, under certain circumstances responses to target words following unrelated word primes (e.g., *horse* following *knife*) are made slower than those to target words preceded by a neutral prime. The present research was aimed at specifying the conditions under which these context effects occur and at providing insight into the underlying processes and the memory structure on which they operate. It is closely related to the research on the influence of incomplete sentences on subsequent visual word recognition. Studies of the latter type, and to a certain extent also the present word-prime studies, can throw light upon the way in which context is used during the reading of text.

In this thesis three processes are assumed to underly the above context effects, viz., (i) automatic spreading activation in the mental lexicon, (ii) prime-induced attentional processing, and (iii) post-lexical coherence check-

ing. The first two probably influence, both in lexical decision and in naming, the recognition of the target as a word, whereas the third operates on sets of minimally two word meanings and only starts after both the prime and the target have been recognized. It presumably affects the duration of the response-selection stage in lexical decision in which the word recognition of the target is translated into a *yes* response. Before the contents of the six chapters in this thesis will be summarized, we shall first describe briefly the workings of these three contextual processes.

Automatic spreading activation in the mental lexicon comes about when a word representation in this lexicon is contacted in consequence of the presentation of its corresponding stimulus, say the word prime. The activation that arises in the memory location 'hit' by the prime spreads out to 'nearby' word representations. If the organization of the mental lexicon reflects word relatedness, with the representations of related words being located closely to one another, the representations of words related to the prime will receive some of the activation that spreads from the memory location originally activated. When a word that corresponds to one of these pre-activated memory representations is subsequently presented as target, its recognition will be facilitated. If, however, a target word is presented that is not represented internally by one of the pre-activated memory locations, its recognition will not be affected, neither positively nor negatively, by the prior presentation of the prime word and the consequent spread of activation. Further characteristics of automatic spreading activation in lexical memory are that it is enacted automatically (hence its name), or, in other words, that it does not require attentional commitment, and that it comes about rapidly. Also, the fact that it is automatic presumably implies that it cannot be avoided.

The second process through which a prime word can affect subsequent target recognition, prime-induced attentional processing, implies the subject's use of the prime word to direct attention to memory locations of one or more words prior to target occurrence. If one of these 'expected' words is subsequently presented as target, it will be recognized relatively fast. But if the target is a word that is not among the expected ones, its recognition will be inhibited. In this respect prime-induced attentional processing differs from automatic spreading activation, that can only facilitate the recognition of certain words without inhibiting that of others. Further differences between the automatic and attentional process are of course that the latter requires attention and consequently acts much slower. Finally, unlike automatic spreading activation, prime-induced attentional processing is an optional strategy that will only be used when profitable.

The third contextual process, post-lexical coherence checking, implies that the subjects always try to relate the meanings of prime and target after both have been recognized. The duration of the response-selection stage in lexical decision can be influenced by the outcome of coherence checking: If prime and target are words that are related in meaning, and if this relationship is discovered before the word recognition of the target is translated into a *yes* lexical decision, the *yes* output of coherence checking shortens the post-lexical response-selection stage. On the other hand, if prime and target are unrelated words, and if the absence of a meaning relationship is discovered before the appropriate *yes* lexical decision has been selected, the *no* output of coherence checking lengthens this post-lexical stage. This thesis presents data suggesting that coherence checking is partly under the control of the subject: Although an effect of this process was already observed when none of the prime-target pairs among the experimental materials consisted of related words, the magnitude of the effect of coherence checking appeared to correlate positively with the number of related prime-target pairs in the set of materials.

In *Chapter I* the role of the associative strength between prime word and target word is investigated. Lexical-decision times to moderately associated targets (words that in a independent free-association test were given as associates to the prime words by about 40% of the subjects) were facilitated relative to targets preceded by a neutral prime. Furthermore, target words unrelated to the prime words were inhibited. Very weak associates (with an associative strength of less than 3%) were neither facilitated nor inhibited. Although these results can be explained in a number of ways, the most parsimonious interpretation is that they are caused by only one of the three contextual processes mentioned above, namely post-lexical coherence checking. Prime-induced attentional processing has probably not been operative in the experiments reported in this chapter, since such a strategy was unprofitable with the materials used. In contrast, automatic spreading activation in the mental lexicon subsequent to the prime word's presentation *must* have taken place, since it can never be prevented. Therefore, a null-effect of the spreading process implies that, although operative, it was not effective in the experiments of Chapter I. This, in turn, suggests that the representations of the moderately and weakly related target words in these experiments were not reached by the activation wave, and that the mental lexicon may have a less closely-knit structure than is often assumed. In addition to exploring the effect of associative strength between prime and target words, Chapter I is also concerned with evaluating a number of neutral primes. This evaluation leads to the conclusion that, compared to neutral primes that are words, neutral primes consisting of rows of *Xs* delay the responses to subsequent targets.

Chapter II primarily deals with automatic spreading activation in lexical memory. The associative strength within the related prime-target pairs presented in (some of) the experiments in this chapter was considerably larger than that within the related prime-target pairs in the experiments of Chapter I. We may therefore assume that, if a prime is ever to influence subsequent target processing through automatic spreading activation, it should be on these strongly related pairs. In Chapter II we particularly investigated the question of 'multiple-step' spreading activation, that is, whether the activation wave spreads not only to the representations of direct associates of the prime word, but also beyond these to locations one step further away in the memory network (e.g., of the location of *bull* via that of *cow* to that of *milk*). The results suggested that the spread stops after having reached the memory locations that most closely neighbour the prime word's representation. This finding provides an interesting new view on the structure of the mental lexicon, involving the multiple storage of words in two qualitatively different types of memory representations. In order to be able to tackle the question of multiple-step spreading activation, the prime words in three of the experiments in Chapter II were masked in such a way that they could not be reported by the subjects. Thus, we prevented prime-induced attentional processing and post-lexical coherence checking, (both of which can only operate if the prime is presented above recognition threshold), from intruding upon automatic spreading activation.

The effectivity of both automatic spreading activation and prime-induced attentional processing, and, consequently, the magnitude of context effects, depend largely upon the stimulus-onset asynchrony (SOA) of prime and target (i.e., the time interval between the onsets of prime and target). The third contextual process, post-lexical coherence checking, is much less dependent upon SOA. Irrespective of SOA, it can exert its effect whenever both prime and target are presented above recognition threshold. *Chapter III* presents a study that explored the development of context effects over 11 SOAs, varying between 100 and 1240 msec. Up to the longest SOA condition, the facilitatory effect of a related prime increased with increasing SOA, whereas the inhibitory effect of an unrelated prime remained virtually constant. Under favourable circumstances all three contextual processes cause related targets to be facilitated; two of them, namely, prime-induced attentional processing and post-lexical coherence checking, produce inhibition for unrelated targets. Therefore, it is difficult to determine to what extent each of the three contextual processes separately has contributed to the total amount of facilitation and inhibition observed in any specific condition. In Chapter III the pseudoword data are analysed in order to enable us to draw some conclusions on the relative contributions of the different context effects.

Chapter IV presents an experiment in which both the SOA of prime and target (three levels) and the proportion of related prime-target pairs in the set of experimental materials (four levels) were varied systematically. The combined manipulation of these two variables is particularly informative on the contribution of prime-induced attentional processing to context effects. Whereas the factor proportion presumably determines whether or not the subjects use this strategy, the SOA of prime and target determines its effectivity. Both variables appeared to affect the size of the context effects. Furthermore, the data suggested interdependence between them: The magnitude of the context effect varied with SOA only when the proportion of related pairs was relatively large. In contrast, there was an effect of proportion in all SOA conditions, although more so with the longest SOA than with the two shorter SOAs. In Chapter IV this finding is interpreted as indicating that prime-induced attentional processing is effective even at very short SOAs. This interpretation is, however, rejected in Chapter V, where it is suggested that not only prime-induced attentional processing, but also post-lexical coherence checking is sensitive to the proportion manipulation. It is proposed there that in the shortest SOA condition the proportion manipulation had influenced the workings and impact of the latter process.

Chapter V compares the effects of a related prime on target processing in lexical decision on the one hand and in word naming on the other hand. Unlike in all other experiments in this thesis, no unrelated prime-target pairs were included in the set of materials. It is argued that the outcome of post-lexical coherence checking can affect response times in lexical decision but not in naming. In contrast, automatic spreading activation in lexical memory and prime-induced attentional processing can influence response times in both tasks. Consequently, larger context effects were expected in lexical decision than in naming. This result was indeed obtained. Furthermore, the SOA of prime and target was systematically varied in this experiment. This manipulation affected the magnitude of facilitation only in naming: Whereas the facilitation was relatively large even at the shortest SOA and did not increase significantly over SOAs in the lexical-decision sub-experiment, a linear increase of facilitation over SOAs was observed in the naming sub-experiment. In the longest SOA condition the facilitation was about equally large in both tasks. The increase of facilitation over SOAs in the naming sub-experiment was attributed to increased effectivity of prime-induced attentional processing. It was argued that in lexical decision this increase of facilitation is concealed by the relatively large effect of post-lexical coherence checking, that occurs even at short SOAs.

Chapter VI, which concludes the thesis, presents a retrospective discussion of all experiments reported in the preceding chapters. It appears from this discussion that automatic spreading activation, prime-induced attentional processing and post-lexical coherence checking can explain the observed priming patterns in a satisfactory way.

CHAPTER I

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ASSOCIATIVE FACILITATION OF WORD RECOGNITION AS MEASURED FROM A NEUTRAL PRIME

A.M.B. de Groot, A.J.W.M. Thomassen, and P.T.W. Hudson

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 neutral *blank* prime, a row of *Xs* inhibits processing of the following target. The latter finding has implications for earlier studies that have used rows of *Xs* 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; Schuberth & 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) 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) of prime and target 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.[3]

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 *Xs* 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, *Xs* 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 *Xs* varying in length from three to six *Xs*. The mean association frequency (De Groot, 1980) to the prime for strong associates was 37.4%, with a standard error (SE) 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 presented to the subjects 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 *Xs* primes in the negative trials was equal to that in the positive trials: Forty-eight of the primes were words; 16 were rows of *Xs* varying in length from three to six *Xs*. The length of primes and targets in 16 word-pseudoword pairs was equated with the length of primes and targets in the category of *Xs*-pseudoword pairs. The remaining 32 word-pseudoword pairs were not strictly controlled in this manner. A second set of materials was constructed. This set was the same as the first, except that the pseudoword targets from the *Xs*-pseudoword pairs and the 16 matched word-pseudoword pairs were swopped. 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 *Xs* 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 *Xs* 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 *Xs*, 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 inter-string 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 further 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 initiated 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.

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 Xs Primes, and of Pseudoword Targets Following Word Primes and Following Xs Primes (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
Xs	549	3.8	Xs	633	3.4

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-items 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 *Xs*-word pairs were all significant at the .01 level. The 16-msec difference between unrelated word pairs and *Xs*-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 *Xs*-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 enhanced by an increase in the number of items per condition.

Data of the Negative Trials. Table 1 shows that pseudowords following rows of *Xs* 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 *Xs* 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 *Xs* primes for the remaining subjects, and vice versa. If for both groups of subjects RTs to *Xs*-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 *Xs*-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-items factors was also significant [F_i (1,60) = 7.75, $p < .01$]. MinF' (Clark, 1973) combining the F-values from the two analyses was also statistically reliable [*minF'* (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 *Xs* 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 *Xs* primes. In a pilot study, he found that subjects tended to respond to the second *linguistic* event. That is, on trials in which rows of *Xs* 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 neutral condition. If this artifactual inhibition does occur, it affects *word* targets that follow *Xs* primes as well. As a consequence, facilitation effects for related targets as measured from the condition with *Xs* as the neutral prime 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 neutral prime to the *Xs* 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 *Xs* primes. Antos chose the word *neutral* as prime in the neutral 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 word *blank* has been successfully used as neutral prime 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 *Xs*-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 *Xs* varying from three to six. The mean baseline RT was the same 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 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 *Xs*-pseudoword pairs. Again, the mean baseline RTs of the targets were the same 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 latencies and error rates for all types of positive and negative trials.

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
Xs	552	2.3	Xs	598	2.9

Note: URW = unrelated word

Data of the Positive Trials. From Table 2, we see that targets following *blank* primes were processed faster than were targets following *Xs* 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 *Xs* 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_s (4,76) = 14.39, $p < .01$; F_i (4,115) = 6.12, $p < .01$; $minF'$ (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 *Xs* 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 *Xs* primes ($p < .05$).

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

Above, we presented two ways of viewing the present data: Measured from the *blank*-prime condition, strong associates are facilitated, whereas RTs to weak associates are approximately similar to those in the *blank*-prime condition; measured from the *Xs*-prime condition, 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 *Xs*-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* 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 absence 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 cancelled each other's effects, resulting in RTs similar to those in the *blank*-prime condition. This explanation is a reasonable one, since it it 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 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'), this is what one would expect. The *blank*-pseudoword trials were 5 msec slower than the word-pseudoword trials. *Xs*-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 responded to 12 msec faster than *Xs*-pseudoword pairs across three different SOAs. RTs to *Xs*-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_s (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 *Xs*-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 *Xs* 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 *Xs* 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 neutral 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 *Xs*-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 *Xs* 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 *Xs* primes. This provides direct evidence that *Xs* 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 *Xs*-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 *Xs* 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, *Xs* primes, and following the word *ready*. The last served as a neutral prime along with *blank* and *Xs* primes. *Ready* was included as a neutral prime since the overall mean RT for *blank*-pseudoword trials in Experiment 2 was a little larger 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, and therefore to linger on this prime. Of course, if this were the case, part of the inhibition by *Xs* 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 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 *Xs* varying from three to six *Xs*, 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 *Xs*-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 both within the set of word-target trials and within the set of pseudoword-target trials the targets of all conditions were connected with the primes of each of these 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 pairs in Set 1 were linked with the word primes in the second condition of unrelated word pairs in Set 2, with the *blank* primes in Set 3, with the *Xs* 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 the RT differences between the different types of positive and negative prime-target pairs that would possibly be obtained could be attributed to differences in prime processing, not in 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 latencies and error rate for all types of positive and negative trials.

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
Xs	583	3.2	Xs	649	3.5
ready	576	3.2	ready	639	2.9

Note: URW = unrelated word

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, some subjects mentioned that they were inhibited by the *ready* prime in a way similar to the one we have assumed for *Xs* 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_s (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 minF' 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 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 *Xs*-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_s (4,140) = 5.93, $p < .01$]. Subsequently, a Newman-Keuls test was performed on the difference scores. The RTs to pseudowords following *Xs* 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 *Xs* primes.

The 18-msec difference between lexical-decision times to pseudowords following *Xs* primes and to those following word primes (631 msec for the combined word-pseudoword conditions) was about the same as the nonsignificant 15-msec difference between these conditions in Experiment 2, but it was considerably smaller than the 39-msec and 43-msec differences between these 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 *Xs* 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 neutral 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 *Xs* varying in length from three to six *Xs*. These substitutions of *Xs* for *blank* primes are distinguished in subsequent analyses from the original neutral *Xs*-prime condition of Experiment 2 because the target items differ. The total number of *Xs* primes in this experiment was 96, 48 preceding a word target and 48 preceding a pseudoword target. By this manipulation, the probability of neutral trials did not change but remained .40, as it was in Experiment 2. If the familiarity with the *Xs* 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 neutral trials determines the size of inhibition, Experiments 2 and 4 should produce equal amounts of inhibition for targets following an *Xs* 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 through 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 through 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 the mean latencies and error rates for all types of positive and negative trials.

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
Xs	565	2.9	Xs	624	2.1
Xs	557	5.0	Xs	632	3.3

Note: URW = unrelated word

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-items variable, the effect of prime type was also significant [F_i (4,115) = 7.82, p < .01]. Clark's (1973) minF' combining the F-values from both analyses was also significant [*minF'* (4,185) = 5.39, p < .001]. Subsequently, a Newman-Keuls test was performed on the difference scores from the subject analysis. The condition with strong associates was significantly faster than both conditions with *Xs* as neutral prime and than the condition of unrelated word pairs, 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 pairs and than the first condition with rows of *Xs* as neutral prime, both at the .01 level, and they were significantly faster than the second condition with rows of *Xs* as prime at the .05 level. The 8-msec difference between the two conditions of neutral trials and the 7-msec and 15-msec differences between the unrelated word pairs on the one hand and the two neutral 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 trials with *Xs* as prime, 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 trials with *Xs* as prime, 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-items variable. On both analyses, as well as on the minF', the effect of prime type was significant [F_s (4,76) = 10.14, p < .01; F_i (4,115) = 4.27, p < .01; *minF'* (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 *Xs*-pseudoword trials. The first and second conditions of word-pseudoword trials were significantly different from both conditions of *Xs*-pseudoword trials, all at the .01 level. The third condition of word-pseudoword trials was significantly different from the second condition of *Xs*-pseudoword trials at the .01 level. The 13-msec difference between the third condition of word-pseudoword trials and the first condition of *Xs*-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 *Xs*-pseudoword trials are processed relatively slowly.

On the basis of these results, we conclude that the relative familiarity with the *Xs* prime in Experiments 2 and 3 was not responsible for the relatively small difference between mean RTs to word-pseudoword and *Xs*-pseudoword pairs: When the number of *Xs* primes is increased, the inhibition for pseudowords following *Xs* 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 *Xs*-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 small difference between mean RTs to word-pseudoword and *Xs*-pseudoword trials in Experiments 2 and 3, only the one concerning probability of the neutral 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 *Xs* 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 *Xs* 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's representation 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 cancelled 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 is 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 was related, and therefore it was assumed that the subjects would not apply a predict-and-match strategy. Yet we found that the targets in 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 for the unrelated word pairs? The coherence assumption may provide a reasonably satisfactory answer to this question. Although the effect also goes in the predicted direction in the second condition of word-word pairs, the difference between the condition with *blank* primes 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 fact that weak associates are not inhibited relative to the *blank*-prime 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 the 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 that serves as prime produce more facilitation on targets that are highly typical members of the category referred to by this prime than on targets that are low-typicality members (see Experiment 5 in Becker, 1980). Becker used a string of five *Xs* as a neutral prime. Therefore, in comparing our results with those of Becker, we will consider the *Xs*-prime condition rather than the *blank*-prime condition as the baseline for determining facilitation and inhibition. 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 *Xs*-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 *Xs* 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 neutral *blank*-prime 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 row of *Xs*, 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* 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 neutral trials within a list of stimuli determines to what extent the priming pattern is distorted by the *Xs* prime: If this probability is .40 or more, the inhibition of targets preceded by *Xs* primes is about 15 msec and is sometimes unreliable (see the pseudoword data of Experiment 2). But *all* inhibition caused by *Xs* primes, the unreliable as well as the reliable, produces a distortion if facilitation and inhibition are calculated from this neutral 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 *Xs* 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. Therefore, relatively little appeal is made to the subjects' memory when such a neutral 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 neutral 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 serve as neutral primes, 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.

REFERENCE NOTES

1. O'Neil, W.M. *The effects of verbal association on tachistoscopic recognition. The role of language in behavior* (Tech. Rep. 4, Contract N80 nr-66216). Minneapolis: University of Minnesota, 1956.
2. Hudson, P.T.W., Maarse, F.J.M., & Bouwhuisen, C. *LEXSYS: A real-time multisubject system for psycholinguistic experiments*. Manuscript in preparation.

REFERENCES

Antos, S.J. Processing facilitation in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1979, *5*, 527-545.

Battig, W.F., & Montague, W.E. Category norms for verbal items in 56 categories: A replication and extension of te Connecticut category norms. *Journal of Experimental Psychology Monograph*, 1969, *80*, 1-46.

Becker, C.A. Semantic context and word frequency effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 1979, *5*, 252-259.

Becker, C.A. Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition*, 1980, *8*, 493-512.

Blank, M.A., & Foss, D.J. Semantic facilitation and lexical access during sentence processing. *Memory & Cognition*, 1978, *6*, 644-652.

Clark, H.H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, 1973, *12*, 335-359.

Collins, A.M., & Loftus, E.F. A spreading-activation theory of semantic processing. *Psychological Review*, 1975, *82*, 407-428.

De Groot, A.M.B. *Mondelinge Woordassociatie Normen: 100 Woordassociaties op 460 Nederlandse Zelfstandige Naamwoorden*. Lisse, The Netherlands: Swets & Zeitlinger, 1980.

Fischler, I. Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 18-26. (a)

Fischler, I. Semantic facilitation without association in a lexical decision task. *Memory & Cognition*, 1977, *5*, 335-339. (b)

Fischler, I., & Bloom, P.A. Automatic and attentional processes in the effects of sentence contexts on word recognition. *Journal of verbal Learning and Verbal Behavior*, 1979, *18*, 1-20.

Fischler, I., & Bloom, P.A. Rapid processing of the meaning of sentences. *Memory & Cognition*, 1980, *8*, 216-225.

Fischler, I., & Goodman, G.O. Latency of associative activation in memory. *Journal of Experimental Psychology: Human Perception and Performance*, 1978, *4*, 455-470.

Forster, K.I. Accessing the mental lexicon. In R.J. Wales & E.C.T. Walker (Eds.), *New approaches to language mechanisms*. Amsterdam: North-Holland, 1976.

Meyer, D.E., & Schvaneveldt, R.W. Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, 1971, *90*, 227-234.

Myers, J.L., & Lorch, R.F. Interference and facilitation effects of primes upon verification processes. *Memory & Cognition*, 1980, *8*, 405-414.

Neely, J.H. Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. *Memory & Cognition*, 1976, *4*, 648-654.

Neely, J.H. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 1977, *106*, 226-254.

Posner, M.I., & Boies, S.J. Components of attention. *Psychological Review*, 1971, *78*, 391-408.

Posner, M.I., & Snyder, C.R.R. Attention and cognitive control. In R.L. Solso (Ed.), *Information processing and cognition: The Loyola symposium*. Hillsdale, N.J.: Erlbaum, 1975.

Rouse, R.O., & Verinis, J.S. The effect of associative connections on the recognition of flashed words. *Journal of Verbal Learning and Verbal Behavior*, 1962, *1*, 300-303.

Scarborough, D.L., Cortese, C., & Scarborough, H.S. Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 1-17.

Schuberth, R.E., & Eimas, P.D. Effects of context on the classification of words and nonwords. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 27-36.

Stanovich, K.E., & West, R.F. Mechanisms of sentence context effects in reading: Automatic activation and conscious attention. *Memory & Cognition*, 1979, *7*, 77-85.

Stroop, J.R. Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 1935, *18*, 643-662.

Tweedy, J.R., Lapinski, R.H., & Schvaneveldt, R.W. Semantic context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context. *Memory & Cognition*, 1977, *5*, 84-89.

Warren, R.E. Association, directionality, and stimulus encoding. *Journal of Experimental Psychology*, 1974, *102*, 151-158.

Warren, R.E. Time and the spread of activation in memory. *Journal of Experimental Psychology: Human Learning and Memory*, 1977, *3*, 458-466.

West, R.F., & Stanovich, K.E. Automatic contextual facilitation in readers of three ages. *Child Development*, 1978, *49*, 717-727.

FOOTNOTES

[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 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 ($p < .001$ 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.

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THE RANGE OF AUTOMATIC SPREADING ACTIVATION IN WORD PRIMING

A.M.B. de Groot

In four unmasked-prime and three masked-prime experiments the question was investigated how far automatic spreading activation (ASA) spreads in semantic memory. The results from the unmasked-prime experiments indicated a one-step spread from the prime's representation to those of its direct associates. These results were inconclusive as to whether ASA spreads, in two steps, to representations of words indirectly related to the prime via an intervening word association. This inconclusiveness was due to a possible post-access process affecting unrelated prime-target pairs and possibly also affecting indirectly related pairs. In the masked-prime experiments such a process was prevented. Again one-step ASA was supported, but now the data unambiguously ruled out any further spread. Implications of this finding with respect to the underlying memory structure are discussed.

It is commonly found that the prior presentation of a word, the prime, that is associatively related to a subsequently presented word, the target, influences performance on the latter in a variety of tasks, e.g., lexical decision (Becker, 1979, 1980; Fischler & Goodman, 1978; Neely, 1976), word naming (Warren, 1977), Stroop colour naming (Warren, 1974) and tachistoscopic recognition (Rouse & Verinis, 1962). A number of recent findings support the view that this priming phenomenon is caused by two types of processes. The first of these is said to come about automatically whenever a word contacts its representation in semantic memory. The activation that originates in the stimulated memory location is assumed to spread automatically along the paths of the memory network and to activate, in turn, the word representations that it encounters on its way. Consequently, the activation levels of the encountered representations are temporarily increased. If a word that corresponds to one of these representations is subsequently presented for recognition, relatively little stimulus information suffices and recognition is facilitated. This view builds upon the assumption that word recognition is effectuated as soon as the activation in a memory location exceeds a certain threshold value (Morton, 1969). The recognition of words represented internally by memory units that are encountered by the activation wave is thus facilitated; the recognition of words associated with unencountered memory representations is not affected, neither positively through facilitation, nor negatively through inhibition. This process of automatic spreading activation (ASA) is said to be enacted rapidly and without depleting the limited resources of the attentional system (Neely, 1977; Posner & Snyder, 1975). If such a process is indeed responsible for the fact that the recognition of words associatively related to the prime is facilitated, the conclusion must be drawn that semantic memory is, at least to some degree, associatively structured.

The second process that is usually considered to cause priming effects arises from the attentional system that, guided by the recognition of the prime, anticipates the presentation of certain targets. Under certain circumstances, especially when the probability of related prime-target pairs in the set of experimental materials is high (Tweedy, Lapinski & Schvaneveldt, 1977; Tweedy & Lapinski, 1981) the subject builds up general or specific expectancies about the target, and the attentional system focuses a certain amount of attention on the memory representation of one or more words that are related to the prime according to these expectancies. If one of these words is subsequently presented, its recognition will be facilitated. However, if, for instance due to an unrelated prime, attention is misdirected to the representations of words none of which is the actual target, recognition is inhibited. This attentional system is said to require a relatively large amount of time between the onsets of prime and target to be able to anticipate the recognition of the latter (Neely, 1977; Posner & Snyder, 1975).

Using the lexical-decision technique, the present series of experiments tests the scope of ASA in memory. In particular the question is investigated whether, as is assumed in the classic version of the theory (Collins & Loftus, 1975; Collins & Quillian, 1969, 1970), this activation spreads not only to memory locations that (via a one-step link) are directly connected to the representation originally activated by the prime, but also to locations indirectly connected to it via one or more intervening word representations.

That a prime can automatically facilitate lexical decisions to directly related targets is a well attested finding. Fischler (1977) found that his subjects responded relatively fast to the sole related word pair embedded in a list of otherwise unrelated word pairs. An explanation of this effect in terms of focused attention is quite unlikely, since the experimental materials did not encourage such a process. Neely (1977) observed facilitation for targets directly related to the prime even though the subject's attention was deliberately directed to memory representations of words other than the prime. Undoubtedly the most compelling evidence for automatic activation spreading from a memory unit to its closest neighbours comes from some recent studies in which the primes were briefly exposed and masked in such a way that they could not be consciously perceived. These primes still facilitated the recognition of subsequent targets (Fowler, Wolford, Slade & Tassinary, 1981; Marcel, in press). In contrast with the fact that evidence is available favouring the notion of one-step ASA (a step being a link between two immediately neighbouring memory representations), to our knowledge no experiments have been run that investigate whether automatic activation spreads, via more than one link, between representations of indirectly related words.

In the experiments below, multiple-step ASA will be tested with targets (e.g., *milk*) that are indirectly related to the prime (*bull*) via a single intervening and not overtly presented word (*cow*). We may expect any facilitation for these targets to be smaller than that obtained for targets directly related to the prime, since ASA is commonly assumed to decline gradually while moving further away from the memory representation at which it started.

These indirectly related word pairs (*bull* - *milk*) were combinations of the first and third words from three-word association chains. That is, the second word was a word association to the first and the third was a word association to the second. The third word (presently the target) was never allowed to occur as a word association to the first word (presently the prime) in the association norms. This was done in order to avoid that any facilitatory effect of the prime on target recognition could have been caused by activation spreading across just a single link between immediately neighbouring locations. At the same time, this restriction put upon the selected materials safeguarded us against the possibility that the attention mechanism described above could produce the effect by focusing attention directly on the target's memory representation prior to its presentation. The latter process was also rendered unlikely by choosing a stimulus-onset asynchrony (SOA) of prime and target of only 240 msec. Neely (1977) has argued that this SOA is too short for attentional focusing to occur. It is even more unlikely that, with the current SOA, attention could have been focused on the target's memory location prior to its occurrence via a chain of several internally generated links between prime and target (for instance, from *bull* to *cow* and from *cow* to *milk*). All in all, we may state that any facilitatory effect for targets indirectly related to the prime obtained in the experiments reported here, must be attributed to multiple-step ASA in semantic memory.

Pairs of words that are connected via an intervening word will be called 'mediator pairs'; the intervening, mediating word will be referred to as the 'mediator', and the phenomenon of priming via a mediator will be called 'mediated priming'.

In order to test multiple-step ASA, seven experiments were run. In four of these (Experiments 1 through 4) the prime was presented for long enough to be read by all subjects. In three experiments (Experiments 5 through 7) the prime was presented considerably shorter and was followed by a masking stimulus in order to prevent its conscious perception. These two groups of experiments will be called the 'unmasked-prime' and the 'masked-prime' experiments, respectively. In all experiments the SOA between prime and target was held constant at 240 msec.

UNMASKED-PRIME EXPERIMENTS

Four experiments were run in which the prime was presented long enough to be read by all subjects. In Experiment 1, apart from unrelated prime-target pairs and pairs in which the target followed a neutral prime, both directly related and mediated prime-target pairs were included in the set of materials. In Experiment 2 the same materials were used as in Experiment 1, except that the directly related pairs were removed from the set. In Experiments 1 and 2 the subjects were not informed about the presence and the nature of the mediator pairs prior to the experiment. In Experiment 3 the materials of Experiment 2 were presented to the subjects, who were now told about the indirect relationship between the words in the mediator pairs. Experiment 4 replicates Experiment 3 with a new set of materials.

Method

Materials. The positive materials (with a word as target) of Experiment 1 consisted of four groups of 30 prime-target pairs each: one group of mediator pairs, one of directly related prime-target pairs, one of unrelated prime-target pairs, and one in which the target followed a neutral prime. The latter group of prime-target pairs constituted the neutral condition against which the effects of the non-neutral primes could be assessed.

The mediator pairs were selected from Dutch association norms (De Groot, 1980). They are shown in Appendix A. The primes of these pairs had served as stimulus words in the norms, and the mediators were given to them as primary or secondary responses. The mediators had also served as stimulus words in the norms. The targets of the mediator pairs were given as primary or secondary responses to the mediators, but never occurred as responses to the primes. The mean association frequency of the mediators to the primes was 47.0% with a standard error of 3.6. The mean association frequency of the targets to the mediators was 24.3% with a standard error of 2.3.

Two preparatory experiments were run on the mediator pairs. In the first of these, the pairs were presented to 30 subjects, who were asked to fill in the 'missing word' in each pair. Across pairs, the mean percentage of subjects who filled in the mediator that was selected from the norms was 90.0; the corresponding standard error was 1.7. We took this result to indicate that, in the case of an associatively structured semantic memory, the representations of the selected mediators would form strong links between the representations of the corresponding primes and targets. The second preparatory study was split up in two parts. In the first part we investigated whether, relative to a neutral condition, the first words in the mediator pairs facilitated lexical decisions to the mediators when the latter were overtly presented as target. In the second part we investigated whether the mediators, when presented overtly as primes, facilitated lexical decisions to the second words in the mediator pairs. Only if both these direct priming effects could be shown would it make sense to proceed with our investigation of indirect priming via an implicit mediator. In both parts of the study different groups of subjects were used. The presentation durations of prime and target and the interval between them were the same as used in Experiments 1 through 4 below. In both parts reliable facilitatory effects of the related primes were obtained.

The primes and targets within the group of directly related prime-target pairs to be used in Experiment 1 were also selected from the above association norms. In the norms the primes had served as stimulus words and the targets were given to them as primary, secondary or (in one case) tertiary responses. The mean association frequency of the targets to the primes was 34.9%, with a standard error of 3.6. The primes within the group of unrelated prime-target pairs of Experiment 1 also occurred as stimulus words in the norms, but the targets were never given as responses to them. The Dutch equivalent of the word *blank* (*blanco*) was chosen as prime in all 30 neutral prime-target pairs of Experiment 1. This neutral prime was preferred to a row of *Xs* that has been used by a number of investigators (Becker, 1980; Neely, 1976, 1977), since some recent studies (Antos, 1979; De Groot, Thomassen & Hudson, 1982) provide evidence of artifactual inhibition resulting from the latter. All primes in the three non-neutral conditions and the implicit mediators in the mediator pairs were nouns. Within each of the four groups of positive prime-target pairs 16 of the targets were nouns, eight were verb-infinitives (with the typical format of Dutch infinitives: *-en* endings), and six were adjectives. Across the four positive conditions the targets were balanced on language frequency, length and number of syllables.

Apart from the 120 positive prime-target pairs, 120 negative pairs (their target being a nonword) were included in the set of materials to be used in Experiment 1. All targets in the negative pairs were pseudowords, that is, nonwords that are orthographically permissible Dutch letter sequences. They were derived from nouns, verb-infinitives and adjectives (different from those used in the positive materials) by adding, deleting or changing one or two letters. The primes in 90 of these pairs were nouns. The remaining 30 negative pairs had the word *blank* as prime. In this, as well as in all further experiments, the negative prime-target pairs will be regarded as fillers.

The materials used in Experiments 2 and 3 were the same as those of Experiment 1, except that the 30 directly related positive pairs and 30 of the non-neutral negative pairs were removed from the set.

Apart from the test pairs, 58 practice pairs were included in the set of materials of Experiment 1 and 88 practice pairs were included in the sets of Experiments 2 and 3. Among the practice materials all types of prime-target pairs appeared in the same proportion as among the test materials, with the exception that in Experiments 1 and 2 no mediator pairs occurred in the practice set.

The positive materials presented in Experiment 4 consisted of three groups of 21 prime-target pairs each: one group of mediator pairs, one of unrelated pairs and one of neutral prime-target pairs. All mediator pairs are presented in Appendix B. According to the association norms (De Groot, 1980) the mean association frequency of the mediators to the primes in the mediator pairs was 64.5%; the corresponding standard error was 2.9. All mediators were nouns and primary associates to their primes. The mean association frequency of the targets to the mediators was 5.3% with a standard error of 1.6. Like the primes in the mediator pairs, the primes in the unrelated prime-target pairs were stimulus words in the association norms that had a strong primary word association, which, of course, did not appear as target in the present experiment. All primes in the mediator and unrelated pairs were nouns. In the group of neutral prime-target pairs the prime was always the word *blank*. All targets in the three groups of positive prime-target pairs were infinitives. Across the three groups of positive prime-target pairs, the targets were equated on language frequency, length and number of syllables.

Apart from the 63 positive pairs, 63 negative pairs were included in the set of materials of Experiment 4, 42 noun-pseudoword pairs and 21 *blank*-pseudoword pairs. All pseudowords were orthographically permissible letter sequences in Dutch and had the appearance of Dutch infinitives (*-en* endings). Furthermore, a practice set was composed consisting of 58 prime-target pairs. In this set all pair types appeared in the same proportion as in the test set.

Subjects and Apparatus. Seventeen, 18, 18 and 21 students of the University of Nijmegen participated as subjects in Experiments 1, 2, 3 and 4, respectively. They were paid for their participation.

In all four experiments the subjects were tested in a group experiment room that allowed independent individual sessions under control of a multiprogramming computer system. Stimuli were presented in uppercase (white on grey) on individual TV monitors under program control. Individual stimulus presentation, RT recording, and feedback were performed by a program called LEXSYS (Hudson, Maarse & Bouwhuisen, Note 1).

Procedure. The subjects of Experiments 1 through 4 were tested in groups of one to four in individual booths that were normally lit. They were first instructed by the experimenter and were then given further instructions on their screens. In the instruction, the subjects were told that pairs of letter 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 string of each pair was a Dutch word. They were also told that the first string would be either the word *blank* or any other word, 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, with their right forefinger, the positive response key on the right-hand side of the keyboard in front of them. 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 letter string of a pair, the prime, a fixation star appeared for one second, slightly above and to the left of the place at which the prime would appear. The star was immediately replaced by the prime, which remained on the screen for 200 msec. The prime offset-target onset interval was

40 msec so that the total SOA was 240 msec. The second string, the target, appeared in the same position as the prime in Experiment 1 and it appeared slightly below the position where the prime had been in Experiments 2, 3 and 4. It remained on the screen until the subject pressed one of the two response keys. Latencies and error rates were recorded on-line. After every trial one of the words *correct*, *slow* or *wrong* appeared. *Slow* occurred whenever a response was correct but exceeded a preset 900-msec deadline. When the subject failed to respond within 2,400 msec from target 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 further error. The prime-target pairs were presented in blocks of 30 in Experiments 1, 2 and 3 and in blocks of 21 in Experiment 4. Since the numbers of practice trials were not multiples of 30 (in Experiments 1, 2 and 3) and of 21 (in Experiment 4), one of the blocks of practice trials in all four experiments contained fewer prime-target pairs. After each block the mean RT and the number of errors for that block were presented on the screen. After a forced rest of minimally 10 sec, the subject initiated the presentation of a new block by pressing one of the response keys.

In Experiments 1 and 2 no mention was made about the presence of related (Experiment 1) and mediator (Experiments 1 and 2) prime-target pairs before the end of the experiment. In Experiments 3 and 4 the subjects were informed about the presence and nature of the mediator pairs prior to the experiment.

Results and Discussion

The mean latencies and error rates for all types of positive prime-target pairs in Experiments 1, 2, 3 and 4 are shown in Table 1.

For each subject in all four unmasked-prime experiments the mean RTs of correct responses within each of the positive prime type conditions (related, mediated, neutral and unrelated in Experiment 1; mediated, neutral and unrelated in Experiments 2, 3 and 4) were calculated and were treated as single scores in an analysis of variance. In these subject analyses prime type was

Table 1

Mean Response Times (in Milliseconds) and, in Parentheses, Error Rates (in Percentages) of Targets in all Types of Positive Prime-Target Pairs in Experiments 1 through 7

		related	mediated	neutral	unrelated
unmasked-prime	1	494(1.0)	518(2.4)	520(3.5)	537(7.5)
experiments	2	-	550(2.2)	543(3.7)	568(4.4)
	3	-	541(1.9)	554(4.1)	573(6.5)
	4	-	565(3.2)	584(4.1)	600(6.1)
masked-prime	5	502(0.8)	-	533(2.1)	526(2.9)
experiments	6	498(2.4)	-	528(2.6)	520(6.0)
	7	-	528(2.6)	529(4.8)	526(4.2)

considered as a within-subjects factor. Furthermore, for each of the unmasked-prime experiments the mean latencies to all word targets (correct responses only) collapsed across subjects were calculated and were treated as single scores in an analysis of variance on items. In these item analyses prime type was considered as a between-items variable.

EXPERIMENT 1

In this experiment the effect of prime type was significant on both the subject and the item analysis [F_s (3,48) = 10.69, $p < .01$; F_i (3,116) = 5.42, $p < .01$]. MinF' (Clark, 1973) combining the F-values from both analyses was also significant [*minF'* (3,162) = 3.60, $p < .05$]. A post hoc Newman-Keuls test was performed on the difference scores from the subject analysis. It showed that the differences between the related pairs on the one hand and the mediator pairs (24 msec), the unrelated pairs (43 msec) and the neutral pairs (26 msec) on the other were all significant at the .01 level; the 19-msec inhibition for unrelated pairs relative to mediator pairs and the 17-msec inhibition for unrelated pairs relative to neutral pairs were both significant at the .05 level.

RTs to mediator and neutral pairs were approximately the same ($p > .10$). A Newman-Keuls test performed on the difference scores from the item analysis showed fewer differences to be statistically reliable: The difference between related and unrelated pairs was significant at the .01 level; the differences between the related and mediator pairs and between the related and neutral pairs were significant at the .05 level. The differences between the unrelated pairs on the one hand and the mediator and neutral pairs on the other were not significant ($p > .10$).

The facilitation of related pairs compared to neutral pairs supports the notion of one-step ASA in semantic memory. With respect to the question of multiple-step ASA the data are not clear-cut. If we compare the RTs to targets in the mediator and neutral conditions it seems most parsimonious to conclude that ASA does not extend beyond the memory representations that most closely neighbor upon the representations at which the activation originated. However, the presence of inhibition for unrelated targets, although only statistically reliable on the subject analysis, suggests a second interpretation, namely that the cause of inhibition for unrelated targets also operated on the targets in the mediator pairs, thereby cancelling a facilitatory effect of multiple-step ASA for these pairs.

The present SOA makes it quite unlikely that the inhibition observed for unrelated targets was caused by the attentional system misdirecting attention towards memory representations none of which was subsequently presented as target. However, the current prime duration (200 msec) does allow a totally different, post-access inhibitory process, proposed by De Groot et al. (1982), to affect decision times to unrelated targets. This process involves a tendency of the subjects always to look for a meaningful relationship between word prime and word target *after* both have been recognized as words, and possibly *after* the translation of a word classification of the target into a *yes* response has been made in the subjects' mind, but *before* they notify this classification by pressing the appropriate button. We suggested that this tendency is caused by an implicit assumption of fluent readers that the relationship between words and the context in which they appear is always meaningful. When the subjects encounter meaningless material they may simply do what readers normally do when they loose track, namely reprocessing the material until it makes sense. We assumed that only prime-target combinations involving two meanings are subjected to this strategy. Since the word *blank* presumably loses its meaning through a process of satiation, prime-target combinations with the word *blank* as prime are probably not affected. affected. Similarly, pairs that have a pseudoword as target, to which, by definition, no meaning is attached, are most likely not affected either. Although the search for meaningfulness will inhibit responding to *all* non-neutral pairs, it will be especially inhibitory to unrelated prime-target pairs, since no relationship will be discovered to stop the search. Presumably some deadline will have to be exceeded before the subject attends again to the actual task, lexical decision. In the case of a related pair a relationship will soon be found and the search can be stopped, resulting in a net positive effect of the present inhibitory process and the facilitation obtained from one-step ASA. With respect to the search for meaningfulness, the mediator pairs may behave like unrelated pairs: None of the targets in the mediator pairs appeared as a word association to the prime in the norms. Also, as will be seen in Experiment 2, the indirect relationship within these pairs is not obvious to the subjects until after it has been explained to them. Nevertheless, no inhibition was obtained for these pairs. Therefore, it may have been overruled by a facilitatory effect of some other process, possibly multiple-step ASA in semantic memory. This possibility was tested in Experiments 2 through 4.

The above inhibitory strategy may also provide an explanation for the inhibition that was found in some recent studies (Antos, 1979; Fischler & Bloom, 1980; Myers & Lorch, 1980) in which SOAs were used as short as 200 msec.

EXPERIMENT 2

In this experiment the materials of Experiment 1 were used, except that the directly related prime-target pairs and an equal number of word-pseudoword pairs were removed from the set. In all other respects Experiments 1 and 2 were the same. It was assumed that the removal of directly related pairs would diminish the above post-access search for meaningfulness. ASA, however, should continue to exert its effect, unobscured by processes operating in an opposite direction. If the inhibitory search for meaningfulness and facilitatory multiple-step ASA cancelled each other's effect on the mediator pairs in Experiment 1, a net facilitatory effect on these pairs should show in Experiment 2.

When the subjects had finished the experiment, they were shown a list consisting of the 30 mediator pairs, and they were asked to discover in what way the words within these pairs could be connected to one another. They were told that the type of connection that was meant was the same for all these pairs.

As can be seen from Table 1, the elimination of directly related pairs hardly affected the overall response pattern. Again, mediated targets were not processed faster, but even slightly slower than the targets in the neutral condition. The effect of prime type was only significant on the subject analysis [F_s (2,34) = 11.38, $p < .01$; F_i (2,87) = 2.01, $p > .10$]. A Newman-Keuls test performed on the difference scores from the subject analysis showed that both the neutral and the mediator pairs were responded to significantly faster than the unrelated pairs ($p < .01$ in both cases). The 7-msec difference between the neutral and the mediator pairs was not significant. When the subjects, after finishing the experiment, were shown the list of mediator pairs, none of them gave even the slightest hint of noticing that the words within these pairs could be connected via an intermediate word association. Many of them, however, reported to sense a feeling of 'weirdness' with these word pairs, as if 'something was wrong'. When informed, they all immediately recognized the relationship.

The results of Experiment 2 replicated those of Experiment 1: (1) The subjects were generally inhibited by the presence of an unrelated prime, although not *all* unrelated targets were responded to slower than targets in the neutral pairs. (2) Mediated targets and targets in the neutral condition were responded to about equally fast. The first result indicates that the above post-access inhibitory process cannot be controlled by the subjects, but is involuntary (cf. De Groot et al., 1982).

Since we did not succeed in removing the cause of inhibition for unrelated targets, that is, the presently assumed post-access search for meaningfulness, we had to face the possibility once more that it acted upon mediated targets as well as upon unrelated targets, and that it cancelled an effect of multiple-step ASA for these pairs.

The following two experiments tried to speed up the post-access process for mediator pairs, thereby diminishing its inhibitory effect on these pairs, and, consequently, revealing a net facilitatory effect of multiple-step ASA.

EXPERIMENT 3

In this experiment the subjects were presented with the materials of Experiment 2 (except that some of the practice trials consisted of mediator pairs), but this time they were informed about the nature of the mediator pairs prior to the experiment: They were told that, when both prime and target were words, these would sometimes be indirectly related to one another via a word association to the prime. An example of such a mediator pair was provided during the instructions. The subjects were also told that RTs were measured starting from target onset, and that they probably would not have sufficient time to generate word associations to the prime before the target appeared. Nevertheless they should try to profit from this indirect relationship. It was assumed that this instruction would assist the subjects in relating the primes and targets of the mediator pairs, so that the inhibitory search for meaningfulness could terminate relatively fast and a net effect of multiple-step ASA should be observed.

The effect of prime type (see Table 1) was statistically reliable [F_s (2,34) = 17.00, $p < .01$; F_I (2,87) = 4.73, $p < .05$; $minF'$ (2,118) = 3.70, $p < .05$]. The Newman-Keuls test performed on the subject analysis showed that the differences between unrelated targets on the one hand and mediated (32 msec) and neutral targets (19 msec) on the other were both significant at the .01 level, and that the difference between mediated and neutral targets (13 msec) was significant at the .05 level. However, according to the Newman-Keuls test on the item analysis only the difference between mediated and unrelated targets was significant ($p < .01$).

Although the mean RT to mediated targets was 13 msec shorter than that to targets in the neutral condition, the item analysis showed that this effect was due to relatively fast processing of only a subset of the mediated targets. Nevertheless, the difference between neutral and mediated targets in the direction predicted by multiple-step ASA and the generalizability of this effect to subjects, prompted us to replicate this experiment with a totally different set of materials.

EXPERIMENT 4

Appendix A shows that the mediator pairs used in Experiments 1, 2 and 3 were not very homogeneous. Some consisted of words with conflicting meanings (*fork-to cut*), others of words with seemingly unrelated meanings (*tap-sea*), and still others of words carrying meanings that seem fitting (*writer-to read*). Furthermore, the positive targets consisted of nouns, adjectives and infinitives. A different, less heterogeneous, set of materials was created to be used in Experiment 4. All targets in this set were infinitives. To ensure that the subjects would succeed in detecting most of the mediators when informed about their presence in a number of pairs, mediator pairs were chosen such that the mediator was a very strong primary word association to the prime. This procedure was followed at the cost of the association frequency of the target to the mediator. According to the association norms, the latter was fairly low in most cases. Further characteristics of the present set of materials are provided in the 'Materials' section above.

The effect of prime type (see Table 1) was reliable both on the subject analysis and on the item analysis [F_s (2,40) = 9.39, $p < .01$; F_i (2,60) = 3.16, $p < .05$]. MinF' was only marginally significant [*minF'* (2,91) = 2.37, $.05 < p < .10$]. A Newman-Keuls test carried out on the difference scores from the subject analysis showed that the 35-msec difference between the mediated and the unrelated targets was significant ($p < .01$). The differences between the neutral targets on the one hand, and the mediated (19 msec) and unrelated targets (16 msec) on the other were also reliable ($p < .05$ in both cases). On the item analysis only the difference between mediated and unrelated targets was significant ($p < .05$). The results of this experiment replicated those of Experiment 3. The use of the more homogeneous set of materials did not have the effect that mediated targets were processed generally faster than targets in the neutral condition.

In Experiments 1 through 4 only weak evidence was collected supporting the notion of multiple-step ASA in semantic memory. In Experiments 1 and 2 no difference was obtained between RTs to targets in the neutral and mediated conditions. In Experiments 3 and 4, in which the subjects were informed about the mediated relation, some but not all of the mediated targets showed an effect, producing an overall facilitation of 13 msec in Experiment 3 and of 19 msec in Experiment 4. If these effects indicated multiple-step ASA, the conclusion must be drawn that this process has very little impact on word recognition.

MASKED-PRIME EXPERIMENTS

Since Experiments 1 through 4 were not conclusive with respect to multiple-step ASA, three further experiments were run in which a totally different procedure was used. A number of recent studies (Fowler et al., 1981; Marcel, in press) have shown facilitation of lexical decision to targets following related but pattern-masked primes. In these experiments the mask followed the prime at a detection-level SOA. That is, for each subject the SOA between prime and *mask* was determined at which the subject no longer performed significantly above chance level when judging whether or not a word had preceded the pattern mask. In Experiments 5 through 7 a similar masking technique is used. We expected that the post-access process that was thought to cause the inhibition for unrelated targets, and that was possibly responsible for the absence of facilitation for mediated targets in Experiments 1 through 4, cannot operate when the prime passes unrecognized: It is only possible to set off a search for a meaningful relation if both the meanings of prime and target have entered consciousness. Therefore, the masking technique provides an excellent opportunity to investigate the question of mediated priming. If, given a successfully masked prime, mediated targets would again be responded to equally fast as targets in the neutral condition, this result can no longer be considered to be caused by two opposing processes. Experiments 5 and 6 investigate the effect of masked primes on lexical decisions to directly related targets. The directly related prime-target pairs in Experiment 5 are the prime-mediator combinations of the mediator pairs in Experiment 4. Those in Experiment 6 are the mediator-target combinations of Experiment 4. If, as in the studies of Fowler et al. and of Marcel, the related targets do show facilitation, this result would most likely indicate one-step ASA in semantic memory. As such, Experiments 5 and 6 serve to prepare Experiment 7, in which the notion of multiple-step ASA will be tested using the mediator pairs of Experiment 4. As in Experiments 5 and 6, the prime is also masked in Experiment 7. If a word automatically primes a second word, and this second word automatically primes a third word, multiple-step ASA in semantic memory predicts priming of the third word by the first. Therefore, according to this theory, if in both Experiments 5 and 6 facilitation occurs in the related condition, the mediated targets in Experiment 7 should also be facilitated. If, however, the related targets in either Experiment 5 or in Experiment 6 will not show facilitation, it would not make sense to continue our investigation of multiple-step ASA with the mediator materials of Experiment 4.

Method

Materials. The test materials of Experiment 5 consisted of 63 positive and 63 negative prime-target pairs. The positive set included 21 related pairs, 21 unrelated pairs, and 21 pairs with the word *blank* as prime and a word as target. The negative set included 42 word-pseudoword pairs and 21 pairs with the word *blank* as prime and a pseudoword as target. The primes and targets in the related pairs were the primes and mediators of the mediation condition in Experiment 4. New targets were chosen for the unrelated and neutral conditions, and these were paired with the old primes. Since all mediators in Experiment 4 were nouns, only nouns were chosen as targets in these conditions. Across the three positive conditions the targets were balanced on language frequency, length and number of syllables. All pseudowords were derived from nouns (different from those used in the positive materials) by changing, adding or deleting one or two letters.

The test materials presented in Experiment 6 were the same as those used in Experiment 4, except that all mediator pairs (e.g., *butcher-to fry*) were replaced by pairs with the same target, but with the mediators as prime (*meat-to fry*).

The test materials of Experiment 7 were the same as those used in Experiment 4.

The test sessions of Experiments 5 through 7 were preceded by a practice session in which 86 prime-target pairs were presented. Among the practice materials all prime-target pairs occurred in about the same proportion as among the test materials.

Subjects and Apparatus. Eighteen, 20, and 18 students of the University of Nijmegen participated as subjects in Experiments 5, 6 and 7, respectively. They were paid for their participation. The apparatus was the same as that used in Experiments 1 through 4.

Procedure. A trial started with the presentation of a fixation star for one second, slightly above and to the left of the place at which the prime would appear. The star disappeared and was immediately replaced by the prime, which remained on the screen for 20 msec. This duration of prime presentation was the shortest we could manage with our TV screen. As will be seen, it was above recognition threshold for about half of the subjects on a number of trials. The prime was replaced by a masking signal that remained on the screen for 200 msec. It consisted of three rows of random letters covering the width of the screen. The second row appeared at the same height as the prime. After the mask had disappeared, the screen remained empty for 20 msec before the target appeared. Therefore, as in Experiments 1 through 4, the total SOA was again 240 msec (20 + 200 + 20). Prime and target appeared at the same place on the screen. The subjects were told the exact build-up of a trial (word or *blank* - band of random letters - word or pseudoword). They were also told that they probably would not be able to read the prime, but would, at best, perceive it as a flash, since its presentation duration would be very short. Nothing was said about the relationship between prime and target on a number of trials. In the unmasked-prime experiments the subjects had been asked not to ignore the prime. In the present masked-prime experiments they were encouraged to pay all their attention to the target. After all prime-target pairs had been presented, the subjects were asked whether they had been able to read the prime. The materials were presented in blocks of 21 prime-target pairs. Since the number of practice trials was not a multiple of 21, one of the blocks in the practice session contained fewer prime-target pairs. In all other respects the procedure was the same as described before.

Results and Discussion

Table 1 shows the mean latencies and error rates for all types of positive prime-target pairs in Experiments 5 through 7. For each subject in all three masked-prime experiments the mean RTs of correct responses within each of the positive prime-type conditions (related, neutral and unrelated in Experiments 5 and 6, and mediated, neutral and unrelated in Experiment 7) were calculated and were treated as single scores in an analysis of variance. In these subject analyses prime type was considered as a within-subjects factor. Furthermore, for each of Experiments 5, 6 and 7 the mean latencies to all word targets (correct responses only) collapsed across subjects were calculated and were treated as single scores in an analysis of variance on items. In these item analyses prime type was considered as a between-items variable.

When asked, following the test sessions, whether they had been able to read the prime, half the subjects in Experiment 5 and 7 reported that they had never been able to do so and the other half stated that they had occasionally read it. In Experiment 6, nine subjects had never read the prime and 11 had sometimes read it. Apart from the above analyses, for each of the masked-prime experiments a second subject analysis was performed, with prime type as a within-subjects factor and group (the subjects who had never read the prime vs. those who had sometimes read it) as a between-subjects variable. These two groups will be called the sub-threshold and supra-threshold groups, respectively. In order to obtain equal numbers for both groups, the data from two supra-threshold subjects in Experiment 6 were randomly deleted. These additional analyses were performed in order to see whether the ability or inability to read the prime had any systematic effect on task performance.

EXPERIMENT 5

On both analyses that did not include group as a factor, the effect of prime type was significant [F_s (2,34) = 12.62, $p < .01$; F_I (2,60) = 5.30, $p < .01$; *minF'* (2,92) = 3.73, $p < .05$]. Newman-Keuls tests carried out on the means of the subject and the item analyses (see Table 1) showed that the 31-msec difference between the mean RTs to targets in the neutral and related conditions was significant ($p < .01$ on both analyses). Also, the 24-msec difference between the mean RTs to related and unrelated targets was significant ($p < .01$ on the subject analysis and $p < .05$ on the item analysis). The 7-msec difference between the targets in the neutral and unrelated conditions was not reliable ($p > .10$ in both cases). The finding that targets in the neutral and unrelated conditions were now responded to about equally fast indicated that, by masking the prime, we had removed the cause of inhibition that was present in Experiments 1 through 4.

On the subject analysis including group as a factor both the main effects of group [F_s (1,16) = 5.63, $p < .05$] and of prime type [F_s (2,32) = 13.05, $p < .01$] were statistically reliable. The mean RT of the supra-threshold group was shorter than that of the sub-threshold group (501 msec and 540 msec, respectively). The interaction between group and prime type was insignificant [F_s (2,32) = 1.58, $p > .10$]. The interaction data are presented in Table 2.

Table 2

Mean Response Times (in Milliseconds) and, in Parentheses, Error Rates (in Percentages) for both Groups of Subjects in the Masked-Prime Experiments

group	experiment	related	mediated	neutral	unrelated
	5	528(0.5)	-	548(1.6)	545(2.1)
sub-threshold	6	527(3.7)	-	546(2.6)	532(3.7)
	7	-	553(1.6)	542(4.2)	551(4.2)
	5	476(1.1)	-	519(2.6)	508(3.7)
supra-threshold	6	467(1.6)	-	505(3.2)	502(6.9)
	7	-	502(3.7)	517(5.3)	501(4.2)

Although the interaction between group and prime type was not reliable, and no firm conclusions can be drawn from it, it is of interest to mention one aspect of this interaction that will also appear in the following experiment: The facilitatory effect of a related prime was twice as large for the supra-threshold group (43 msec) as for the sub-threshold group (20 msec). As can be seen from Table 2, for both groups the unrelated pairs were processed faster than the neutral pairs; in other words, the inhibitory effect of an unrelated prime was negative in both groups. This finding is important, since it indicates that the facilitation for related targets in both groups has to be attributed to automatic processes solely (Posner & Snyder, 1975).

The combination of findings that, firstly, in both groups of subjects related targets were facilitated, and that, secondly, unrelated targets were not inhibited, justifies the conclusion that the observed facilitation was caused by automatic processing, for instance by (one-step) ASA in semantic memory.

EXPERIMENT 6

In all respects this experiment was the same as Experiment 5, except that other materials were used. Instead of the prime-mediator pairs, the mediator-target pairs of Experiment 4 were used as directly related prime-target pairs. The unrelated and neutral positive prime-target pairs as well as all negative pairs were the same as those used in Experiment 4.

On both analyses that did not include group as a factor, the effect of prime type was significant [F_s (2,38) = 8.56, $p < .01$; F_i (2,60) = 3.18, $p < .05$]. MinF' was only marginally significant [$minF'$ (2,92) = 2.32, $p = .10$]. A Newman-Keuls test performed on the difference scores from the subject analysis showed that both the 30-msec difference between directly related and neutral pairs and the 22-msec difference between related and unrelated pairs (see Table 1) were significant at the .01 level. A second Newman-Keuls test on the means of the item analysis showed both differences to be only marginally significant ($.05 < p < .10$).

On the subject analysis that included the variable group, the main effect of group was marginally significant [F_s (1,16) = 4.15, $.05 < p < .10$]. The effect of prime type was significant [F_s (2,32) = 6.70, $p < .01$]. As in Experiment 5, the overall mean RT of the supra-threshold group was shorter than that of the sub-threshold group (491 msec and 535 msec, respectively). The interaction between group and prime type was insignificant [F_s (2,32) = 1.84, $p >$ .10]. The interaction data are shown in Table 2. Again, the facilitatory effect of a related prime was twice as large for the supra-threshold group (38 msec) than for the sub-threshold group (19 msec), and the inhibitory effect was negative for both groups (-3 msec and -14 msec, respectively).

Since the analysis that included the variable group produced very similar results for Experiments 5 and 6, the combined data of these experiments were submitted to an analysis of variance, including the factors group, prime type and experiment (5 and 6). With more subjects a significant interaction between group and prime type could thus arise. On this analysis, the main effect of experiment was not significant ($F < 1$). The main effects of group and prime type were both reliable [in order, F_s (1,32) = 9.38, $p < .01$; F_s (2,64) = 18.30, $p < .01$]. The interaction between the variables group and prime type was marginally significant [F_s (2,64) = 2.98, $.05 < p < .10$], indicating that the supra-threshold group tends to profit more from the presence of a related prime than the sub-threshold group. No other interactions were significant.

Overall, the results of Experiment 6 were similar, although slightly less reliable, than those of Experiment 5. Again, for both groups of subjects, targets directly related to the primes were facilitated, whereas targets unrelated to their primes were not inhibited. The combined results of Experiments 5 and 6 allowed us to proceed our investigation of multiple-step ASA in Experiment 7.

EXPERIMENT 7

The set of materials used in this experiment was the same as that used in Experiment 4. On the basis of the results of Experiments 5 and 6, the notion of multiple-step ASA predicts that the subjects in this experiment will generally show facilitation on the mediated targets, indirectly related to the primes via an implicit word association. Due to decay of activation (Collins & Loftus, 1975), this effect may be smaller than the approximately 30-msec facilitation that was obtained for directly related targets in Experiments 5 and 6. Also, in view of the marginality of the direct facilitation for related targets on the item analysis in Experiment 6, we expected this remaining indirect facilitation to be unreliable on the item analysis.

Table 1 shows that the overall mean RTs for the targets in the positive conditions were very similar. Unlike the directly related targets in Experiments 5 and 6, the mediated targets were not facilitated. On both the analyses (across subjects and across items) that did not include the variable group, the effect of prime type was insignificant ($F < 1$ in both cases).

On the subject analysis with group as a factor, the main effect of group was marginally significant [F_s (1,16) = 3.62, $.05 < p < .10$]. As in Experiments 5 and 6, the overall mean RT for the supra-threshold group was shorter than that for the sub-threshold group (507 msec and 548 msec, respectively). The main effect of prime type was insignificant ($F < 1$). The interaction between group and prime type was marginally significant [F_s (2,32) = 2.50, $.05 < p < .10$]. The interaction data are presented in Table 2. In the supra-threshold group the mean RT for the neutral condition was longer than that for the remaining two conditions, whereas in the sub-threshold group it was shorter. Consequently, the facilitatory and inhibitory effects were reversed between the groups. It is not clear why the neutral condition is treated differently in the two groups. However, with respect to our concern with multiple-step ASA, the finding that in neither group of subjects mediated targets were processed faster than unrelated targets is more important. It strongly suggests that the activation originating at the prime's memory representation stops after having reached the representations of words directly related to the prime.

SUMMARY AND GENERAL DISCUSSION

In the unmasked-prime studies little evidence was collected supporting the notion of multiple-step ASA in semantic memory. Only in Experiments 3 and 4 a small (approximately 15 msec) facilitation, insignificant on the item analysis, was obtained for mediated targets.

The most consistent finding in Experiments 1 through 4 was an inhibition for unrelated targets that was, in all cases, only reliable on the subject analysis. The short interval between prime onset and target onset seems to defy an interpretation of this effect in terms of attention focused on a set of memory representations other than that of the target *before* it is recognized (Neely, 1977). Instead, this effect was attributed to a post-access tendency of the subjects to try to relate the meanings of pairwise presented words. Since the relationship between the words within mediator pairs is not immediately obvious to the subjects, the possibility was considered that this search for meaningfulness had negatively affected the lexical decisions to mediated targets as well as those to unrelated targets, thereby overruling, in Experiment 1, a possible facilitatory effect of multiple-step ASA in semantic memory. In order to reveal facilitation for mediated targets, we tried to remove or reduce this hypothetical inhibitory search for meaningfulness by deleting the directly related pairs from the set of materials in Experiment 2. This manipulation did not produce any change in the data, and the conclusion was drawn that the search cannot easily be controlled. In Experiments 3 and 4 we tried to diminish its inhibitory effect on the mediator pairs by speeding up the search whenever such a pair was encountered by the subjects. This manipulation did indeed produce a small but unreliable facilitation for targets in the mediator pairs. All in all, Experiments 1 through 4 were not conclusive with respect to multiple-step ASA. Therefore, three additional experiments were run in which the prime was masked in order to prevent that it would be consciously perceived, and, consequently, to preclude the post-access search for meaningfulness. In Experiments 5 and 6 one-step ASA was tested on direct associates of masked primes. These experiments also served to prepare Experiment 7, in which multiple-step ASA was tested on targets indirectly related to masked primes. Although the mask was not totally effective, the overall response pattern in Experiments 5 and 6 supported the notion of one-step ASA by showing facilitation for related targets. However, on the basis of the results of Experiment 7, the multiple-step version of the theory had to be rejected.

Since the data obtained with masked primes seem not to be contaminated by processes other than ASA, it is most parsimonious to take the overall data to indicate that the spread of activation in semantic memory stops after having reached the most closely neighbouring memory locations of the originally activated representation. With the acceptance of this interpretation, new explanations are required for the null-effect of mediated targets in Experiments 1 and 2 and of the small and unreliable facilitation of these targets in Experiments 3 and 4. To start with the latter, an alternative interpretation of the relatively short RTs to mediated targets is suggested by the mean RTs in Table 1. As can be seen, the subjects in Experiments 3 and 4 were slowed down overall compared to those in the remaining experiments (except in Experiment 2).

This may have been caused by the additional task set to the subjects, namely to try to profit from the presence of a mediator on some trials. Due to an occasional fast detection of the mediator, the overall delay may have affected mediated targets relatively little. The equivalence of RTs to mediated targets and targets in the neutral condition in Experiments 1 and 2 was interpreted in terms of opposing effects on mediated targets of facilitatory multiple-step ASA and the inhibitory post-access search for meaningfulness. If the first of these processes has not operated on mediated targets, we must draw the conclusion that the second has not affected them, although the unrelated-targets data lead us to uphold the notion of the post-access search. Consequently, it must be concluded that the subjects, although they cannot verbalize how prime and target in the mediator pairs are related (Experiment 2), still recognize some relationship between them. This explains why they sensed a feeling of 'weirdness' with these pairs. This recognition comes about extremely fast, since otherwise the targets should have showed inhibition.

There is one aspect of the unrelated-targets data in Experiments 1 through 4 that still needs to be explained: Why are they, on the item analysis, not responded to significantly slower than targets in the neutral condition? This result may simply be due to the fact that the item analyses, with different targets in all conditions, are less sensitive than the subject analyses to detect reliable differences between conditions. Alternatively, the post-access search for meaningfulness may occasionally succeed, very rapidly, in relating the meanings of words that we have operationally defined as unrelated, for instance by building sentences around them.

The present interpretation of the data depends on the assumption that the neutral condition provides a proper baseline against which the effects in the non-neutral conditions can be assessed. As pointed out by Fischler and Bloom (1980) and others, "the assessment of facilitation and inhibition will be accurate only if this neutral condition controls for factors unrelated to the content of prime and test (target) that may affect response latency. The two factors of greatest concern are the alerting properties of the prime and the processing demands of the prime" (Fischler & Bloom, 1980, pp. 218-219). Indeed, we have shown (De Groot et al., 1982) that the alerting properties are not the same for different types of neutral primes: RTs to targets following the *blank* prime are shorter than those following a row of *Xs*, indicating that the *blank* prime alerts the subjects to a relatively high level. But even then the alerting effect of the repeated *blank* prime may be smaller than that of a non-neutral prime, that is only presented once and is therefore less 'boring'. Consequently, the latencies observed in the neutral condition may be systematically overestimated. On the other hand, the processing demands of the repeated neutral prime are presumably less than those of non-neutral primes. This should result in a systematic underestimation of the latencies in the neutral condition. Furthermore, in a recent paper (De Groot, Note 2) data are reported supporting the view that the alerting properties and processing demands of neutral primes vary with the SOA of prime and target (see also Posner & Boies, 1971), which was presently held constant at 240 msec, and with the proportion of related prime-target pairs in the set of materials. All in all, we have no guarantee whether a proper neutral condition will ever be achieved.

If we only had the unmasked-prime data at our disposal, the above considerations would suggest an interpretation different from the present rejection of multiple-step ASA: If we consider the neutral-prime data as meaningless, and accept the unrelated pairs as neutral condition instead, the remaining data could be taken to mean that both directly and indirectly related targets benefit from ASA, but that more processing time is required to generate the activation for the indirectly related targets. The masked-prime study, however, in which indirectly related and unrelated targets have equal RTs, defies this interpretation.

The finding that a prime does automatically facilitate the recognition of directly related words, whereas it does not facilitate the recognition of indirectly related words, constitutes a serious attack on the theory of ASA. Furthermore, it may have consequences for the memory structure that needs to be assumed in order to explain such a restricted spread of activation. The spreading-activation theory departs from the assumption that the internal representations of directly related words are separate but connected memory units, which together form a closely interlinked structure (Collins & Loftus, 1975). According to this view, the facilitation for words directly related to the prime is the result of activation spreading between neighbouring representations. Since the activation starting from the prime's memory location presumably spreads simultaneously to the representations of several prime-related words, the activation arriving at the location of the directly related target will be smaller than that departing from the original activation source. Also, the amount of activation that arrives at neighbouring locations will be lessened due to decay of activation. Therefore, the absence of facilitation for a word indirectly related to the prime may simply indicate that a minimum amount of activation is required in a memory location if it is to spread further, and that this amount is not present in the representation of the directly related word, the mediator.

Alternatively, we may take the absence of any facilitation for mediated targets as an indication that, after having encountered the directly neighbouring representations, there is nothing more for the activation wave to spread to. For instance, the representation of *shepherd* sends off activation to that of *sheep*, to which it is connected, but not to that of *wool*, because there is no pathway to follow between the locations for *sheep* and *wool*. It is obvious that this picture is not complete, since *sheep does* prime *wool*, and, consequently, there must be a direct connection between their memory locations somewhere. A solution to this problem is the assumption of multiple storage of words in two qualitatively different types of memory representations, that we will call 'core representations' and 'peripheral representations'. Going back to the above example, the core representation of *shepherd* has in its immediate surrounding a peripheral representation of *sheep* as well as peripheral representations of a number of other directly related words. The activation of these peripheral representations depends upon the activation of the corresponding core representation. There probably exist peripheral representations of *sheep* in connection with core representations of a number of other words to which *sheep* is an associate. Apart from being stored in a number of peripheral representations, the word *sheep* itself has a core representation in semantic memory. A peripheral representation of *wool* as well as a number of other peripheral representations are linked up with this core representation. If the word *shepherd* is presented, its core representation is accessed, and activation is sent off to its peripheral representations, including that of *sheep*. If subsequently the word *sheep* is presented as target, this activated peripheral representation is rapidly accessed and recognition is facilitated. Probably, the target *sheep* also contacts its core representation independent from the prior access of the core representation of *shepherd*. The fact that facilitation is observed for targets preceded by directly related primes indicates that the access of the pre-activated peripheral representation is faster than the access of the core representation. If the presentation of *sheep* is not preceded by a related word, only its unprimed core representation is accessed, and responding is relatively slow. It is necessary to assume that not only the core representation, but also the peripheral representations contain information about the graphic (and presumably the phonetic) properties of the corresponding word, since otherwise it is hard to see how the latter are accessed by the primed target.

The idea of multiple storage in relation to spreading activation is not new. Conrad (1972) rejects the single storage of 'properties' (e.g., *can fly* and *has wings* are properties of, for instance, *sparrow*) postulated in Quillian's original model, and Collins and Loftus (1975) argue that the single-storage conception of Quillian's model is based on a misinterpretation. The present multiple-storage conception does not assume a closely interlinked memory network. Instead, it assumes a memory consisting of disconnected macro-units that contain a core representation of a word and a number of peripheral representations directly connected to the core, but not interlinked among themselves. Presumably, one-step ASA does not take place *between* different macro-units, but *within* any such unit from its core to its peripheral representations. At present it is not yet clear of which words a peripheral representation is linked up with the core. Possibly, the core representation of a word has peripheral representations of all words to which it has become, for whatever reason, very strongly associated in the past. For instance, the core representation of the word *foal* will have a peripheral representation of *horse* since this word is part of the definition of *foal*.

Whereas automatic priming of directly related targets may take place within single macro-units from the core representation to the peripheral representations, the post-access search for meaningfulness that was suggested in this paper presumably takes place between different macro-units after both their core representations have been accessed independently. Since we have assumed that the macro-units are not mutually connected, the post-access search cannot proceed along existing pathways, but generates the relationship ad hoc.

A final issue that deserves some attention is the relationship between the subjects' ability to read the prime, the overall RT, and the size of the facilitatory effect of a related prime in the masked-prime studies. In all these studies the supra-threshold group was about 40 msec faster overall than the sub-threshold group. Furthermore, the supra-threshold groups tended to profit more from the presence of a directly related prime than the sub-threshold groups. According to Fowler et al. (1981) and Marcel (in press) the effect of a pattern mask is to prevent conscious perception of a prime after the graphic and phonetic properties of a word have been unconsciously perceived. Apparently, the prime duration of 20 msec prior to the occurrence of the mask is sufficient for the supra-threshold subjects to perceive the prime at both levels of perception. Presumably, they are relatively fast at visually analysing the prime. This will contribute to the difference in speed between the two groups of subjects. The finding that the supra-threshold subjects tend to show more facilitation for directly related targets than the sub-threshold subjects may indicate that, in terms of the above memory structure, they possess stronger or more accessible links between the core representations on the one hand and their peripheral representations on the other. The strength of these links and the consequent size of facilitation as well as the speed at which visual features are extracted from the prime, may both depend upon the frequency with which the subject has encountered the prime in written material and therefore upon his reading proficiency. Since the differences between groups of subjects are based upon post hoc analyses of the data, it seems as yet premature to enter further into the relationship between reading proficiency and the ability to read the masked prime. However, this relationship is interesting enough to deserve further study.

REFERENCE NOTES

1. Hudson, P.T.W., Maarse, F.J.M., & Bouwhuisen, C. LEXSYS: A real-time multi-subject system for psycholinguistic experiments. Internal publication. Department of Experimental Psychology, University of Nijmegen, P.O. Box 9104, Nijmegen 6500 HE, The Netherlands.
2. De Groot, A.M.B. Primed lexical decision: Combined effects of the proportion of related prime-target pairs and of the stimulus-onset asynchrony of prime and target. Paper submitted for publication.

REFERENCES

Antos, S.J. Processing facilitation in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1979, *5*, 527-545.

Becker, C.A. Semantic context and word frequency effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 1979, *5*, 252-259.

Becker, C.A. Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory and Cognition*, 1980, *8*, 493-512.

Clark, H.H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, 1973, *12*, 335-359.

Collins, A.M., & Loftus, E.F. A spreading-activation theory of semantic processing. *Psychological Review*, 1975, *82*, 407-428.

Collins, A.M., & Quillian, M.R. Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, 1969, *8*, 240-247.

Collins, A.M., & Quillian, M.R. Facilitating retrieval from semantic memory: The effect of repeating part of an inference. *Acta Psychologica*, 1970, *33*, 304-314.

Conrad, C. Cognitive economy in semantic memory. *Journal of Experimental Psychology*, 1972, *92*, 149-154.

De Groot, A.M.B. *Mondelinge Woordassociatie Normen: 100 Woordassociaties op 460 Nederlandse Zelfstandige Naamwoorden*. Lisse, The Netherlands: Swets & Zeitlinger, 1980.

De Groot, A.M.B., Thomassen, A.J.W.M., & Hudson, P.T.W. Associative facilitation of word recognition as measured from a neutral prime. *Memory and Cognition*, 1982, *10*, 358-370.

Fischler, I. Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 18-26.

Fischler, I., & Bloom, P.A. Rapid processing of the meaning of sentences. *Memory and Cognition*, 1980, *8*, 216-225.

Fischler, I., & Goodman, G.O. Latency of associative activation in memory. *Journal of Experimental Psychology: Human Perception and Performance*, 1978, *4*, 455-470.

Fowler, C.A., Wolford, G., Slade, R., & Tassinary, L. Lexical access with and without awareness. *Journal of Experimental Psychology: General*, 1981, *110*, 341-362.

Marcel, A. Conscious and unconscious reading: The effects of visual masking on word perception. *Cognitive Psychology*, in press.

Morton, J. Interaction of information in word recognition. *Psychological Review*, 1969, *76*, 165-178.

Myers, J.L., & Lorch, R.F. Interference and facilitation effects of primes upon verification processes. *Memory and Cognition*, 1980, *8*, 405-414.

Neely, J.H. Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. *Memory and Cognition*, 1976, *4*, 648-654.

Neely, J.H. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 1977, *106*, 226-254.

Posner, M.I., & Boies, S.J. Components of attention. *Psychological Review*, 1971, *78*, 391-408.

Posner, M.I., & Snyder, C.R.R. Attention and cognitive control. In R.L. Solso (Ed.), *Information Processing and Cognition: The Loyola Symposium*. Hillsdale N.J.: Erlbaum, 1975.

Rouse, R.O., & Verinis, J.S. The effect of associative connections on the recognition of flashed words. *Journal of Verbal Learning and Verbal Behavior*, 1962, *88*, 454-462.

Tweedy, J.R., & Lapinski, R.H. Facilitating word recognition: Evidence for strategic and automatic factors. *Quarterly Journal of Experimental Psychology*, 1981, *33A*, 51-59.

Tweedy, J.R., Lapinski, R.H., & Schvaneveldt, R.W. Semantic-context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context. *Memory and Cognition*, 1977, *5*, 84-89.

Warren, R.E. Association, directionality, and stimulus encoding. *Journal of Experimental Psychology*, 1974, *102*, 151-158.

Warren, R.E. Time and the spread of activation in memory. *Journal of Experimental Psychology: Human Learning and Memory*, 1977, *3*, 458-466.

APPENDIX A

MEDIATED WORD PAIRS (Experiments 1, 2 and 3)

	Dutch			English				
	prime	mediator	target	prime	mediator	target	af[1)] prime-mediator	af mediator-target
1	aambeeld	(hamer)	spijker	anvil	(hammer)	nail	41	28
2	bek	(mond)	lip	beak	(mouth)	lip	45	19
3	herder	(schaap)	wol	shepherd	(sheep)	wool	75	26
4	kraan	(water)	zee	tap	(water)	sea	62	16
5	pastoor	(kerk)	toren	priest	(church)	tower	31	20
6	rapport	(cijfer)	getal	report	(mark)	number	42	23
7	snoer	(draad)	naald	string	(thread)	needle	21	33
8	stier	(koe)	melk	bull	(cow)	milk	51	44
9	woestijn	(zand)	strand	desert	(sand)	beach	44	19
10*	klant	(koning)	keizer	customer	(king)	emperor	33	15
11	duif	(vrede)	oorlog	dove	(peace)	war	24	44
12	hel	(hemel)	aarde	hel	(heaven)	earth	30	18
13	hemd	(broek)	riem	vest	(trousers)	belt	23	13
14	kluif	(hond)	kat	bone	(dog)	cat	53	48
15	web	(spin)	insekt	web	(spider)	insect	86	9
16	veter	(schoen)	voet	shoelace	(shoe)	foot	94	9
17	*deksel*	*(pan)*	*koken*	*lid*	*(pan)*	to cook	55	23
18	schrijver	(boek)	lezen	writer	(book)	to read	39	45
19	steel	(bezem)	vegen	stick	(broom)	to sweep	32	32
20	aap	(noot)	kraken	monkey	(nut)	to crack	30	14
21	nest	(vogel)	vliegen	nest	(bird)	to fly	63	22
22	vork	(mes)	snijden	fork	(knife)	to cut	51	19
23	bakker	(brood)	eten	baker	(bread)	to eat	72	26
24	kip	(haan)	kraaien	chicken	(cock)	to crow	28	13
25	hooi	(gras)	groen	hay	(grass)	green	30	55
26	kapstok	(jas)	koud	hall-stand	(coat)	cold	74	12
27	wolk	(regen)	nat	cloud	(rain)	wet	28	22
28	dag	(nacht)	donker	day	(night)	dark	60	38
29	dal	(berg)	hoog	valley	(mountain)	high	38	13
30	maan	(zon)	warm	moon	(sun)	warm	54	11
							$\bar{X}$ 46.97	24.30

1) af = association frequency in percentages

* Dutch phrase: The customer is king (the customer is always right)

APPENDIX B

MEDIATED WORD PAIRS (Experiments 4 and 7)

	Dutch			English				
	prime	mediator	target	prime	mediator	target	af[1)] prime-mediator	af mediator-target
1	antwoord	(vraag)	stellen	answer	(question)	to pose	79	0
2	bakker	(brood)	smeren	baker	(bread)	to spread	72	0
3	slager	(vlees)	braden	butcher	(meat)	to fry	79	1
4	kraan	(water)	zwemmen	tap	(water)	to swim	62	11
5	kluif	(hond)	blaffen	bone	(dog)	to bark	53	3
6	snavel	(vogel)	vliegen	beak	(bird)	to fly	53	22
7	vaas	(bloem)	plukken	vase	(flower)	to pick	85	0
8	veulen	(paard)	rijden	foal	(horse)	to ride	64	5
9	veter	(schoen)	poetsen	shoelace	(shoe)	to polish	94	2
10	tijger	(leeuw)	brullen	tiger	(lion)	to roar	41	3
11	dag	(nacht)	slapen	day	(night)	to sleep	60	4
12	klink	(deur)	sluiten	latch	(door)	to close	75	1
13	maan	(zon)	branden	moon	(sun)	to burn	54	0
14	venster	(raam)	wassen	window	(window)	to clean	58	0
15	merg	(been)	lopen	marrow	(bone)	to walk	54	9
16	kapstok	(jas)	aandoen	hall-stand	(coat)	to put on	74	2
17	pijl	(boog)	spannen	arrow	(bow)	to bend	66	5
18	donder	(bliksem)	flitsen	thunder	(lightning)	to flash	52	0
19	vork	(mes)	snijden	fork	(knife)	to cut	51	19
20	kalf	(koe)	loeien	calf	(cow)	to moo	74	1
21	deksel	(pan)	koken	lid	(pan)	to cook	55	23
							$\bar{X}$ 64.52	5.29

1) af = association frequency in percentages

CHAPTER III

(submitted for publication)

PRIMED LEXICAL DECISION: THE EFFECT OF VARYING THE STIMULUS-ONSET ASYNCHRONY OF PRIME AND TARGET

A.M.B. de Groot, A.J.W.M. Thomassen,
and P.T.W. Hudson

Lexical decisions to word targets preceded by associatively related word primes are usually found to be faster than those to words that follow a neutral prime. Also, it has been shown that, under certain circumstances, lexical decisions to words preceded by unassociated word primes are slower than to those following a neutral prime. The present study explores the influence of the stimulus-onset asynchrony (SOA) of prime and target on these priming effects. Eleven SOAs were investigated ranging from 100 msec to 1240 msec. The facilitatory effect of related primes was reliable in all SOA conditions. The inhibitory effect of unrelated primes was reliable in all but one SOA conditions. Furthermore, it was found that, up to the longest SOA, facilitation increases with SOA, whereas inhibition remains virtually constant. In the longest SOA condition both facilitation and inhibition decrease. Three processes are described that are presumably responsible for associative priming in lexical decision, viz., automatic spreading activation in semantic memory, prime-induced attentional processing, and a post-access search for meaningfulness. Apart from the word data, the pseudoword data were analysed in order to find out in what way prime-induced attentional processing produces priming effects. On the whole, the pseudowords following non-neutral primes were processed faster than those preceded by neutral primes. This supports a matching strategy similar to the one proposed by Neely (1976, 1977) and by Posner and Snyder (1975b).

When two words are presented in close succession, the first influences performance on the second in a number of tasks, including lexical decision (Becker, 1979, 1980; Fischler & Goodman, 1978; Neely, 1976), word naming (Warren, 1977) Stroop colour naming (Warren, 1974) and tachistoscopic recognition (Rouse & Verinis, 1962). This phenomenon has become known as 'priming'. The first word is commonly called the 'prime' and the second word, to which the subjects respond, is usually called the 'target'. Whether the influence of the prime results in facilitation or inhibition of processing the subsequent target depends upon many factors. Amongst these are the semantic relationship between prime and target, the task requirements, certain characteristics of the stimulus materials surrounding the critical prime-target pair, the instructions given to the subjects, and the temporal relation between prime and target.

The experiment reported below primarily deals with the effect of the stimulus-onset asynchrony (SOA) of prime and target on primed lexical decision. In an experiment of that type the subjects classify strings of letters, which are preceded by a prime, as words or nonwords. It is typically found that lexical decisions to word targets associatively related to a preceding word prime are shorter than those to word targets unrelated to their prime. In the present experiment word targets follow related or unrelated word primes, or they follow a neutral prime. A neutral prime is one that does not set off processes that influence the recognition of a subsequent target. Without such a prime it is impossible to tell whether the difference between lexical decisions to targets related and those unrelated to the word prime occurs because related targets are facilitated, or because unrelated targets are inhibited, or both. Such knowledge about the nature of the priming effect is often desirable, since it provides insight in the underlying processes as well as in the structure of semantic memory. In the present experiment we use the Dutch equivalent of the word *blank* (*blanco*) as the neutral prime rather than the more common row of *Xs* (e.g., Becker, 1980; Neely, 1976, 1977; Schvaneveldt & McDonald, 1981) since a number of studies (Antos, 1979; De Groot, Thomassen & Hudson, 1982) provide evidence of artifactual inhibition resulting from the latter.

At least three processes have been proposed to underlie the priming effect in lexical decision. Two of them, automatic spreading activation in semantic memory and prime-induced attentional processing, constitute the two components of a theory of attention developed by Posner & Snyder (1975a, b), and verified by them in a number of letter matching and animal-name classification experiments. As will become clear, the effectiveness of these two processes depends upon the SOA of prime and target. The third process that presumably underlies the priming effect in lexical decision is a post-access search for meaningfulness between prime and target that inhibits the correct lexical decision to word targets unrelated to the prime (De Groot et al., 1982) and that possibly facilitates the correct lexical decision to word targets related to the prime. Evidence for such a post-access inhibitory process also comes from studies using incomplete sentence fragments as primes (see West & Stanovich, 1982, for an overview of the relevant literature). Presumably, the post-access search for meaningfulness is much less dependent upon the SOA of prime and target than are automatic spreading activation and limited-capacity attention. Before indicating in what way the SOA of prime and target as well as a number of other temporal factors can influence priming, the workings and properties of these three processes will be described.

Automatic spreading activation is the result of past learning and it operates whenever a familiar stimulus is perceived. If such a stimulus is a word, its perception automatically excites the word's memory representation and presumably also the memory representations of directly related words. The stimulus can thus act as a prime for any of a limited set of words if one of these is subsequently presented as target word. If, after the activation of the original word's representation has had sufficient time to build up, and before it has died out completely, a target is presented that "shares the same pathway" (Posner & Snyder, 1975a) as the prime, its processing will be facilitated. Automatic spreading activation is said to occur without intention and without conscious awareness, and it is assumed to leave unaffected the processing of stimuli along pathways not encountered by the activation wave (Posner & Snyder, 1975a).

Several findings suggest that an automatic component is indeed operative in primed lexical decision. Fischler (1977) showed facilitation for a related prime-target pair that was the first related pair to be presented to the subjects. Neely (1977) found facilitation for targets that were associates of the prime, although he deliberately directed the subjects' attention to unrelated targets. Finally, facilitation has been observed for words related to the prime when the prime was masked in such a way that it could not be consciously perceived by the subjects (De Groot, in press; Fowler, Wolford, Slade & Tassinary, 1981; Marcel, in press).

The second prime-induced process capable of influencing the lexical decision to a subsequent target involves the commitment of conscious attention to the prime and to one or more words that are generated from the prime. The identity of these generated words depends upon the experimental materials surrounding the critical prime-target pair and upon the instructions to the subjects. If many of the prime-target pairs consist of associatively related words, and if the subjects are not explicitly instructed to direct their attention to certain other words, they will typically generate word associations to the prime. But the identity of the prime-generated words may be different if the subjects are asked to attend to a particular class of words unrelated to the prime (Neely, 1977). If the time between prime onset and target onset is sufficient to generate one or more words in time, and if the target happens to be the attended word or (if attention is distributed over more than one word) to be among the attended words, then target processing will be facilitated. But, if the target is *not* among the words attended to, its processing will be inhibited.

In Posner and Snyder's original model, the latter type of inhibition is due to the limited capacity nature of attentional commitment. Some of Neely's (1976, 1977) data necessitate a revision of this view. If the limited-capacity nature of attentional processing would be responsible for the inhibition of unattended targets, the responses to pseudowords following non-neutral primes should take longer than the responses to pseudowords following neutral primes, because only the former type of primes are assumed to direct the subjects' attention to certain words and, consequently, consume a relatively large amount of capacity. Contrary to this prediction, the pseudowords following a neutral prime appeared to take longer. This led Neely to suggest that, instead of the limited-capacity nature of attentional processing, a matching strategy pursued by the subjects causes unattended word targets to be inhibited. This strategy implies that the attended words are matched onto the actual target. It was assumed that a match induces a general tendency towards a *yes* response and that a mismatch biases the subjects to responding *no*. Such a strategy would facilitate both correct *no* responses to pseudoword targets preceded by non-neutral primes and correct *yes* responses to word targets that correspond to one of the attended words. But the matching strategy would inhibit correct *yes* responses to unattended word targets preceded by a non-neutral prime. Posner & Snyder themselves (1975b) proposed a similar matching strategy to explain some of the data from their letter matching and animal-name classification experiments that could not be handled by the above limited-capacity interpretation. It is important to note that the rejection of the limited-capacity nature of attentional processing, and the acceptance of the matching strategy as the source of inhibition for unattended word targets that follow non-neutral primes and of facilitation of unattended pseudoword targets that are preceded by non-neutral primes does not invalidate the operation of a prime-directed attentional component per se. In the experiment to be reported here we have included an analysis of the pseudoword data to see *how* prime-induced attentional processing, if it is operative, causes its effects.

Support for the view that under certain circumstances prime-induced attentional processing is committed in primed lexical decision comes from studies that have shown that the priming effect is sensitive to the specific instructions given to the subjects and to the overall characteristics of the stimulus materials surrounding the critical related prime-target pair. For instance, Tweedy, Lapinski and Schvaneveldt (1977) found that the size of the priming effect depends upon the proportion of related prime-target pairs among the experimental materials. Some of our own data (De Groot, Note 1) suggest that the relationship between this proportion and the amount of attention allocated is not linear. Some changes in the proportion of related prime-target pairs (out of the sum of related and unrelated pairs) appear not to be critical, given that a shift in proportion from .25 to .50 hardly affects the size of the facilitatory and inhibitory effects, whereas e.g. a shift from .50 to .75 *does* affect the size of these effects (De Groot, Note 1). In the present experiment the proportion related prime-target pairs is always .75, since this proportion condition clearly engenders prime-induced attentional processing.

A further indication that, in primed lexical decision, the prime is sometimes used to direct attention comes from a study by Becker (1980). He showed that subjects adjust their strategies to the strength of the relationship within related prime-target pairs. In the experiment reported below, the relationship between the words in the associatively related pairs is always very strong.

A search for a meaningful relation between prime word and target word was mentioned as the third process that presumably affects priming effects in lexical decision. We have proposed such a process (De Groot et al., 1982) as an alternative to prime-induced attentional processing as the source of inhibition that was observed for target words unrelated to the prime words. The materials used in that experiment did not encourage such attentional processing very much, because neither the associative strength between the words in the related prime-target pairs nor the proportion of related pairs were particularly large. Also, in that experiment the RTs to pseudowords following word primes did not differ from those preceded by the neutral prime *blank*, which suggested that no prime-induced attentional processing had occurred. The search for meaningfulness, or coherence checking, as it may better be called, was assumed to involve a tendency of the subjects always to look for a meaningful relationship between word prime and word target *after* both have been recognized as words, and possibly *after* the translation of a word classification of the target into a *yes* response has been made in the subjects' mind, but *before* they notify this classification by pressing the appropriate button. We suggested that this tendency is due to an implicit assumption by fluent readers (*and* listeners) that the relationship between a word and the context in which it appears is always meaningful, and that, therefore, they reprocess meaningless material in an attempt to discover a touch of previously unnoticed meaningfulness. We assumed that only prime-target pairs involving two word meanings are subjected to this strategy, and that trials with the neutral prime *blank* were not affected, since this word, repeatedly presented, presumably loses its meaning by satiation. If such checking is indeed done *after* the translation of a word classification into a *yes* response has already been made in the mind of the subjects, it may inhibit related as well as unrelated prime-target pairs. Therefore, the facilitation that is usually obtained for related pairs led us to conclude that successful coherence checking is enacted very rapidly with these pairs, and that its inhibitory effect is overruled by the facilitation resulting from automatic spreading activation, and possibly from directed attention. Furthermore, it was assumed that an unsuccessful checking procedure in the case of an unrelated prime-target pair continues until some deadline is exceeded.

A recent paper by West and Stanovich (1982) suggests some elegantly modified views on the workings of this coherence checking, although the basic notion of a post-access search for a meaningful relation remains unaltered. In a comparison of a number of studies that all used incomplete sentences as primes, but that either had the subjects name the target words out loud (Perfetti & Roth, 1981; Stanovich & West, 1979, 1981; West & Stanovich, 1978) or that had them classify the targets as words or nonwords (Fischler & Bloom, 1979, 1980; Schuberth & Eimas, 1977), they concluded that the lexical-decision studies showed considerably more inhibition for words incongruous (semantically anomalous) with the preceding sentence fragment than did the naming experiments. They substantiated this finding in a direct comparison of these two tasks in a single experiment (West & Stanovich, 1982). The relative complexity of the lexical-decision task, that "requires more information translation subsequent to lexical access in order to arrive at a response than does the naming task" (West & Stanovich, 1982, p. 393) was held responsible for the difference between the two tasks. This complexity causes lexical decisions to take longer than naming responses. Due to the lengthened processing time subsequent to target recognition, processes at the sentence level may interact with the translation of the word recognition of the target into a *yes* response. In order to illustrate how such interaction may come about, West and Stanovich consulted Forster's (1979) language-processing system. This system contains three subsystems, viz., a lexical processor that accesses the memory representation of the stimulus word, a syntactic processor that assigns a syntactic structure to the words composing a sentence, and a message processor that assigns meaning to this syntactic structure. A decision-making mechanism can access the output of each of these three components of the language processor. The inhibition for word targets incongruous with the prior sentence fragment may result from the decision-making mechanism receiving conflicting evidence from the three subsystems before the word recognition of the target has been translated into a *yes* decision. As soon as the lexical processor has recognized the target as a word, but the translation into the appropriate response has not yet been completed, the message processor may note the incongruence, and it may send off a *no* output to the decision maker. This output may bias the subjects to respond *no*. Such a bias must of course be overcome, and, consequently, responses to incongruous word targets would be relatively slow. Similarly, a *yes* bias for targets that are accepted by the message processor as congruous with the preceding sentence fragment could produce part of the facilitation for congruous words.

Two of the three subsystems of Forster's (1979) language processor, the lexical and the message processors, may also be operative in primed lexical-decision experiments that use words as primes. In fact, coherence checking that we proposed earlier (De Groot et al., 1982) is typically the kind of operation enacted by the message processor. Forster's model and its application by West and Stanovich (1982) allow us to specify further the workings and locus of this process. On the basis of this model we are inclined to reject our earlier suggestion that coherence checking may be enacted *after* the translation of the word classification of the target has been made, but before this classification is notified by pressing the *yes* button. It is much more elegant to assume that the *yes* decision is notified as soon as it is made, but that the complex, and therefore time consuming, process that leads to this decision allows other ongoing processing to interfere with it. Also, we no longer have to consider the possibility that coherence checking inhibits related prime-target pairs as well as unrelated pairs, although to a lesser degree. On the contrary, in the case of a related pair a *yes* output from the message processor may speed up the decision process and the consequent response. Apart from specifying our coherence-checking procedure, Forster's model also provides us with a welcome opportunity to relate word prime lexical-decision studies to lexical-decision studies using sentence fragments as primes, and to language processing in general.

As was implied in the description of these two processes above, the effectiveness of both automatic spreading activation and of prime-induced attentional processing depends upon the amount of time between the onsets of prime and target. The time course of the effects caused by one or both of these processes has been investigated by varying the latter onset asynchrony (Antos, 1979; Fischler & Goodman, 1978; Neely, 1976, 1977; Posner & Snyder, 1975b; Warren, 1977). In this way facilitation resulting from automatic spreading activation has been shown to occur earlier than facilitation and inhibition arising from prime-induced attentional processing (Neely, 1977; Posner & Snyder, 1975b). Neely's (1977) data suggest that automatic spreading activation has already died out by 400 msec after prime onset. It has also appeared that prime-induced attentional processing produces inhibition of unattended targets before it facilitates the processing of attended targets (Neely, 1977). The third process that was assumed to cause priming effects in lexical decision, coherence checking, is presumably less dependent on the SOA of prime and target. Irrespective of the SOA, this process can be enacted whenever both prime and target have been consciously recognized. If, for instance, the prime is masked in such a way that it cannot be consciously perceived by the subjects, coherence checking cannot take place. Of course, when the prime cannot be identified, prime-induced attentional processing will also be prevented (cf. De Groot, in press). In the experiment to be reported below, prime and target will be presented above recognition threshold in all SOA conditions, so that coherence checking can occur with all these SOAs.

In addition to the physical SOA of prime and target there are a number of other temporal factors that determine the time available for automatic activation to spread and for attention to be directed to certain words, and that, therefore, influence the size of facilitation and inhibition. Fischler and Goodman (1978) found larger priming effects for targets following 'fast' primes than for targets preceded by 'slow' primes. Fast and slow primes were those that had been classified as words rapidly and slowly, respectively, in an unprimed lexical-decision experiment. Also, Stanovich and West (1979, 1981) showed that the visual quality of the target and its difficulty (as determined by language frequency and word length) influence the size of the priming effect (see also Fischler & Goodman, 1978). Degraded and difficult words, which take relatively long to be recognized, showed the largest effects. Since in the various SOA studies mentioned above different primes and targets have been used that are very likely to vary in difficulty, the time courses of facilitation and inhibition obtained may be expected to differ. The focusing of attention, that was probably not equally time consuming in all these SOA studies, may have also introduced some variance. For instance, it probably takes less time to attend to word associations of the prime (Neely, 1976), or to the name of a category of which the prime is an exemplar (Antos, 1979), than to direct attention to exemplars of a specified category different from the one named by the prime (Neely, 1977). All in all, it seems unfeasible to combine the data from the above SOA studies in order to obtain a reasonably complete picture of how time factors influence priming effects. None of these SOA studies separately produces such a picture, since either the number or the range of the SOA conditions that are investigated is quite small. Therefore, the purpose of the present study is to fill this knowledge gap by presenting the same set of experimental materials in 11 different SOA conditions ranging from 100 msec to 1240 msec. The reported experiment is most similar to Neely's (1976) study. The subjects' task is also to make lexical decisions about the target letter strings, and the non-neutral prime-target pairs with a word as target also consist of words that are either associatively related or unrelated to one another. Beside investigating a larger number of SOAs (11 instead of 3), the current study differs from Neely's (1976) in that the strength of the associative relationship within related prime-target pairs and the proportion of related pairs are both higher. Therefore, larger priming effects may be expected to occur.

Method

Materials. The test materials consisted of 240 prime-target pairs, 120 positive (their target being a word) and 120 negative (their target being a nonword). The primes in 80 of the positive pairs were all stimulus words taken from Dutch association norms (De Groot, 1980) with a strong primary word association. Sixty of these stimulus word-primary association combinations appeared as related prime-target pairs in the present set of materials. Each of the 20 remaining stimulus words was combined with a word that neither occurred as an associate to this word in the norms, nor was related to it in any other obvious way. These word pairs served as unrelated prime-target pairs in the experiment reported here. The primes and targets in these positive related and unrelated pairs were all nouns. The prime in the remaining 40 positive prime-target pairs was the word *blank*. The targets in these pairs were also nouns, a different noun in each pair. These *blank*-noun pairs served as neutral pairs from which facilitation (for related pairs) and inhibition (for unrelated pairs) were to be determined. Of the 60 related prime-target pairs only 20 were regarded as critical pairs. Similarly, of the 40 neutral pairs only 20 were considered critical. All 20 unrelated pairs were critical pairs. The remaining 40 related and 20 neutral pairs were regarded as fillers and were not included in the analyses below. The 40 related filler pairs were included in order to obtain the .75 proportion condition that was mentioned above. Thus, out of each four non-neutral positive prime-target pairs three were related and one was unrelated. The 20 neutral filler pairs were added to the set of materials, because an earlier experiment (De Groot et al., 1982) indicated that neutral prime-target pairs are inhibited when there are relatively few of them among the experimental materials.

The mean association frequency of the target to the prime in the 20 critical related prime-target pairs was 65.7% with a standard error of 2.8. (The overall mean association frequency of the target to the prime in all 60 related pairs was 56.9%.) The mean association frequency of the primary associates to the primes in the 20 unrelated pairs was about the same as that of the targets to the primes in the 20 critical related pairs, namely 64.9%; the corresponding standard error was 2.9%. Of course, these primary associates did not appear as targets in the present experiment.

Across the three groups of critical positive pairs the targets were balanced on language frequency (Uit den Boogaart, 1975), length in letters and number of syllables. The mean language frequencies were 75.3 for the targets in the critical related word pairs, 75.2 for those in the unrelated word pairs, and 75.7 for the critical targets following the neutral prime *blank*. The corresponding standard errors were 17.5, 17.4 and 18.3, respectively. Appendix A presents all critical positive prime-target pairs together with the language frequency of the target, and, for the related pairs, the association frequency of the target to the prime.

All targets in the 120 negative prime-target pairs were pseudowords, i.e., nonwords that, however, were orthographically permissible Dutch letter sequences. They were derived from nouns by changing, adding or deleting one or two letters. Eighty of the 120 negative prime-target pairs had a noun as prime, a different noun in each pair. Forty of these negative pairs were considered critical; the other 40 were regarded as fillers.[1] The remaining 40 negative pairs had the word *blank* as prime. The non-neutral primes in the negative pairs were not, as a rule, selected from association norms, although, by chance, some of them occurred as stimulus words in the above norms.

Apart from the test materials 86 practice prime-target pairs were included in the set of materials, viz., 43 positive and 43 negative. Among the practice materials all types of prime-target pairs appeared in about the same proportion as among the test materials. With the exception of the word *blank*, all the words in the complete set of materials, practice and test sets combined, occurred only once, either as a prime or as a positive target. Furthermore, the pseudoword targets were derived from nouns different from those used as primes or positive targets in the practice and test sessions.[2]

Subjects and Apparatus. In this experiment 176 students of the University of Nijmegen participated as subjects. They were paid 6.50 guilders. In order of arrival the subjects were assigned to one of 11 groups. A group consisted of 16 subjects all of whom were tested under the same SOA condition (see Procedure section).

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 grey) on individual TV monitors under program control. Individual stimulus presentation, response time (RT) recording and feedback were performed by a program called LEX-SYS (Hudson, Maarse & Bouwhuisen, Note 2).

Procedure. The subjects were tested in groups of one to four in a normally lit room, separated from one another by screens. They sat at a comfortable reading distance in front of a monitor. They were told that pairs of letter strings were going to be presented on the monitor, one string after the other, and that they had to decide, as quickly and as accurately as possible, whether or not the second letter string of each pair was a Dutch word. They were also told that the first letter string would be either the word *blank* or any other word, 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, with their right forefinger, the positive response key on the right-hand side of the keyboard in front of them. 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. Until after the experiment the subjects were not informed about the presence of associatively related prime-target pairs among the experimental materials.

Prior to every first letter string of a pair (the prime), a fixation star appeared for one second, slightly above and to the left of the place at which the prime would appear. The prime replaced the fixation star immediately. The prime duration was different for each group of subjects and depended upon the particular SOA condition under which a group was tested. There were 11 SOA conditions: 100, 160, 240, 300, 400, 540, 680, 800, 920, 1040 and 1240 msec.[3] In all these SOA conditions, the prime duration was 40 msec shorter than the total SOA. Following prime offset and prior to the presentation of the second letter string (the target) the screen was empty for 40 msec. Subsequently, 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 *correct, slow* or *wrong* appeared. *Slow* occurred whenever a response was correct, but exceeded a preset 900-msec deadline. When the subject failed to respond within 2,400 msec from target 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 further error. The test materials were presented in ten blocks of 24 prime-target pairs each. After each block the mean RT and the number of errors for that block were presented on the screen. After a forced rest of minimally 10 sec the subject initiated the presentation of a new block by pressing one of the response keys. Prior to the test materials the practice materials were presented in three blocks of 24 prime-target pairs each and one last block of 14 pairs only.

Results

Word-Target Data. Table 1 presents the mean RTs, the mean subjects' standard deviations (collapsed across items) and error rates (incorrect responses and responses slower than 1,400 msec combined) for each of the three groups of critical positive prime-target pairs in all 11 SOA conditions. Furthermore, for each SOA condition the facilitatory, inhibitory and total priming effects (facilitatory and inhibitory effects combined) are given in this table.

Within all SOA conditions, the targets in the neutral positive pairs were responded to slower than those in the related positive pairs, and the targets in the unrelated positive condition were responded to slowest. The facilitatory, inhibitory and total priming effects presented in Table 1 are the differences between RTs in the related and neutral, the neutral and unrelated, and the related and unrelated conditions, respectively, within each SOA condition.

In order to test the significance of the facilitatory, inhibitory and total priming effects in the various SOA conditions, the subjects' mean RTs to the targets in each of the three groups of critical positive prime-target pairs within each of the 11 SOA conditions separately, were subjected to a 3 (prime type: related, neutral, unrelated) by 16 (subjects) ANOVA. In these analyses prime type was treated as a within-subjects factor. Error responses and responses slower than 1,400 msec (the latter occurred on less than 0.5% of the

Table 1

Mean Response Times (in Milliseconds), Standard Deviations and Error Rates (in Percentages) for the Different Types of Word-Target Pairs in all SOA Conditions

SOA	prime type												priming effect		
	related			neutral			unrelated			X			fac	inh	tot
	RT	SD	ER	RT	SD	ER	RT	SD	ER	RT	SD	ER			
100	525	95	2.5	548	103	2.2	577	129	1.9	550	109	2.2	23[1]	29	52
160	482	97	0.6	518	92	2.8	543	108	3.4	514	99	2.3	36	25	61
240	487	98	0.9	547	131	1.6	561	116	5.9	532	115	2.8	60	14[2]	74
300	474	86	0.9	518	102	1.9	554	112	8.8	515	100	3.9	44	36	80
400	458	78	2.2	504	93	1.9	535	95	6.6	499	89	3.5	46	31	77
540	451	109	0.6	499	96	3.4	542	106	7.8	497	104	4.0	48	43	91
680	453	95	0.6	511	95	2.2	550	100	7.2	505	97	3.3	58	39	97
800	452	105	0.3	519	110	1.9	554	110	5.6	508	108	2.6	67	35	102
920	450	93	0.6	531	118	0.9	569	118	8.8	517	110	3.4	81	38	119
1040	454	117	2.2	537	131	1.6	577	123	7.5	523	124	3.8	83	40	123
1240	489	99	1.6	538	107	3.1	564	108	4.1	530	105	2.9	49	26	75
X	470	97	1.2	525	107	2.1	557	111	6.1	517	105	3.1	55	32	87

Note: Priming effects without superscript are significant at the .05 level or better on both the subject and item analyses.
[1]Significant at the .01 level on the subject analysis and nonsignificant on the item analysis
[2]Nonsignificant on both the subject and the item analyses

trials) were discarded from the analyses, as well as from all further analyses reported below. Also, for each of the 11 conditions a 3 (prime type) by 20 (critical items) ANOVA was run on the item means for correct responses faster than 1,400 msec, collapsed across subjects. In these item analyses prime type was treated as a between-items factor. The effect of prime type was significant in all 11 subject analyses as well as in all 11 item analyses ($p < .001$ in all cases). Furthermore, a minF' (Clark, 1973) was calculated for each of the SOA conditions, combining the F-values of the subject and item analyses. All minF' analyses showed a significant effect of prime type ($p < .01$ in all cases). Subsequently, Newman-Keuls tests were performed on the differences between the mean RTs to the targets in the three prime-type conditions. For each SOA condition two such tests were performed, one on the subject analysis and one on the item analysis. The significance levels of the different priming effects that were obtained from these tests are presented in Table 1.

On the subjects' means to the targets in the three critical groups of positive prime-target pairs of all 11 SOA conditions combined, a 3 (prime type) by 11 (SOA) by 16 (subjects) ANOVA was performed, treating prime type as a within-subjects factor and SOA as a between-subjects factor. Also, a 3 (prime type) by 11 (SOA) by 20 (critical items) ANOVA was run on the item means collapsed across subjects, treating prime type as a between-items factor and SOA as a within-items factor.

As was expected from the results of the separate SOA conditions, the main effect of prime type was highly reliable on both analyses [F_s (2,330) = 514.99, $p < .001$; F_i (2,57) = 51.81, $p < .001$]. MinF' combining the F-values from both analyses was also significant [*minF'* (2,68) = 47.07, $p < .001$]. The overall means for the three different prime type conditions were 470, 525 and 557 msec for the related, neutral and unrelated pairs, respectively. Thus, collapsed across SOA conditions, the targets in the related condition were responded to 55 msec faster than those in the neutral condition. The latter, in turn, were processed 32 msec faster than the targets in the unrelated condition. Consequently, the average total priming effect was 87 msec. All three differences between the mean RTs of the factor prime type were statistically reliable on the Newman-Keuls tests that were subsequently performed on the subject and item analyses ($p < .01$ in all cases).

The main effect of SOA was only significant on the item analysis [F_s (10,165) = 1.50, $p > .10$; F_i (10,570) = 23.72, $p < .001$]. The mean RTs for the 11 SOA conditions collapsed across the three types of positive prime-target pairs are shown in Table 1. As can be seen from this table, these means tend to decrease when SOA increases from 100 msec to 400 msec, and to increase again from the SOA of 680 msec onwards.

The interaction between prime type and SOA was significant on both the subject and the item analyses [F_s (20,330) = 3.73, $p < .001$; F_i (20,570) = 5.31, $p < .001$; *minF'* (20,744) = 2.19, $p < .01$]. The interaction data are shown in Figure 1. Apart from the irregularities in the 240-msec SOA condi-

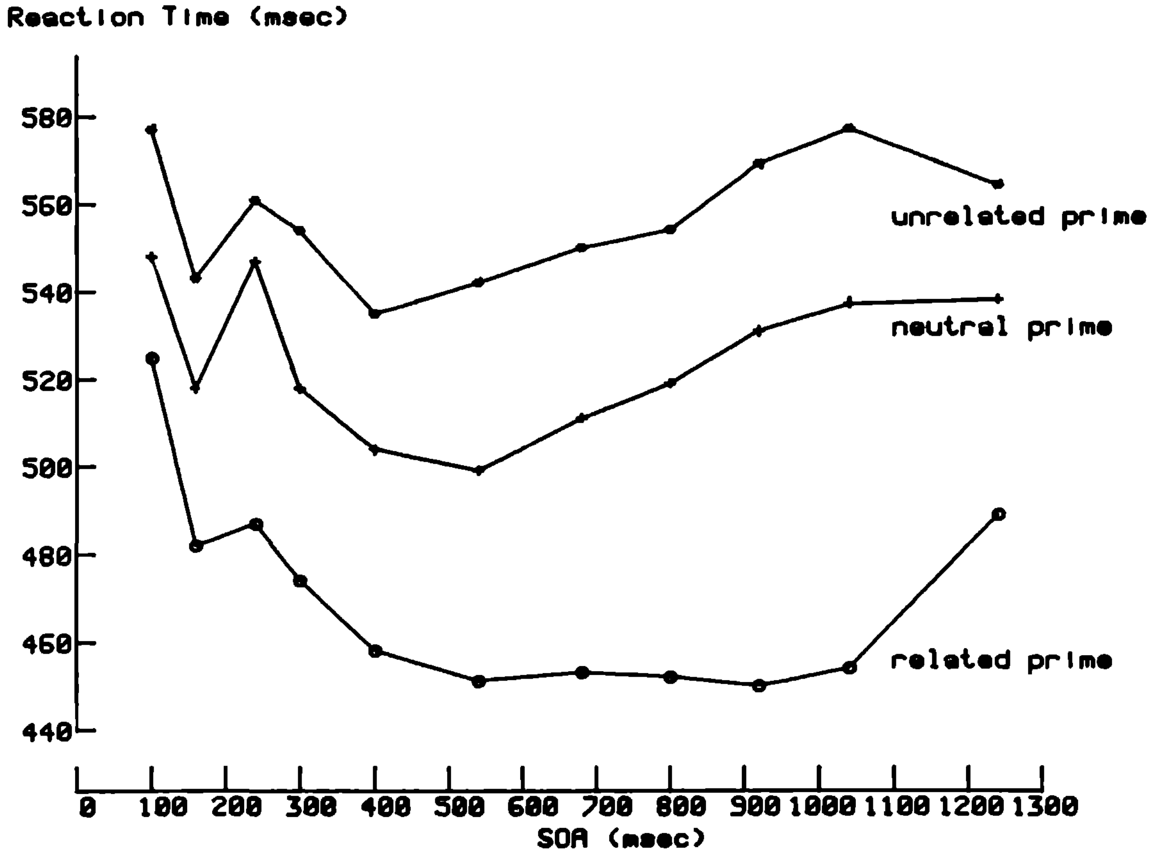

Figure 1. Reaction time for correct responses to word targets (positive trials) as a function of stimulus-onset asynchrony.

tion, the RTs to the targets in all three types of positive prime-target pairs decrease gradually between 100- and 400-msec SOA. From that point onwards, the curves for the unrelated and neutral positive pairs follow approximately the same course, reflecting a gradual slowing down upto the 1040-msec SOA condition. The RTs to the targets in the related positive pairs deviate from those to the remaining positive pairs. Over a wide range of intermediate SOAs (from 400- to 1040-msec SOA) they remain constant at about 450 msec, until they suddenly increase beyond the 1040-msec condition. As a consequence of the way in which the three functions behave over SOAs, the inhibitory effect of an unrelated prime, that is measured from the neutral condition, changes little over SOAs, whereas the facilitatory effect of a related prime is affected much more by changing SOA.

To see whether these observations could be confirmed statistically, four further analyses were performed on the data. To see whether varying SOA does indeed affect the size of the facilitatory effect, a 2 (prime type) by 11 (SOA) by 16 (subjects) ANOVA and a 2 (prime type) by 11 (SOA) by 20 (items) ANOVA were performed on the RTs to the targets in the related and neutral conditions, leaving out the unrelated prime-target pairs. Subsequently, the same analyses were performed on the RTs to the targets in the neutral and unrelated conditions only, to see whether the size of the inhibitory effect does indeed not change over SOAs. Of these analyses only the interaction data will be reported. All analyses supported the ideas suggested by Figure 1: The subject and item analyses on the RTs to targets in the related and neutral prime-target pairs showed a significant interaction between SOA and prime type [F_s (10,165) = 4.67, $p < .001$; F_i (10,380) = 6.41, $p < .001$; $minF'$ (10,400) = 2.70, $p < .01$]. In other words, the facilitatory effect changes significantly over SOAs. However, the analyses on the RTs to the targets in the neutral and unrelated pairs indicated that the size of the inhibitory effect does not change over SOAs [F_s (10,165) < 1; F_i (10,380) = 1.35, $p > .10$].

A growing facilitatory effect for related prime-target pairs and a virtually constant inhibitory effect for unrelated pairs could easily be associated intuitively with RTs for related pairs decreasing with increasing SOAs and with a relatively flat RT function for unrelated pairs, respectively. What actually happens (Figure 1) is quite the opposite: The growth of the facilitatory effect is due to a slowing down of responses in the neutral condition beyond the 540-msec SOA rather than to speeded responses in the related condition. Similarly, the relative stability of the inhibitory effect is due to the fact that the RTs to targets in the unrelated and neutral positive pairs increase at approximately the same rate beyond the 540-msec SOA condition.

With respect to the error data, Table 1 shows that, on the whole, more errors were made in the neutral condition than in the related condition, and that most errors were made in the unrelated condition. Therefore, the differences in RTs between these three types of positive prime-target pairs were not caused by a trade-off between speed and accuracy. Since few errors were made on the word targets (3.1% overall), no ANOVA was performed on them.

Pseudoword-Target Data. Table 2 shows the mean RTs, the mean subjects' standard deviations (collapsed across items) and error rates (incorrect responses and responses slower than 1,400 msec combined) for the critical noun-pseudoword and the *blank*-pseudoword pairs in all SOA conditions. For each SOA, the difference score between these two means is also presented in this table.

Within all but the two shortest SOAs the neutral negative condition received longer RTs than the non-neutral negative condition. On the subjects' mean RTs to the targets in the 40 critical noun-pseudoword pairs and to those in the 40 *blank*-pseudoword pairs in the set of materials a 2 (prime type) by 16 (subjects) ANOVA was performed for each SOA condition, treating prime type as a within-subjects factor. Also, for each of the 11 SOA conditions a 2 (prime type) by 40 (items) ANOVA was run on the item means for correct responses faster than 1,400 msec, collapsed across subjects. In these item analyses prime type was treated as a between-items factor. The effect of prime type was significant on the subject analyses of all but the two shortest SOA conditions (100 and 160 msec) and it was significant on the item analyses of seven out of the 11 SOA conditions. It was insignificant on the item analyses of the SOA conditions of 100, 160, 800 and 1240 msec. The minF' that was calculated

Table 2

Mean Response Times (in Milliseconds), Standard Deviations and Error Rates (in Percentages) for the Groups of Critical Pseudoword-Target Pairs in all SOA Conditions

SOA	prime type									priming effect
	non-neutral			neutral			X			
	RT	SD	ER	RT	SD	ER	RT	SD	ER	
100	629	105	3.0	635	116	5.3	632	111	4.1	6[1]
160	598	118	2.7	602	119	2.2	600	119	2.4	4[1]
240	592	114	2.3	617	123	3.6	604	119	3.0	25
300	568	102	2.0	591	102	3.4	579	102	2.7	23
400	561	96	1.6	582	111	2.5	571	104	2.0	21
540	560	115	3.4	583	112	4.8	571	114	4.1	23
680	558	95	0.9	594	109	2.8	576	102	1.9	36
800	568	115	3.1	583	114	3.1	576	115	3.1	15[2]
920	569	99	1.4	608	122	3.8	588	111	2.6	39
1040	588	128	3.3	623	129	4.1	606	129	3.7	35
1240	604	118	1.9	619	123	3.0	612	121	2.4	15[2]
X	581	110	2.3	603	116	3.5	592	113	2.9	22

Note: Priming effects without superscript are significant at the .05 level or better on both the subject and the item analyses.
[1]Nonsignificant on both the subject and the item analyses
[2]Significant at the .05 level on the subject analysis and nonsignificant on the item analysis

for the SOA conditions with statistically reliable effects of prime type on both the subject and the item analysis was, in all cases, significant at the .05 level or better. The significance levels of the difference scores between the means for the critical non-neutral and the neutral negative conditions are shown in Table 2.

On the subjects' mean RTs to the 40 critical noun-pseudoword pairs and the 40 *blank*-pseudoword pairs a 2 (prime type) by 11 (SOA) by 16 (subjects) ANOVA was performed, treating prime type as a within-subjects factor and SOA as a between-subjects factor. Also, a 2 (prime type) by 11 (SOA) by 40 (items) ANOVA was performed on the item means collapsed across subjects, treating prime type as a between-items factor and SOA as a within-items factor.

As was expected from the results of the separate SOAs, the main effect of prime type was statistically reliable on both analyses [F_s (1,165) = 133.53, $p <$ .001; F_l (1,78) = 9.43, $p <$ .001; *minF'* (1,89) = 8.80, $p <$ .01]. The mean RT to the 40 critical noun-pseudoword pairs was 581 msec, which was 22 msec shorter than the mean RT to the *blank*-pseudoword pairs (603 msec).

The main effect of SOA was also significant on both analyses [F_s (10,165) = 2.00; $p <$ .05; F_l (10,780) = 48.05, $p <$ .001; *minF'* (10,178) = 1.92, $p <$ .05]. The mean RTs for the 11 SOA conditions collapsed across the two negative prime-type conditions are shown in Table 2. They tend to decrease gradually between the SOAs of 100 and 400 msec and to increase again from the SOA of 680 msec onwards. This result is similar to the development over SOAs of mean RTs collapsed across the different types of positive prime-target pairs.

The interaction between SOA and prime type was statistically reliable [F_s (10,165) = 3.42, $p <$ .01; F_l (10,780) = 4.28, $p <$ .01; *minF'* (10,470) = 1.90, p < .05]. As can be seen from Figure 2, the priming effect is virtually nil within the two shortest SOAs and increases beyond the 160-msec SOA. From 240-msec SOA onwards it remains relatively constant for about 900 msec, until it declines rapidly between the 1040- and 1240-msec SOA conditions. A comparison of Figures 1 and 2 shows that the SOA conditions that produce small effects of prime type on the negative trials synchronize with those that produce small effects of prime type on the positive trials. The curves for the two types of negative prime-target pairs are very much alike, and they have a shape similar to those for the positive-pair curves. Overall, the RTs to the targets in negative pairs are longer than those to the targets in the positive pairs.

With respect to the error data, Table 2 shows that, on the whole, more errors were made to *blank*-pseudoword pairs than to noun-pseudoword pairs. Therefore, the difference in RT between these two types of negative prime-target pairs was not caused by a trade-off between speed and accuracy. Since few errors were made on the pseudoword targets (2.9% overall), no ANOVA was performed on them.

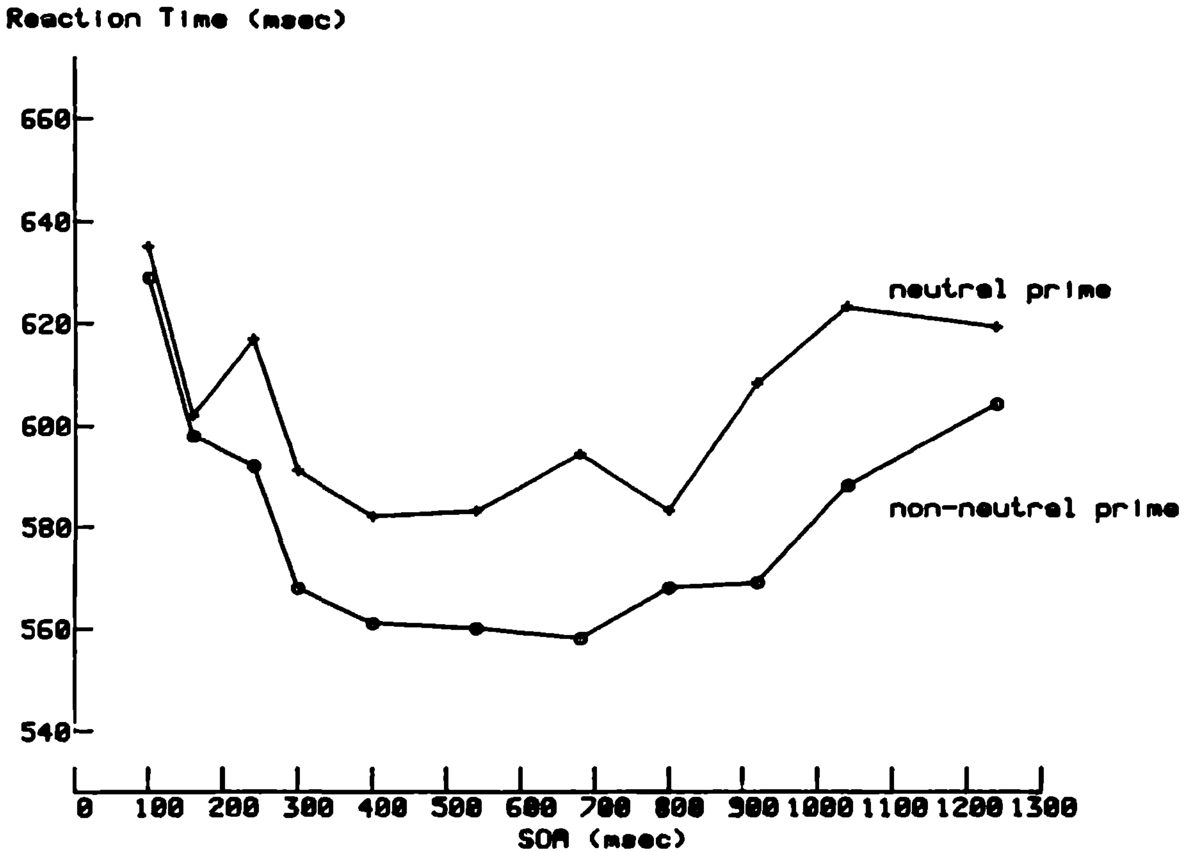

Figure 2. Reaction time for correct responses to pseudoword targets (negative trials) as a function of stimulus-onset asynchrony.

DISCUSSION

Even though 11 different groups of subjects provided the data for the various SOA conditions, Figures 1 and 2 show remarkably smooth curves. Furthermore, the RT functions of all types of prime-target pairs, positive and negative, are very similar. Apart from the irregularities in the 240-msec SOA condition, the RTs for all types of prime-target pairs decrease between 100- and 400-msec SOA. The functions differ only with respect to the number of intermediate SOAs over which they remain flat. All functions are reminiscent of those obtained by Posner and Boies (1971) who found that the RTs are minimal when the subjects are given about 500 msec between a preparatory stimulus and a subsequent stimulus. According to Posner and Boies, these functions reflect the time necessary to encode the first stimulus in a form which is optimal for processing the second (see also Antos, 1979).

Discussing the present RT functions in terms of the three processes described in the introduction to this paper may be a hazardous enterprise. This is due to the fact that the present design confounds the facilitatory effects of automatic spreading activation and of prime-induced attentional processing, and presumably also one of coherence checking, since in the present experiment all these three processes positively affect the lexical decisions to the *same* targets (namely to word targets that are associatively related to a word prime). It was assumed that the effectiveness of at least two of these processes, automatic spreading activation and directed attention, depends upon the SOA of prime and target. But since little is known about the range of SOAs over which these processes are effective, it is virtually impossible to tell which part of our functions results from their combined effects. An assumption supported in the literature (Neely, 1977) is that beyond about 400-msec SOA automatic spreading activation no longer exerts a priming effect, since it has died out by then.

Apart from confounding facilitatory effects of different processes, the present design also confounds the inhibitory effects of prime-induced attentional processing and of coherence checking on unrelated positive prime-target pairs. Using a different paradigm, Neely (1977) found a way of disentangling the facilitatory effects of automatic spreading activation and of directed attention. He included a shift condition in his experiment, in which the subjects were instructed to direct their attention to a category of words unrelated to the prime. If such an unrelated word was subsequently presented as target and its processing was facilitated, this effect had to be attributed to prime-induced attentional processing. In contrast, if an unexpected but related target word was presented, and it appeared to be facilitated, automatic spreading activation must have caused this effect. Whereas the facilitatory effects of automatic spreading activation and directed attention indeed seem to have been dissociated in Neely's (1977) study, the third process, coherence checking, presumably continued to confound the sources of facilitation and inhibition. It may even have done so in a much more complex manner than in our present design, since the latter process can be expected to have facilitated the (related) targets that profited by automatic spreading activation, whereas it presumably inhibited the (unrelated) targets that showed benefit from directed attention. One reason for not adopting Neely's (1977) design was the present consideration that it would presumably preclude only part of the confounding effects of the different priming processes. The main reason that we did not adopt his design in the present research was, however, that it was felt to lack naturalness. This would cause extra difficulties when relating the findings to natural verbal processing tasks such as reading, and to the priming studies mentioned above, that have used sentence fragments as primes.

One of the priming effects in the present data, the difference between the neutral and non-neutral negative conditions, is presumably the result of a single process, namely, prime-induced attentional processing. This conclusion is supported by our earlier finding (De Groot et al., 1982) that the difference between the two negative conditions is absent if the set of experimental materials does not encourage such directed attention particularly strongly. If directed attention is indeed the source of priming in the pseudoword data, we can infer that this process starts to be effective between the SOAs of 160 and

240 msec. The fact that targets following a non-neutral prime are processed faster, except in the two shortest SOA conditions, than those following a neutral prime indicates that the subjects used the non-neutral prime to generate one or more words that they subsequently matched onto the actual target, and that they were biased towards a *yes* response in case of a match and towards a *no* response in case of a mismatch (see introduction; cf. Neely, 1976, 1977; Posner & Snyder, 1975b). It is most parsimonious to conclude from the pseudoword data that the onset time of prime-induced attentional facilitation for word targets related to the prime, and of prime-induced attentional inhibition for word targets unrelated to the prime also have to be localized between the SOAs of 160 and 240 msec. If this assumption is correct, the inhibition for unrelated targets that is observed with the two shortest SOAs (Figure 1) must be attributed solely to the second process that produces inhibition for unrelated words, viz., coherence checking; from 240-msec SOA onwards the inhibitory effects of this process and of directed attention are confounded. Similarly, the facilitation for related targets in the two shortest SOA conditions must be due to two priming processes at the most, namely, automatic spreading activation and coherence checking. Combined with Neely's (1977) result that automatic spreading activation is no longer effective at about 400-msec SOA, the complete picture of confounding sources of facilitation over SOAs is as follows: With SOAs of 100 and 160 msec, only automatic spreading activation and coherence checking cause facilitation for related targets. Between 160- and 240-msec SOA directed attention joins the other two as a source of facilitation. From 400-msec SOA onwards only coherence checking and directed attention continue to contribute to this effect.

With respect to the role of attention in primed lexical decision, the 1240-msec SOA condition is particularly interesting. Figures 1 and 2 show that with this SOA all priming effects in the non-neutral positive and negative conditions are relatively small. This result is suggestive of a decrease of attentional processing.

A noteworthy aspect of the data is the invariability of the mean RT to related targets over six intermediate SOAs. From 400- to 1040-msec SOA this RT is approximately 450 msec, as if a ceiling has been reached here. In an earlier experiment (De Groot, Note 1) we found that the mean lexical-decision RT to the same related prime-target pairs as were used in the present study decreased further at intermediate and longer SOAs (to 432 msec in the 1040-msec SOA condition) if all unrelated prime-target pairs were replaced by related pairs, thus effectuating a 1.00 proportion condition (instead of the current .75 proportion condition). This finding suggests that the removal of unrelated prime-target pairs simplifies processing in a lexical-decision task.

Finally, the development over SOAs of RTs to word targets preceded by the neutral prime *blank* deserves some special attention. The RTs in the neutral conditions are particularly important, since they provide the baseline from which facilitation and inhibition are assessed. It is due to the fact that the RTs in the neutral positive condition grow concurrently with those in the unrelated positive condition that the facilitatory effect of a related prime increases over SOAs, whereas the inhibitory effect of an unrelated prime remains constant. It was mentioned above that the subjects are optimally ready to respond to the target when the SOA is about 500 msec. The relatively long RTs with the short SOAs that is found for all types of prime-target pairs reflects incomplete prime processing (Posner & Boies, 1971). The increase in RT towards the end of the SOA range may indicate that attention relaxes over time. If the effect of readiness affects all types of prime-target pairs to the same extent it could be safely ignored, since it would not interfere with the development of priming effects over SOAs. However, there is reason to believe that this effect of readiness influences neutral and non-neutral prime-target pairs differently. Because it is repeatedly presented, the neutral prime *blank* is presumably encoded more rapidly than the non-neutral primes, causing an overestimation of the inhibitory effect of an unrelated prime and an underestimation of the facilitatory effect of a related prime in the short SOA conditions. In contrast, with the longer SOAs inhibition may be underestimated and facilitation overestimated, since the (for the subjects) uninteresting neutral prime conceivably causes attention to relax faster than a non-neutral prime that is only presented once and is therefore more interesting. As a consequence of these differential effects of readiness in the neutral and non-neutral conditions, the interpretation of the development of the size of facilitatory and inhibitory effects over SOAs could be complicated. Possibly, the only priming effects that can be safely relied on are those obtained by comparing non-neutral conditions. As we have pointed out on various occasions (De Groot et al, 1982; De Groot, in press) there appears to be no satisfactory solution to this problem. But it would be even less satisfactory to conlude from these considerations that a neutral condition may as well be left out, since by removing this condition we would lose the best means presently available for the identification of the processes underlying word priming.

REFERENCE NOTES

1. De Groot, A.M.B. Primed lexical decision: Combined effects of the proportion of related prime-target pairs and of the stimulus-onset asynchrony of prime and target. Paper submitted for publication.
2. Hudson, P.T.W., Maarse, F.J.M., & Bouwhuisen, C. LEXSYS: A real-time multi-subject system for psycholinguistic experiments. Report. Department of Experimental Psychology, University of Nijmegen, P.O. Box 9104, Nijmegen 6500 HE, The Netherlands.

REFERENCES

Antos, S.J. Processing facilitation in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1979, *5*, 527-545.

Becker, C.A. Semantic context and word frequency effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 1979, *5*, 252-259.

Becker, C.A. Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory and Cognition*, 1980, *8*, 493-512.

Clark, H.H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, 1973, *12*, 335-359.

De Groot, A.M.B. *Mondelinge Woordassociatie Normen: 100 Woordassociaties op 460 Nederlandse Zelfstandige Naamwoorden*. Lisse, The Netherlands: Swets & Zeitlinger, 1980.

De Groot, A.M.B. The range of automatic spreading activation in word priming. *Journal of Verbal Learning and Verbal Behavior*, in press.

De Groot, A.M.B., Thomassen, A.J.W.M., & Hudson, P.T.W. Associative facilitation of word recognition as measured from a neutral prime. *Memory and Cognition*, 1982, *10*, 358-370.

Fischler, I. Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 18-26.

Fischler, I., & Bloom, P.A. Automatic and attentional processes in the effects of sentence context on word recognition. *Journal of Verbal Learning and Verbal Behavior*, 1979, *18*, 1-20.

Fischler, I., & Bloom, P.A. Rapid processing of the meaning of sentences. *Memory and Cognition*, 1980, *8*, 216-225.

Fischler, I., & Goodman, G.O. Latency of associative activation in memory. *Journal of Experimental Psychology: Human Perception and Performance*, 1978, *4*, 455-470.

Forster, K.I. Levels of processing and the structure of the language processor. In W.E. Cooper & E. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett*. Hillsdale, N.J.: Erlbaum, 1979.

Fowler, C.A., Wolford, G., Slade, R., & Tassinary, L. Lexical access with and without awareness. *Journal of Experimental Psychology: General*, 1981, *110*, 341-362.

Marcel, A. Conscious and unconscious reading: The effects of visual masking on word perception. *Cognitive Psychology*, in press.

Neely, J.H. Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. *Memory and Cognition*, 1976, *4*, 648-654.

Neely, J.H. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 1977, *106*, 226-254.

Perfetti, C.A., & Roth, S. Some of the interactive processes in reading and their role in reading skill. In A.M. Lesgold & C.A. Perfetti (Eds.), *Interactive processes in reading*. Hillsdale, N.J.: Erlbaum, 1981.

Posner, M.I., & Boies, S.J. Components of attention. *Psychological Review*, 1971, *78*, 391-408.

Posner, M.I., & Snyder, C.R.R. Attention and cognitive control. In R.L. Solso (Ed.), *Information Processing and Cognition: The Loyola Symposium*. Hillsdale N.J.: Erlbaum, 1975. (a)

Posner, M.I., & Snyder, C.R.R. Facilitation and inhibition in the processing of signals. In P.M.A. Rabbitt & S. Dornic (Eds.), *Attention and Performance V*. New York: Academic Press, 1975. (b)

Rouse, R.O., & Verinis, J.S. The effect of associative connections on the recognition of flashed words, *Journal of Verbal Learning and Verbal Behavior*, 1962, *88*, 454-462.

Schuberth, R.E., & Eimas, P.D. Effects of context on the classification of words and nonwords. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 27-36.

Schvaneveldt, R.W., & McDonald, J.E. Semantic context and the encoding of words: Evidence for two modes of stimulus analysis. *Journal of Experimental Psychology: Human Perception and Performance*, 1981, *7*, 673-687.

Stanovich, K.E., & West, R.F. Mechanisms of sentence context effects in reading: Automatic activation and conscious attention. *Memory and Cognition*, 1979, *7*, 77-85.

Stanovich, K.E. & West, R.F. The effect of sentence context on ongoing word recognition: Tests of a two-process theory. *Journal of Experimental Psychology: Human Perception and Performance*, 1981, *7*, 658-672.

Tweedy, J.R., Lapinski, R.H., & Schvaneveldt, R.W. Semantic-context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context. *Memory and Cognition*, 1977, *5*, 84-89.

Uit den Boogaart, P.C. (Ed.). *Woordfrequenties in Geschreven en Gesproken Nederlands*. Utrecht, The Netherlands: Oosthoek, Scheltema & Holkema, 1975.

Warren, R.E. Association, directionality and stimulus encoding. *Journal of Experimental Psychology*, 1974, *102*, 151-158.

Warren, R.E. Time and the spread of activation in memory. *Journal of Experimental Psychology: Human Learning and Memory*, 1977, *3*, 458-466.

West, R.F. & Stanovich, K.E. Automatic contextual facilitation in readers of three ages. *Child Development*, 1978, *49*, 717-727.

West, R.F., & Stanovich, K.E. Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 1982, *5*, 385-399.

FOOTNOTES

[1]The choice of the 40 critical noun-pseudoword pairs was based on the results of a post hoc unprimed lexical-decision experiment in which all targets of the present set of materials were presented to 20 subjects (different from those who took part in the current priming study, but taken from the same population) who classified them as words or pseudowords. Prior to this unprimed lexical-decision experiment the 80 noun-pseudoword pairs of the priming study were randomly divided into two sets of 40 each. The mean unprimed lexical-decision RTs to the pseudowords in these two sets of noun-pseudoword pairs were 575 and 562 msec, with standard errors of 5.1 and 4.3 msec, respectively. The mean unprimed lexical-decision RT to the pseudowords in the 40 *blank*-pseudoword pairs was 577 msec, with a standard error of 4.9. On the basis of these results the former of the two sets of noun-pseudoword pairs was chosen as the critical set.

[2]The present set of materials is the same as one of the four sets used in a related study (De Groot, Note 1) in which both SOA and the proportion of related prime-target pairs were systematically varied.

[3]The data of three of these SOA conditions, namely 240, 540 and 1040 msec, have also been reported in a related study (De Groot, Note 1; see also Footnote 2).

Appendix A (positive prime-target pairs: related pairs)

	Dutch prime	Dutch target	English prime	English target	association[1] frequency	language[2] frequency
1	antwoord	vraag	answer	question	79	320
2	bakker	brood	baker	bread	72	31
3	slager	vlees	butcher	meat	79	41
4	kraan	water	tap	water	62	193
5	kluif	hond	bone	dog	53	57
6	snavel	vogel	beak	bird	53	102
7	vaas	bloem	vase	flower	85	64
8	veulen	paard	foal	horse	64	54
9	veter	schoen	shoelace	shoe	94	34
10	dag	nacht	day	night	60	139
11	klink	deur	latch	door	75	166
12	maan	zon	moon	sun	54	49
13	venster	raam	window	window	58	83
14	merg	been	marrow	bone	54	90
15	kapstok	jas	hall-stand	coat	74	31
16	pijl	boog	arrow	bow	66	12
17	donder	bliksem	thunder	lightning	52	7
18	vork	mes	fork	knife	51	11
19	kalf	koe	calf	cow	74	5
20	deksel	pan	lid	pan	55	16
				X	65.7	75.3
				SD	12.6	78.4

[1]association frequency in percentages
[2]language frequency per 600,000 words

Appendix A (positive prime-target pairs: unrelated pairs)

	Dutch prime	Dutch target	English prime	English target	language frequency
1	karper	week	carp	week	308
2	kei	bord	boulder	plate	28
3	haan	trein	cock	train	44
4	kwast	maand	brush	month	209
5	lam	neus	lamb	nose	52
6	web	tafel	web	table	106
7	zoon	grens	son	frontier	61
8	zwijn	vrede	hog	peace	55
9	rozijn	kerel	raisin	fellow	35
10	dame	brief	lady	letter	175
11	meisje	lucht	girl	air	83
12	peer	bos	pear	wood	46
13	haver	vriend	oats	friend	123
14	peper	les	pepper	lesson	27
15	teen	rook	toe	smoke	12
16	vlam	mond	flame	mouth	96
17	mantel	afgrond	coat	abyss	8
18	wiek	pet	sail	cap	13
19	gesp	wol	buckle	wool	6
20	zus	rat	sister	rat	16
				X	75.2
				SD	78.0

Appendix A (positive prime-target pairs: neutral pairs)

	Dutch prime	Dutch target	English prime	English target	language frequency
1	blanco	werk	blank	work	349
2	blanco	gras	blank	grass	23
3	blanco	steen	blank	stone	43
4	blanco	avond	blank	evening	178
5	blanco	reis	blank	journey	55
6	blanco	gezin	blank	family	106
7	blanco	leger	blank	army	64
8	blanco	paus	blank	pope	53
9	blanco	adres	blank	address	35
10	blanco	middel	blank	means	133
11	blanco	geld	blank	money	159
12	blanco	vis	blank	fish	42
13	blanco	krant	blank	newspaper	85
14	blanco	hart	blank	heart	97
15	blanco	gat	blank	hole	34
16	blanco	doos	blank	box	12
17	blanco	inbraak	blank	burglary	7
18	blanco	bad	blank	bath	11
19	blanco	das	blank	scarf	8
20	blanco	kip	blank	chicken	19
				X	75.7
				SD	81.8

CHAPTER IV

(submitted for publication)

PRIMED LEXICAL DECISION: COMBINED EFFECTS OF THE PROPORTION OF RELATED PRIME-TARGET PAIRS AND THE STIMULUS-ONSET ASYNCHRONY OF PRIME AND TARGET

A.M.B. de Groot

Lexical decisions to word targets preceded by associatively related word primes are generally faster than those to words following neutral primes, whereas, under certain circumstances, lexical decisions to words preceded by unassociated word primes are slower than those to words following neutral primes. An experiment is reported that investigates the influence of the proportion of related prime-target pairs in the set of materials and of the stimulus-onset asynchrony (SOA) of prime and target on these associative priming effects. Four levels of proportion and three levels of SOA are systematically varied. Both variables are found to affect the size of the associative priming effects. Furthermore, the data suggest interdependence between them. The size of the priming effects only varies with SOA if the proportion of related pairs is relatively large. The data are interpreted primarily in terms of changes in the amount of prime-induced attentional processing engendered by the subjects.

In a lexical-decision experiment, subjects decide whether letter strings are words or nonwords. Typically, word decisions are faster when the word being classified, the target, is an associate of a preceding word, the prime (Fischler, 1977; Fischler & Goodman, 1978; Neely, 1976, 1977). Several findings suggest that this associative priming effect occurs automatically. First, Fischler (1977) showed that it was equally large for related prime-target pairs that had and those that had not been preceded by other related pairs in an experiment. Second, Neely (1977) showed facilitation for targets associatively related to the prime even though the subjects had to direct their attention to words unrelated to the prime. Finally, the associative priming effect has been observed when the prime was not consciously perceived by the subjects (De Groot, in press; Fowler, Wolford, Slade & Tassinary, 1981; Marcel, in press). One way in which this automatic facilitation effect has been interpreted is to attribute it to an activation wave in lexical memory spreading from the prime's memory representation to representations for associatively related words. If a word corresponding to one of these activated representations is subsequently presented, relatively little stimulus information is needed for it to be recognized.

Automatic spreading activation is presumably insensitive to specific instructions given to the subjects and to overall characteristics of the stimulus materials surrounding the critical related prime-target pair. Nevertheless, these factors have been shown to influence the associative priming effect. For example, Schmidt (1976) observed shorter response times for related targets when the subjects were led to expect them than when they were left uncertain about the fact that prime and target would be related. Using a lexical-decision task, Tweedy, Lapinski and Schvaneveldt (1977) found that the size of the priming effect depended upon the proportion of related prime-target pairs in the stimulus set. In their experiment three independent groups of subjects were tested, each in a single proportion condition. In a further experiment (Tweedy & Lapinski, 1981) they found that a gradual increase in the number of related prime-target pairs per block of trials, while keeping the total number of prime-target pairs per block constant, enhanced the priming effect in successive blocks presented to the same subjects; a gradual decrease in the number of related prime-target pairs in successive blocks presented to a second group of subjects reduced the effect. The fact that the priming effect is sensitive to test instructions and to the composition of the materials indicates that, apart from the automatic component, an adaptive strategy must also be postulated in order to explain the priming mechanism. Two studies by Neely (1976, 1977) suggest that such adaptive strategies in primed lexical-decision experiments involve the subjects' use of the prime to direct attention to the memory representations of one or more words that may subsequently occur as target.

To account for priming effects in a number of experiments using paradigms different from lexical decision, Posner and Snyder (1975a, b) have developed a theory of attention that incorporates two types of processing, automatic and attentional. The former is similar to the automatic activation of lexical representations mentioned above, while the latter is presumably involved in the above adaptive strategies. The theory attributes a number of different properties to the two types of processing. One of these differences is that automatic processing is enacted very rapidly, whereas directing attention to one or more memory representations prior to the occurrence of the corresponding words requires more time. This view predicts that the effect of the proportion of related prime-target pairs on the size of priming must depend upon the time duration between prime onset and target onset. Only if there is sufficient time for attention to be directed to the representation of the subsequent target word, varying the proportion of related pairs should influence the priming effect. That is, whereas varying the proportion of related pairs presumably determines whether or not and to what extent attention is committed to prime-induced attentional processing, it is likely that the stimulus-onset asynchrony (SOA) of prime and target does not affect the *amount* of prime-induced attentional processing, but determines whether or not such processing is *effective*.

Both the effect of the SOA of prime and target (Neely, 1976, 1977) and of different proportions of related prime-target pairs (Tweedy et al., 1977; Tweedy & Lapinski, 1981) on the size of the priming effect in lexical-decision tasks have been investigated before. However, no primed lexical-decision experiments have been reported in which both variables were systematically varied. The present study seeks to investigate the development of associative priming over three SOAs for each of four different proportions of related prime-target pairs in a lexical-decision task.

A second difference between automatic and attentional processing in Posner and Snyder's theory is that, while both types of processing can facilitate word recognition, only attentional processing can hinder responses to certain words, namely to those that correspond to memory representations to which no attention is being directed prior to the word's presentation. Unless the subjects are instructed to direct attention to the representations of certain words unrelated to the prime (Neely, 1977), the attended word representations in primed lexical decision are generally those of word associates of the prime. Therefore, if attention is committed to the task, lexical decisions to unrelated words will usually be inhibited. However, if one of the words that correspond to attended representations is presented, the lexical decision will be facilitated. Since, according to Posner and Snyder's theory, automatic spreading activation only facilitates the processing of certain words without inhibiting the processing of others, it follows that whenever inhibition is observed attentional processes must be operative. Facilitatory *and* inhibitory effects of a prime on subsequent lexical decisions can only be assessed if the stimulus set incorporates a neutral condition in which the prime does not influence target processing. The proportion studies by Tweedy and his collaborators did not incorporate such a neutral condition, nor did they systematically vary the SOA of prime and target.

Several investigators have proposed a process different from prime-induced attentional processing as a second source of inhibition for word targets unrelated to the prime in lexical-decision experiments (De Groot, Thomassen & Hudson, 1982, Note 1; Forster, 1979; West and Stanovich, 1982). In a recent paper (De Groot et al., Note 1) we called this process 'coherence checking' and we sketched its workings in lexical-decision experiments using words as primes in the following manner. When the lexical processor (Forster, 1979) recognizes the target as a word, this recognition must subsequently be translated into a *yes* response. This translation process is relatively time consuming (West & Stanovich, 1982), and before it is completed a 'message processor' (Forster, 1979) sends out a *yes* or a *no* output to a decision-making mechanism (Forster, 1979) that accesses the output of both the lexical processor and the message processor. The message processor sends a *yes* output to the decision-making mechanism if it recognizes a relationship between the meanings of word prime and word target, thereby biasing the decision maker towards a *yes* response and facilitating the appropriate *yes* response. When, in case of an unrelated-word target, the message processor discovers unrelatedness between the meanings of prime and target, it sends off a *no* output, that biases the decision maker towards a *no* response. This *no* bias has to be overcome, and, consequently, the lexical decision to the target will be inhibited. For a more complete account of this post-lexical coherence checking, the reader is referred to the De Groot et al. paper (Note

1), and to West and Stanovich (1982) for a similar interpretation of inhibitory effects in lexical-decision tasks in which incomplete sentences were used as primes. It was mentioned above that prime-induced attentional processing requires a relatively long SOA of prime and target in order to be effective. Presumably, coherence checking is much less dependent upon SOA. It can be enacted whenever both prime and target have been consciously recognized. It cannot operate if, for instance, the prime is masked in such a way that it cannot be consciously perceived. Of course, in that case prime-induced attentional processing will also be prevented.

The present experiment is not designed to dissociate the facilitatory and inhibitory effects of automatic spreading activation, prime-induced attentional processing and post-lexical coherence checking, since it appears that attempts to separate out the effects of these processes (Neely, 1977) require an experimental set-up that has a considerably smaller ecological validity for visual word processing tasks such as reading than the present task. Also, to prevent confounding of these processes much more detailed knowledge is required about the way in which they behave over SOAs than is presently available. We have chosen to concentrate primarily on the way in which prime-induced attentional processing operates, the reason for this being that this type of processing allows the strongest predictions about the development of priming effects. With respect to the effect of proportion on the size of the associative priming effects we can make the following prediction. The larger the proportion of related prime-target pairs, the more the subject will make use of the prime to direct attention, and, consequently, the larger the effects of this strategy will be. We have reason to expect that the proportion of related prime-target pairs does not only influence the size of the priming effects on word targets, but also that on nonword targets. The reason for this assumption is that RTs to nonwords following non-neutral primes have been shown to be shorter than those to nonwords following neutral primes, and that this finding has been interpreted in terms of an attentional predict-and-match strategy (Neely, 1976, 1977). The way in which this strategy operates will be explained in the Discussion section below. If we will find such difference between RTs to nonwords following neutral and non-neutral primes, and if indeed an attentional strategy induced by the prime causes this difference, it follows that the size of this difference must be sensitive to the proportion of related word pairs, since this factor determines the amount of attentional commitment. Of course, if we *do* find an interaction between prime type and proportion on the nonword data, this will support the view that attentional processing is the source of the difference between the two types of nonword-target pairs.

Since no detailed information is available about the way in which priming processes behave over SOAs, we will not hazard a detailed prediction about the development of priming effects over SOAs. Yet, from Neely's (1976, 1977) data we may expect some growth of these effects over SOAs due to increased effectivity of attentional processing, even though the facilitatory effect of automatic spreading activation may diminish over the range of SOAs that we have chosen to use here.

Apart from the interactions between prime type and SOA and between prime type and the proportion of related pairs, we also predict an interaction between prime type, SOA and proportion, since we may only expect the variable proportion to affect the size of the priming that is caused by prime-induced attentional processing if the SOA is large enough for such attentional processing to be effective. Also, we may only expect SOA to affect the size of the priming that is caused by prime-induced attentional processing if the subjects consider the proportion of related pairs large enough to engender such processing.

Even though we will be primarily concerned with the effects of prime-induced attentional processing, the present experiment is more than a replication of the studies by Tweedy and his collaborators. Since in the present experiment, unlike in those of Tweedy et al., (i) SOA was manipulated and (ii) a neutral condition was included, it provides a much more detailed picture about the workings and the impact of prime-induced attentional processing.

Method

Materials. The test materials consisted of four sets of 240 prime-target pairs each, viz., 120 with word targets and 120 with nonword targets. The primes in 80 of the word-target and in 80 of the nonword-target pairs were nouns, a different noun in each pair. The prime in the remaining 40 word-target and 40 nonword-target pairs was the Dutch equivalent of the word *blank* (*blanco*). The targets in all 120 word-target pairs were nouns. The targets in all 120 nonword-target pairs were pseudowords, i.e., nonwords that, however, were orthographically permissible Dutch letter sequences. They were derived from nouns by changing, adding or deleting one or two letters.

The four sets of materials differed from one another with respect to the proportion of related word-target pairs. A pair is considered related if the target appears as a word association to the prime in Dutch association norms (De Groot, 1980). A pair is considered unrelated if the target neither occurs as a word association to the prime in these norms, nor has any other obvious relation to the prime. In Set 1 the target was associatively related to the prime in all 80 pairs that had a noun both as prime and as target (proportion 1.00). All associatively related targets had appeared as strong primary word associations to the corresponding primes in the norms. In Set 2 the target was related to the prime in 60 of the pairs that had a noun both as prime and as target, and the target was unrelated to the prime in 20 of these pairs (proportion .75). In Sets 3 and 4 these proportions were .50 (40 related and 40 unrelated) and .25 (20 related and 60 unrelated), respectively. The remaining 40 of the total of 120 word-target pairs in each of the four sets were *blank*-noun pairs. These pairs served as neutral prime-target pairs from which facilitation (for related pairs) and inhibition (for unrelated pairs) were to be determined. The neutral prime *blank* was preferred to a row of *Xs* that has been used more often (e.g., Becker, 1980; Neely, 1976, 1977; Schvaneveldt & McDonald, 1981) since a number of studies (Antos, 1979; De Groot, Thomassen & Hudson, 1982) provide evidence of artifactual inhibition resulting from the latter. Set 2 was formed by rearranging the primes and targets of 20 out of the 80 related word-target pairs of Set 1 in such a way that in the association norms none of the targets appeared as word association to the prime. Set 3 was formed by rearranging 20 more related pairs of Set 1 into unrelated word-target pairs. Finally, Set 4 was formed by rearranging 20 out of the 40 remaining related word-target pairs of Set 3 into unrelated pairs. In all other respects the four sets were the same. That is, the four sets had in common 20 related word-target pairs, 40 neutral word-target pairs and all 120 pseudoword-target pairs. Furthermore, Sets 2, 3 and 4 had 20 unrelated word-target pairs in common. Of the 120 word-target pairs in Sets 1 to 4, only those 20 related pairs that were common to all four sets, 20 of the 40 common neutral pairs, and the 20 unrelated pairs common to Sets 2, 3 and 4 will be regarded as critical. The 20 common neutral pairs that were not considered critical but were regarded as fillers were added to the set of materials because an earlier experiment (De Groot et al., 1982) indicated that neutral prime-target pairs are inhibited when there are relatively few of them among the experimental materials. The mean association frequency of the target to the prime in the critical related pairs was 65.7% with a standard error of 2.8%. The mean association frequency of the primary associates to the primes in the 20 critical unrelated pairs was about the same as that of the targets to the primes in the 20 critical related pairs, namely 64.9%; the corresponding standard error was 2.9%. Of course, these combinations of stimulus word and primary word association were dissociated in the unrelated prime-target pairs in the present experiment. Across the three groups of critical word-target pairs the targets were balanced on language frequency (Uit den Boogaart, 1975), length, and number of syllables. The mean language frequencies were 75.3 for the targets in the critical related pairs (per 600,000 words), 75.2 for those in the critical unrelated pairs, and 75.7 for the critical targets following the neutral prime *blank*. The corresponding standard errors were 17.5, 17.4 and 18.3.[1]

Of the 80 pseudoword-target pairs that had a noun as prime, 40 were considered critical; the other 40 were regarded as fillers.[2] All 40 pseudoword-target pairs with the word *blank* as prime were considered critical. The primes in the noun-pseudoword pairs were from the same population of words as those in the noun-word pairs, but they did not, as a rule, occur as stimulus words in the association norms.

The test materials of each set were preceded by 86 practice pairs, viz., 43 word-target pairs and 43 pseudoword-target pairs. Among the practice materials all types of prime-target pairs appeared in the same proportion as among the subsequent test materials. In all other respects the practice sets preceding the different sets of test materials were the same. With the exception of the word *blank*, all the words in the complete set of materials, practice and test sets combined, occurred only once, either as a prime or as a word target. Furthermore, the pseudoword targets were derived from nouns different from those used as primes or word targets in the practice and test sessions.

Subjects and Apparatus. In this experiment 192 students of the University of Nijmegen participated as subjects. They were paid 6.50 guilders. In their order of arrival, the subjects were assigned to one of 12 groups. A group consisted of 16 subjects all of whom were presented with the same stimulus set under the same SOA condition (see Procedure section). Therefore, each single subject was presented with only one of the four sets of material under only one of the three SOA conditions.

The subjects were tested in a group experiment room that simultaneously allowed up to four individual, independent sessions under control of a multiprogramming computer system. Stimuli were presented in uppercase (white on grey) on individual TV monitors under program control. Individual stimulus presentation, response time (RT) recording and feedback were performed by a program called LEXSYS (Hudson, Maarse & Bouwhuisen, Note 2).

Procedure. The subjects were tested in groups of one to four in a normally lit room, separated from one another by screens. They sat at a comfortable reading distance in front of a monitor. They were told that pairs of letter strings were going to be presented on the monitor, one string after the other, and that they had to decide, as quickly and as accurately as possible, whether or not the second letter string of each pair was a Dutch word. They were also told that the first letter string would be either the word *blank* or any other word, 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, with their right forefinger, the positive response key on the right-hand side of the keyboard in front of them. 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. Until after the experiment the subjects were not informed about the presence of associatively related prime-target pairs among the experimental materials.

Prior to every first letter string of a pair (the prime) a fixation star appeared for one second, slightly above and to the left of the place at which the prime would appear. The prime replaced the fixation star immediately. Prime duration depended upon the particular SOA condition in which the subject participated. There were three SOA conditions: 240, 540 and 1040 msec. The prime was presented for 200, 500 and 1000 msec, respectively, in these conditions. Following prime offset and prior to the presentation of the second letter string (the target) the screen was empty during 40 msec. Subsequently, 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. The choice of 240-msec SOA as shortest SOA was based on Neely's (1977) finding that this SOA is too short for prime-induced attentional processing to be effective. Latencies and errors were recorded on-line. After every trial one of the words *correct*, *slow* or *wrong* appeared. *Slow* appeared whenever a response was correct, but exceeded a preset 900-msec deadline. When the subject failed to respond within 2,400 msec from target 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 further error. The test materials were presented in 10 blocks of 24 prime-target pairs each. After each block the mean RT and the number of errors for that block were presented on the screen. After a forced minimal rest of ten sec the subject initiated the presentation of a new block by pressing one of the response keys. Prior to the test materials the practice materials were presented in three blocks of 24 prime-target pairs each and one last block of 14 pairs.

Results

Word-Target Data

Analysis of the Separate Conditions. All RTs longer than 1,400 msec were excluded from the RT data and were scored as errors. Table 1 presents the mean RTs, the mean subjects' standard deviations (collapsed across items), and the error rates for the groups of critical word-target pairs in all 12 conditions formed by the three levels of the factor SOA and the four levels of the factor proportion. Furthermore, for each SOA by proportion condition the facilitatory, inhibitory and total priming effects (facilitatory and inhibitory effects combined) are given in this table.

The facilitatory, inhibitory and total priming effects reported in Table 1 are the differences between RTs in the related and neutral, the neutral and unrelated, and the related and unrelated conditions, respectively. In order to test the significance of these effects in the various SOA by proportion conditions, the subjects' mean RTs to the targets in each of the groups of critical word-target pairs within each of the 12 SOA by proportion conditions separately, were subjected to a 3 (prime type: related, neutral and unrelated) by 16 (subjects) ANOVA, or, for the 1.00 proportion condition, to a 2 (prime type: related and neutral) by 16 (subjects) ANOVA. In these analyses prime type was treated as a within-subjects factor. Error responses including responses slower than 1,400 msec (the latter occurred on less than 0.5% of the trials) were discarded from these analyses, as well as from all further analyses reported below. Also, for each of the SOA by proportion conditions a 3 (prime type) by 20 (critical items) ANOVA, or, for the 1.00 proportion condition, a 2 (prime type) by 20 (items) ANOVA was performed on the item means, collapsed across subjects. In these item analyses prime type was treated as a between-items factor. The effect of prime type was significant on all these analyses ($p < .001$ in all cases). Subsequently, Newman-Keuls tests were performed on the differences between the mean RTs to the targets in the three

Table 1

Mean Response Times (in Milliseconds), Standard Deviations and Error Rates (in Percentages) for the Groups of Critical Word-Target Pairs in all SOA by Proportion Conditions

proportion of related pairs	SOA (msec)	related RT	related SD	related ER	neutral RT	neutral SD	neutral ER	unrelated RT	unrelated SD	unrelated ER	priming effect fac	priming effect inh	priming effect tot
	240	514	96	0.9	558	112	1.9	572	116	5.0	44	14[1]	58
.25	540	461	80	0.6	499	72	1.9	527	97	2.8	38	28	66
	1040	471	89	1.3	510	92	1.6	530	91	2.8	39	20	59
	240	482	87	2.2	508	89	2.2	533	93	6.9	26	25	51
.50	540	484	105	0.3	519	92	1.9	549	103	3.4	35	30	65
	1040	470	98	1.3	514	97	1.3	541	99	6.6	44	27	71
	240	487	98	0.9	547	131	1.6	561	116	5.9	60	14[1]	74
.75	540	451	109	0.6	499	96	3.4	542	106	7.8	48	43	91
	1040	454	117	2.2	537	131	1.6	577	123	7.5	83	40	123
	240	480	103	0.9	533	117	2.8	-	-	-	53	-	-
1.00	540	442	102	0.6	510	114	2.5	-	-	-	68	-	-
	1040	432	123	1.6	505	90	1.3	-	-	-	73	-	-

Note: Priming effects without superscript are significant at the .05 level or better on both the subject and item analyses.
[1]Nonsignificant on both the subject and item analyses

prime-type conditions, or, in other words, on the facilitatory, inhibitory and total priming effects within each of the SOA by proportion conditions. The significance levels of the different priming effects that were obtained from these tests are presented in Table 1.

Overall Analysis. The data of the .25, .50 and .75 proportion conditions were analysed in two 3 (prime type) by 3 (proportion) by 3 (SOA) ANOVAs, one for subjects and one for items. Because in the 1.00 proportion condition no unrelated prime-target pairs were presented, its data were analysed in two separate 2 (prime type) by 3 (SOA) ANOVAs.

Proportions .25, .50 and .75. On the subjects' mean RTs to the targets in the three critical groups of word-target pairs of the nine SOA by proportion conditions that included unrelated prime-target pairs, a 3 (prime type: related, neutral and unrelated) by 3 (SOA) by 3 (proportion: .25, .50 and .75) by 16 (subjects) ANOVA was performed, treating prime type as a within-subjects factor and SOA and proportion as between-subjects factors. Furthermore, a 3 (prime type) by 3 (SOA) by 3 (proportion) by 20 (items) ANOVA was run on the item means collapsed across subjects, treating prime type as a between-items factor and SOA and proportion as within-items factors. With respect to the main questions posed in the present article, namely whether variations in SOA and proportion produce changes in the size of priming effects and whether any such changes show interdependence, the interactions among prime type, SOA and proportion are more important than their main effects. Yet the presentation of the interaction data will be postponed until after the main effects have been presented.

As was expected from the results of the separate SOA by proportion conditions, and in accordance with the literature on associative priming of lexical decisions, the main effect of prime type was highly reliable on both analyses [F_s (2,270) = 298.32, $p < .001$; F_I (2,57) = 46.47, $p < .001$]. MinF' combining both F-values (Clark, 1973) was also significant [$minF'$ (2,75) = 40.21, $p < .001$]. The overall mean RTs were 475 msec for the related targets, 521 msec for the targets in the neutral pairs, and 548 msec for the unrelated targets. Newman-Keuls tests that were performed on the differences between these prime-type means showed that on both the subject and the item analysis all three differences were statistically reliable ($p < .01$ in all cases).

The main effect of SOA was also significant on both analyses [F_s (2,135) = 3.11, $p < .05$; F_I (2,114) = 52.16, $p < .001$; $minF'$ (2,150) = 2.94, $p = .05$]. The overall mean RTs to the targets in the three SOA conditions of 240, 540 and 1040 msec were, in order, 529, 503 and 512 msec. Newman-Keuls tests showed that on the subject analysis only the 26-msec difference between the 240- and 540-msec SOAs was statistically reliable ($p < .05$), whereas on the item analysis both this difference and the 17-msec difference between the 240- and 1040-msec SOAs and the 9-msec difference between the 540- and 1040-msec SOAs were significant at the .01 level. As will be seen below, this same effect of SOA also occurred on the pseudoword-target data. It was also reported by Neely (1976), although it was not statistically reliable on his word-target data. Neely interpreted this effect in terms of Posner and Boies' (1971) prime-encoding functions (see below).

The main effect of proportion was only significant on the item analysis [F_s (2,135) < 1; F_i (2,114) = 3.97, $p < .05$]. The overall mean RTs to the targets within the .25, .50 and .75 proportion conditions were 516, 512 and 518 msec, respectively. A Newman-Keuls test performed on the differences between these means on the item analysis showed that only the 6-msec difference between the .50 and .75 proportion conditions was significant. Since this effect was relatively weak and small, and since it is unclear what causes it, it will be ignored furtheron.

The prediction that the proportion of related pairs influences the amount of attention that is committed to the prime and to prime-induced attentional processing was supported by the statistical reliability of the interaction between prime type and proportion [F_s (4,270) = 7.96, $p < .001$; F_i (4,114) = 12.78, $p < .001$; *minF'* (4,370) = 4.91, $p < .01$]. The mean RTs to the targets in the various prime type by proportion conditions collapsed across SOAs are depicted in Figure 1. A noteworthy aspect of the data shown in this figure is that the mean RTs to targets in the unrelated and neutral pairs are both longer within the .75 proportion condition than with proportions of .25 and .50, whereas the mean RT to targets in the related pairs is shorter. Newman-Keuls tests performed on the relevant means of both the subject and the item analysis showed that the targets in the neutral pairs of the .75 proportion condition were processed significantly slower than those in the neutral pairs of the .50 condition. Furthermore, these tests showed that the targets in the unrelated pairs of the .75 condition were processed significantly slower than those in the unrelated pairs of the remaining proportion conditions, and that the targets in the related pairs of the .75 condition were responded to significantly faster than those in the related pairs of the remaining proportion conditions. With respect to the effect of prime type, the Newman-Keuls tests showed that the facilitatory, inhibitory and total priming effects were significant for all three proportions ($p < .01$ in all cases). Collapsed across SOAs,

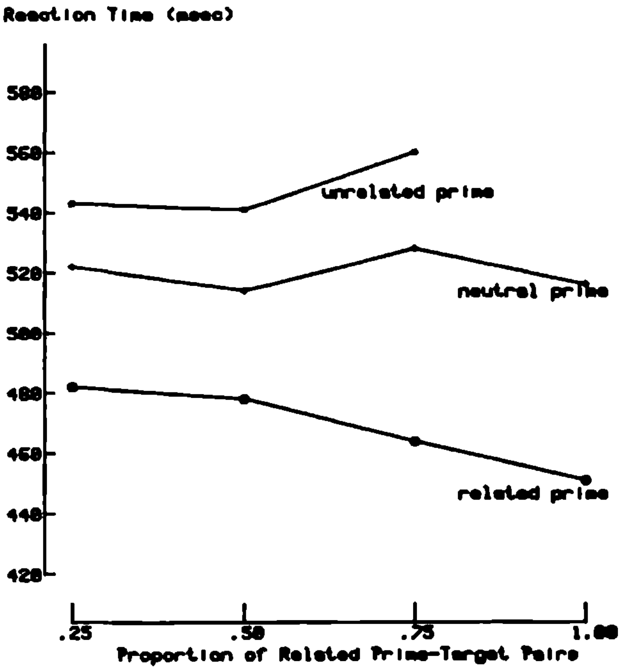

Figure 1. Reaction time for responses to word targets as a function of the proportion of related prime-target pairs, collapsed across SOAs.

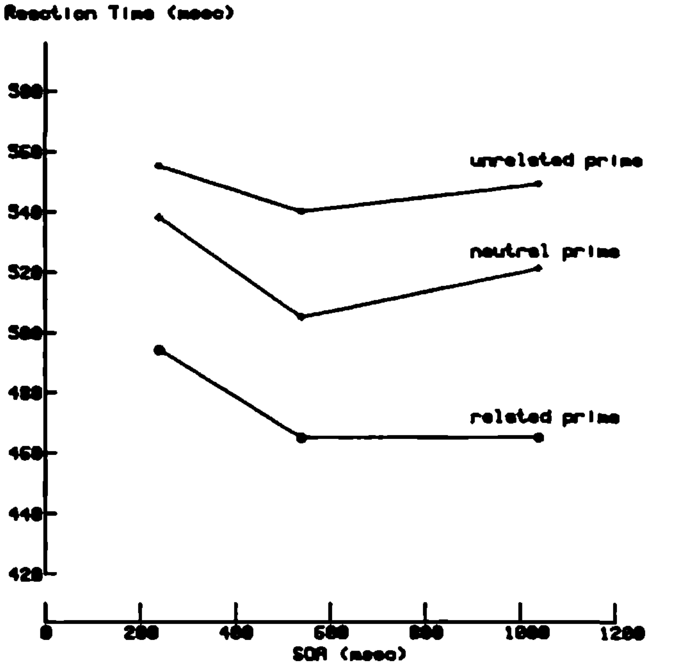

Figure 2. Reaction time for responses to word targets as a function of the SOA of prime and target, collapsed across the proportion conditions .25, .50 and .75.

the facilitatory effects with proportions of .25 and .50 are about the same (40 and 36 msec, respectively), and both are considerably smaller than the one observed with a proportion of .75 (64 msec). Collapsed across SOAs, the inhibitory effects remain virtually constant when varying proportion (21, 27 and 32 msec for the proportion conditions .25, .50 and .75, respectively). In order to see whether this observation could be statistically confirmed we removed the RTs to related targets from the data sets and performed a 2 (prime type: neutral and unrelated) by 3 (SOA) by 3 (proportion) by 16 (subjects) ANOVA, and a 2 by 3 by 3 by 20 (items) ANOVA on the data. On these analyses the prime type by proportion interaction was indeed not significant [F_s (2,135) = 1.26, $p > .10$; F_i (2,76) = 2.55, $0.5 < p < .10$], indicating that the inhibitory effect of an unrelated prime is not affected by the factor proportion. However, the same analyses performed on the data for related and neutral pairs, excluding unrelated pairs, showed that the facilitatory effect of a related prime *does* change over different proportions, as indicated by the significant interaction between prime type and proportion [F_s (2,135) = 9.05, $p < .01$; F_i (2,76) = 12.02, $p < .01$; $minF'$ (2,206) = 5.16, $p < .01$].

The second interaction of importance, namely that between prime type and SOA, was also significant on both analyses, indicating that the effectivity of attentional processing changes when SOA is varied [F_s (4,270) = 3.39, $p < .05$; F_i (4,114) = 5.16, $p < .01$]. MinF' just failed to reach significance [$minF'$ (4,366) = 2.05, $.05 < p < .10$]. The mean RTs to the targets in the various prime type by SOA conditions collapsed across proportions are depicted in Figure 2. Collapsed across proportions, the facilitatory effects in the 240- and 540-msec SOA conditions are approximately the same (44 and 40 msec, respectively) and both are smaller than the one observed at an SOA of 1040 msec (56 msec). In contrast, inhibition increases from 17 msec at an SOA of 240 msec to 35 at an SOA of 540 msec, and it remains about the same from there on (28 msec in the 1040-msec SOA condition). Collapsed across proportions, the total priming effect increases gradually over SOAs from 61 msec at an SOA of 240 msec to 75 msec at one of 540 msec, and to 84 msec at an SOA of 1040 msec. The mean RTs to the targets in all three prime-type conditions tend to be shorter at an SOA of 540 msec than at the other two SOAs (cf. Neely, 1976). Newman-Keuls tests showed that the mean RTs to the targets in the neutral pairs were significantly longer at SOAs of 240 and 1040 msec than at the SOA of 540 msec, both on the subject and the item analysis ($p < .01$ in all cases). Furthermore, the differences between the mean RTs to unrelated targets in the SOA 240- and 540-msec conditions and between the mean RTs to related targets at these two SOAs were also statistically reliable ($p < .01$ in all cases). With respect to the effect of prime type, the Newman-Keuls tests showed that the facilitatory, inhibitory and total priming effects were significant in all three SOA conditions ($p < .01$ in all cases).

The interaction between proportion and SOA [F_s (4,135) = 1.87, $p > .10$; F_i (4,228) = 37.47, $p < .001$], and, more importantly, the prime type by proportion by SOA interaction [F_s (8,270) = 1.36, $p > .10$; F_i (8,228) = 2.42, $p < .05$] were only significant on the item analysis. As can be seen in Table 1, changing SOA does not appear to influence the priming effects to the same amount in all proportion conditions. The largest changes in priming effects between the different levels of SOA occur when the proportion of related pairs is .75; the changes are less in the .50 condition, and they are virtually absent in the .25 condition. On the other hand, changes in proportion appear to influence the priming effect in the same way in all SOA conditions, showing, for all three SOAs, a sudden increase in the facilitatory and total priming effects with an increase in proportion from .50 to .75. But the effect of changing the proportion of related pairs on the size of associative priming is particularly strong in the 1040-msec SOA condition. The significance levels of the third-order interaction, however, only permit us to generalize these results over items. The discrepancy between the reliability of these effects on the subject and the item analyses is very likely due to the fact that nine different groups of subjects provided the data for the nine proportion by SOA conditions, which, unfortunately, renders our design rather insensitive with respect to the present interactions on the subject analysis. On the other hand, repeated measures were taken of the same items in all different proportion by SOA conditions.[3]

Proportion 1.00. A 2 (prime type: related and neutral) by 3 (SOA) by 16 (subjects) ANOVA was performed on the subjects' means for the groups of critical word-target pairs in the 1.00 proportion conditions, treating prime type as a within-subjects factor and SOA as a between-subjects factor. Also, a 2 (prime type) by 3 (SOA) by 20 (critical items) ANOVA was run on the item means collapsed across subjects, treating prime type as a between-items factor and SOA as a within-items factor.

Again, as expected, the main effect of prime type was significant on both analyses [F_s (1,45) = 119.59, p < .001; F_i (1,38) = 66.25, p < .001; *minF'* (1,72) = 42.63, p < .001]. The overall mean RTs were 451 msec for the related targets and 516 msec for the targets in the neutral condition. That is, collapsed across SOAs, the facilitatory effect is about the same in the 1.00 proportion condition (65 msec) as in the .75 proportion condition (64 msec).

The main effect of SOA was only significant on the item analysis [F_s (2,45) = 1.96, p > .10; F_i (2,76) = 28.51, p < .001]. The overall mean RTs to the targets in the three SOA conditions of 240, 540 and 1040 msec were, in order, 506, 476 and 468 msec. A Newman-Keuls test performed on the differences between these means on the item analysis showed that both the differences between the 240- and 540-msec SOAs and between the 240- and 1040-msec SOAs (in order, 30 and 38 msec) were statistically reliable (p < .01 in both cases). The 8-msec difference between the 540- and 1040-msec SOA conditions was not significant.

The interaction between prime type and SOA was insignificant on both analyses [F_s (2,45) < 1; F_i (2,76) = 1.93, p > .10]. In order to see whether this result is consistent with the remaining proportion conditions, in which the interaction between prime type and SOA *was* significant, but that were different from the present one in that they included unrelated prime-target pairs, we removed the RTs to the targets in the unrelated pairs from the data sets of the .25, .50 and .75 proportion conditions, and performed the same 2 (prime type) by 3 (SOA) by 16 (subjects) and 2 by 3 by 20 (items) ANOVAs on each of them separately. The interaction between prime type and SOA was only significant on the analyses of the .75 proportion [F_s (2,45) = 3.70, p < .01;

F_I (2,76) = 5.14, $p < .01$]. Thus, in only one of the four proportion conditions the facilitatory effect changes significantly over SOAs.

With respect to the error data, Table 1 shows that, on the whole, more errors were made in the neutral condition than in the related condition, and that most errors were made in the unrelated condition. Therefore, the differences in RTs between these three types of word-target pairs were not caused by a trade-off between speed and accuracy. Since few errors were made on the word targets (2.6% overall), no ANOVA was performed on them.

Pseudoword-Target Data

Analysis of the Separate Conditions. Table 2 presents the mean RTs for correct responses, the mean subjects' standard deviations (collapsed across items), and the error rates (incorrect responses and responses slower than 1,400 msec combined) for the two groups of critical pseudoword-target pairs in all 12 proportion by SOA conditions. Also, for each of the proportion by SOA conditions the priming effect (the difference between the two prime-type conditions) is shown in this table. In order to test the significance of the priming effect in the various proportion by SOA conditions, the subjects' mean RTs to the targets in each of the two groups of 40 critical pseudoword-target pairs within each of the 12 proportion by SOA conditions separately, were subjected to a 2 (prime type: non-neutral and neutral) by 16 (subjects) ANOVA. In these subject analyses prime type was treated as a within-subjects factor. Also, for each of the 12 proportion by SOA conditions a 2 (prime type) by 40 (critical items) ANOVA was performed on the item means collapsed across subjects. In these item analyses prime type was treated as a between-items factor.

The effect of prime type was significant on the subject analyses of all but one of the 12 proportion by SOA conditions ($p < .05$ or better). The effect of prime type was significant on the item analyses of all but two of the 12 proportion by SOA conditions ($p < .05$ or better; see Table 2).

Overall Analysis. On the subjects' mean RTs to the 40 critical noun-pseudoword pairs and the 40 *blank*-pseudoword pairs of the 12 different

Table 2

Mean Response Times (in Milliseconds), Standard Deviations and Error Rates (in Percentages) for the Groups of Critical Pseudoword-Target Pairs in all SOA by Proportion Conditions

proportion of related pairs	SOA (msec)	prime type non-neutral RT	SD	ER	neutral RT	SD	ER	priming effect
	240	628	113	2.5	636	118	2.8	8[1]
.25	540	566	105	2.8	588	95	2.8	22
	1040	595	121	3.1	614	117	3.1	19
	240	570	103	3.4	594	113	4.1	24
.50	540	575	102	2.3	604	114	3.9	29
	1040	579	111	2.8	595	115	3.8	16[2]
	240	592	114	2.3	617	123	3.6	25
.75	540	560	115	2.7	583	112	3.4	23
	1040	588	128	3.3	623	129	4.1	35
	240	578	102	2.2	612	128	3.9	34
1.00	540	543	107	2.3	581	119	3.0	38
	1040	540	100	1.9	583	114	4.7	43

Note: Priming effects without superscript are significant at the .05 level or better on both the subject and item analyses.
[1]Nonsignificant on both the subject and item analyses
[2]Significant at the .05 level on the subject analysis and nonsignificant on the item analysis

proportion by SOA conditions combined a 2 (prime type) by 4 (proportion) by 3 (SOA) by 16 (subjects) ANOVA was performed, treating prime type as a within-subjects factor and proportion and SOA as between-subjects factors. Also, a 2 by 4 by 3 by 40 (items) ANOVA was performed on the item means collapsed across subjects, treating prime type as a between-items factor and proportion and SOA as within-items factors.

As was expected from the results of the separate proportion by SOA conditions, the main effect of prime type was statistically reliable on both analyses [F_s (1,180) = 220.05, p < .01; F_i (1,78) = 13.13, p < .001; $minF'$ (1,87) = 12.39, p = .001]. The overall mean RT to the 40 critical noun-pseudoword pairs was 576 msec and to the 40 *blank*-pseudoword pairs it was 603 msec.

The finding that pseudowords following non-neutral primes are processed faster than those following neutral primes has been reported before by Neely (1976, 1977), who interpreted it in terms of the attentional predict-and-match strategy mentioned above. It was argued there that evidence supporting the view that an attentional source underlies this effect could be obtained from the prime type by proportion interaction on the pseudoword data. Since the proportion of related pairs presumably influences the amount of attentional commitment, the difference between the two pseudoword-target conditions, if it has an attentional source, should be sensitive to this variable. This prediction was indeed supported by the corresponding interaction data [F_s (3,180) = 7.01, $p < .001$; F_I (3,234) = 6.89, $p < .001$; $minF'$ (3,407) = 3.48, $p < .05$]. Collapsed across SOA conditions, the differences between the non-neutral and neutral pseudoword-target pairs were 16, 23, 28, and 38 msec for the proportions .25, .50, .75 and 1.00, respectively.

The main effect of SOA was again significant [F_s (2,180) = 4.12, $p < .05$; F_I (2,156) = 72.21, $p < .001$; $minF'$ (2,200) = 3.90, $p < .05$]. The overall mean RTs for the SOAs of 240, 540 and 1040 msec were 603, 575 and 590 msec, respectively. Again, the intermediate SOA produced the shortest RTs. Newman-Keuls tests showed that on the subject analysis only the 28-msec difference between the 240- and 540-msec SOA condition was significant ($p < .05$). On the item analysis all three differences between these means were statistically reliable ($p < .01$ in all cases).

The main effect of proportion was significant on both analyses [F_s (3,180) = 2.78, $p < .05$; F_I (3,234) = 58.87, $p < .001$; $minF'$ (3,197) = 2.65, $p < .05$]. The overall mean RTs for the proportion conditions of .25, .50, .75 and 1.00 were 605, 586, 594 and 573 msec, respectively. Newman-Keuls tests showed that on the subject analysis only the 32-msec difference between the .25 and 1.00 proportions was significant ($p < .05$), and that on the item analysis all differences between these means were statistically reliable ($p < .05$ or better).

Finally, the interaction between proportion and SOA was significant, but only on the item analysis [F_s (6,180) = 1.24, $p > .10$; F_I (6,468) = 32.97, $p < .001$]. No further interactions approached significance.

Chapter IV

SUMMARY AND DISCUSSION

On the whole, the data reported here are in accordance with the literature on primed lexical decision. The most solid finding was the 'classical' priming effect (Meyer & Schvaneveldt, 1971). In all nine proportion by SOA conditions that included unrelated word-target pairs, lexical decisions to word targets associatively related to the word prime were made faster (73 msec overall) than those to word targets following an unrelated prime. In seven out of these nine conditions the inhibitory effect, i.e. the difference between the neutral and unrelated prime-type conditions, was reliable. The facilitatory effect, the difference between the related and neutral conditions, was reliable in all 12 proportion by SOA conditions.

As on the word-target pairs, the factor prime type also produced a systematic effect on the pseudoword-target pairs. In 11 out of the 12 different proportion by SOA conditions the targets following a non-neutral prime were responded to significantly faster than those preceded by the neutral prime *blank*. The direction of this difference is quite the opposite from what Posner and Snyder (1975a) originally expected. Because a neutral prime, since it is repeated so often and since it does not set off attentional processing, requires less attention than a non-neutral prime, thereby leaving more for the lexical decision to the target, Posner and Snyder predicted longer RTs for targets following non-neutral primes. Neely (1976, 1977) and Posner and Snyder (1975b) themselves also obtained data defying an interpretation in terms of the limited-capacity nature of attentional processing. Instead, Neely suggested that a matching strategy pursued by the subjects causes pseudowords following non-neutral primes to be facilitated. This strategy implies that a non-neutral prime, but not a neutral prime, induces the subjects to attend to the memory representations of certain words, presently, to those of words associatively related to the prime word, and that they subsequently match these attended word representations onto the actual target. If a target word is subsequently presented that corresponds to one of the attended representations, the match is successful, and the subjects are biased towards responding *yes*.

On the other hand, if a pseudoword is presented as target, or a word that does not correspond to one of the attended representations, the subjects will be biased towards a *no* response. Since *no* is the correct response in the case of a pseudoword target, this matching strategy thus facilitates responding to pseudowords preceded by a non-neutral prime. Posner and Snyder (1975b) proposed a similar matching strategy to explain some of the data from their letter-matching and animal-name-classification experiments that could not be handled by the above limited-capacity interpretation. It is important to note that the rejection of the limited-capacity nature of attentional processing, and the acceptance of the matching strategy as the source of inhibition of unattended word targets and of facilitation of attended word targets and pseudowords does not invalidate the notion of prime-induced attentional processing, but merely modifies the views on how it operates.

The difference between RTs to pseudowords preceded by neutral and non-neutral primes does not always occur. In an earlier experiment (De Groot et al., 1982), in which the associative strength between prime and target in the related word-target pairs was considerably smaller than in the present study, and, consequently, prime-induced attentional processing was less strongly encouraged, the pseudowords following both types of primes were responded to about equally fast. We suggested that in that experiment the subjects had not used the prime to direct their attention to certain memory representations of words prior to target presentation, and that the inhibition that was obtained for unrelated word targets had to be attributed solely to post-lexical coherence checking (see introduction). Because it is hard to see how such coherence checking could differentially affect pseudowords following non-neutral and neutral primes, we have since then accepted the occurrence of a difference between the two pseudoword conditions as indicative of prime-induced attentional processing. Additional evidence for this view from the present data is provided by the significant interaction between prime type and proportion on the pseudoword data. Collapsed across SOAs, the size of the priming effect on pseudowords increases concurrently with the proportion of related word-target pairs, indicating an attentional source of this effect.

Also, the only proportion by SOA condition that does not show a difference in processing time between pseudowords following non-neutral and neutral primes is the condition with the shortest SOA and the smallest proportion of related word-target pairs. This is the condition in which the effect of prime-induced attentional processing may be expected to be smallest.

Further support for the occurrence of prime-induced attentional processing in the present experiment comes from the word-target data, that also showed a significant interaction between prime type and proportion. The facilitatory effect of a related prime, and the total priming effect remain about the same with a change in the proportion of related pairs from .25 to .50, and they increase abruptly with a change from 50 to 75 The inhibitory effect of an unrelated prime is not affected by changing the proportion of related word-target pairs This finding replicates and extends the results of Tweedy et al. (1977, 1981) who also found that changing the proportion of related pairs influences the size of the total priming effect What is new is that only one of the two components that constitute this total priming effect, the facilitatory effect, appears to be affected This extension of the Tweedy et al results was possible by our inclusion of a neutral prime As shown in Figure 1, this neutral prime-type condition is equally sensitive to the proportion manipulation as the related and unrelated conditions are. Whereas responses to targets in the related condition are speeded up with a proportion of 75, those in the unrelated and neutral conditions are equally slowed down Considering the nature of the neutral prime, this finding was rather unexpected As was mentioned in the introduction above, a neutral prime is commonly assumed not to influence the processing of a subsequent target This is not to say that the neutral prime neither automatically activates some memory representations of words, nor consumes some of the subject's attention Being a word itself, the prime *blank* will automatically activate its own memory representation and presumably those of a number of related words, but it will not activate the representation of the subsequent target, and, consequently, it will not affect the lexical decision to this target through prior activation Also, the prime *blank* will probably draw the subject's attention (although presumably less so than a more interesting non-neutral prime), but the subject will not use this uninformative prime to direct attention to certain memory representations of words prior to target presentation. This suggests that the sensitivity of the neutral prime to the proportion of related pairs is caused in a processing stage that follows target recognition. In a way, unrelated and neutral pairs are similar in that in both of them prime word and target word are unrelated to one another. It may be that, when the target is unrelated to the prime, whether neutral or non-neutral, the strong expectation of related pairs in the .75 proportion condition hinders, *after* the target has been recognized as a word, the execution of a *yes* response. For instance, in the .75 proportion condition Forster's (1979) semantic processor (see introduction) may not only send off a *no* bias to the decision maker whenever a pair of unrelated words is recognized as such, but also whenever a neutral pair is encountered. Alternatively, the decision-making mechanism may interpret, in the .75 proportion condition, all occasions on which it does not receive a *yes* bias from the semantic processor as information favouring a *no* response. In this respect it is noteworthy that the RTs to targets in the neutral condition decrease again with a proportion of 1.00, as if the semantic processor (or the decision maker) only judges the meaningfulness of neutral pairs (as well as that of related and unrelated pairs) if the proportion of related pairs is high, and if, *at the same time*, the set of materials incorporates a condition of unrelated pairs. But it may also be that the 1.00 proportion condition produces faster responses to targets in the neutral condition than the .75 condition does, because the removal of unrelated word pairs from the set of materials possibly simplifies processing in general. If this suggestion is correct, the decrease in processing time for prime-related targets in the 1.00 proportion condition (see Figure 1) may be due to the same processing simplification, rather than to the increase in the proportion of related pairs, and the consequent increase of prime-induced attentional processing.

Let us now turn to the effect of SOA and the way in which it influences the size of associative priming. Both for the word data and the pseudoword data, the subjects responded fastest in the 540-msec condition and slowest in the

240-msec condition (cf. Neely, 1976). The relatively fast responses for targets following prime onset after 540 msec is in accord with Posner and Boies (1971) who suggested that the SOA functions reflect the time necessary to encode the prime in a form which is optimal for processing the second. According to this view, the relatively long RT at an SOA of 240 msec presumably indicates that at this SOA prime processing was incomplete when the target arrived (see also Antos, 1979). The slowing down in the 1040-msec SOA condition may be the result of relaxed attention. The significance of the interaction between SOA and prime type on the word data shows that SOA affects the size of the different priming effects (see also Neely, 1976, 1977). Furthermore, the interaction between the variables prime type, proportion and SOA, although only reliable on the item analysis, suggests that the influence of SOA on the size of the priming effects depends upon the proportion of related prime-target pairs in the set of materials. If this proportion is relatively small (.25), the size of the priming effects remains constant over SOAs.

The increase of priming effects over SOAs is suggestive of an increase of the effectivity of attentional processing. There is at least one indication in the word-target data that the onset time of effective prime-induced attentional processing has to be localized at an SOA shorter than 240 msec: As can be seen in Table 1, at an SOA of 240 msec as well as at SOAs of 540 and 1040 msec the facilitatory effect of a related prime tends to correlate positively with the proportion of related word-target pairs. This finding is not necessarily inconsistent with the fact that Neely (1977) located the onset point of effective attentional processing between SOAs of 250 and 400 msec. As was mentioned earlier, this finding led us to choose 240 msec as shortest SOA. Neely (1977) had his subjects attend to the representations of a prespecified group of words unassociated to the prime. It is very likely that this takes more time than to focus attention on representations of word associates of the prime.

Adherents of Posner and Snyder's (1975a) theory (see introduction) may find further evidence of effective prime-induced attentional processing at an SOA of 240 msec, namely the fact that, collapsed across proportions, a reliable inhibition is obtained for this SOA as well as for the two remaining SOAs (although, considering the different proportion conditions separately, the inhibitory effect was insignificant in two of them). However, as we have explained above, apart from prime-induced attentional processing there probably exists a second source of inhibition for unrelated word targets in primed lexical-decision experiments, namely post-lexical coherence checking. This process is as such independent of SOA, and may have caused the inhibition at an SOA of 240 msec.

Summarizing the results of the present experiment we may say that all predictions stated above have been confirmed in the present set of data. Both the proportion of related prime-target pairs and the SOA of prime and target have been shown to influence the size of the priming effects on the word-target data. As expected, the variable proportion also influenced the size of the priming effect on the pseudoword-target data. Furthermore, we obtained data that suggested interdependence between the effects of proportion and SOA on the size of priming. Whether SOA affects the size of priming seems to depend upon the proportion of related pairs. Of course, one implication of this result is that, if one wants to investigate the development of priming effects over SOAs, the choice of a proper proportion, or of a proper set of different proportions, of related word-target pairs is of prime importance.

REFERENCE NOTES

1. De Groot, A.M.B., Thomassen, A.J.W.M., & Hudson, P.T.W. Primed lexical decision: The effect of varying the stimulus-onset asynchrony of prime and target. Paper submitted for publication.
2. Hudson, P.T.W., Maarse, F.J.M., & Bouwhuisen, C. LEXSYS: A real-time multi-subject system for psycholinguistic experiments. Internal publication. Department of Experimental Psychology, University of Nijmegen, P.O. Box 9104, Nijmegen 6500 HE, The Netherlands.

Chapter IV

REFERENCES

Antos, S.J. Processing facilitation in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1979, *5*, 527-545.

Becker, C.A. Allocation of attention during visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, *2*, 556-566.

Becker, C.A. Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory and Cognition*, 1980, *8*, 493-512.

Clark, H.H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, 1973, *12*, 335-359.

De Groot, A.M.B. *Mondelinge Woordassociatie Normen: 100 Woordassociaties op 460 Nederlandse Zelfstandige Naamwoorden*. Lisse, The Netherlands: Swets & Zeitlinger, 1980.

De Groot, A.M.B. The range of automatic spreading activation in word priming. *Journal of Verbal Learning and Verbal Behavior*, in press.

De Groot, A.M.B., Thomassen, A.J.W.M., & Hudson, P.T.W. Associative facilitation of word recognition as measured from a neutral prime. *Memory and Cognition*, 1982, *10*, 358-370.

Fischler, I. Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 18-26.

Fischler, I., & Goodman, G.O. Latency of associative activation in memory. *Journal of Experimental Psychology: Human Perception and Performance*, 1978, *4*, 455-470.

Forster, K.I. Levels of processing and the structure of the language processor. In W.E. Cooper & E. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett*. Hillsdale, N.J.: Erlbaum, 1979.

Fowler, C.A., Wolford, G., Slade, R., & Tassinary, L. Lexical access with and without awareness. *Journal of Experimental Psychology: General*, 1981, *110*, 341-362.

Marcel, A. Conscious and unconscious reading: The effects of visual masking on word perception. *Cognitive Psychology*, in press.

Meyer, D.E., & Schvaneveldt, R.W. Facilitation in recognizing pairs of words: Evidence of dependence between retrieval operations. *Journal of Experimental Psychology*, 1971, *90*, 227-234.

Neely, J.H. Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. *Memory and Cognition*, 1976, *4*, 648-654.

Neely, J.H. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 1977, *106*, 226-254.

Posner, M.I., & Boies, S.J. Components of attention. *Psychological Review*, 1971, *78*, 391-408.

Posner, M.I., & Snyder, C.R.R. Attention and cognitive control. In R.L. Solso (Ed.), *Information processing and cognition: The Loyola symposium*, Hillsdale N.J.: Erlbaum, 1975. (a)

Posner, M.I., & Snyder, C.R.R. Facilitation and inhibition in the processing of signals. In P.M.A. Rabbitt & S. Dornic (Eds.), *Attention and Performance V*, New York: Academic Press, 1975. (b)

Schmidt, R. Semantic expectancy effects on word access. *Psychological Research*, 1976, *39*, 147-161.

Schvaneveldt, R.W., & McDonald, J.E. Semantic context and the encoding of words: Evidence for two modes of stimulus analysis. *Journal of Experimental Psychology: Human Perception and Performance*, 1981, *7*, 673-687.

Tweedy, J.R., & Lapinski, R.H. Facilitating word recognition: Evidence for strategic and automatic factors. *Quarterly Journal of Experimental Psychology*, 1981, *33a*, 51-59.

Tweedy, J.R., Lapinski, R.H., & Schvaneveldt, R.W. Semantic-context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context. *Memory and Cognition*, 1977, *5*, 84-89.

Uit den Boogaart, P.C. (Ed.). *Woordfrequenties in Geschreven en Gesproken Nederlands*. Utrecht, The Netherlands: Oosthoek, Scheltema & Holkema, 1975.

West, R.F., & Stanovich, K.E. Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 1982, *5*, 385-399.

FOOTNOTES

[1]A complete list of the critical related, neutral and unrelated word-target pairs, together with the language frequencies of the targets and the association frequency of the prime to the target in the critical related word-target pairs, are provided in an Appendix to a paper (see Note 1) reporting a related study in which the factor SOA was systematically varied over 11 levels. In that SOA study all subjects were tested under the .75 proportion condition. The data of the .75 proportion condition in the present experiment are the same as those reported for the 240-, 540- and 1040-msec SOAs of the SOA study.

[2]The choice of the 40 critical noun-pseudoword pairs was based on the results of a post hoc unprimed lexical-decision experiment in which all targets of the present sets of materials were presented to 20 subjects (all different from those who took part in the current priming study, but taken from the same population) who classified them as words or pseudowords. Prior to this unprimed lexical-decision experiment the 80 noun-pseudoword pairs of the priming study were randomly divided into two sets of 40 each. The mean unprimed lexical-decision RTs to the pseudowords in these two sets of noun-pseudoword pairs were 575 and 562 msec, with standard errors of 5.1 and 4.3 msec, respectively. The mean unprimed lexical-decision RT to the pseudowords in the 40 *blank*-pseudoword pairs was 577 msec, with a standard error of 4.9 msec.

On the basis of these results the former of the two sets of noun-pseudoword pairs was chosen as the critical set.

[3]We chose this design with SOA and proportion as between-subjects variables, since pilot studies had indicated that a design with within-subjects measures on one or both of these variables faces the problem that priming effects are confounded with practice effects (a subject that participates a second time in a lexical-decision experiment can respond over 100 msec faster than the first time) and with repetition effects that occur if the same target is presented more than once.

CHAPTER V

(submitted for publication)

LEXICAL-CONTEXT EFFECTS IN WORD NAMING AND LEXICAL DECISION

A.M.B. de Groot

Comparing the lexical-decision task and the naming task, West and Stanovich (1982) demonstrated that lexical decisions to target words preceded by incongruous sentence contexts are inhibited more by these contexts than are naming responses. They argued that this difference between the two tasks was due to post-lexical processing at the message level in the lexical-decision task. The operations of the mechanism thought to underly this post-lexical processing also predict more facilitation for congruous completions of the sentence context in lexical decision than in naming. The present study tests and confirms this prediction for targets following word contexts. Furthermore, the stimulus-onset asynchrony of context word and target word was varied. This manipulation affected the magnitude of facilitation in the naming sub-experiment, thus providing stronger support for context-induced attentional processing in word context studies than is presently available from lexical-decision studies. In the lexical-decision sub-experiment the SOA manipulation did not influence the size of facilitation. It is suggested that an effect of SOA was concealed by post-lexical processing. Since these post-lexical processes affect a processing stage subsequent to word recognition it was concluded, with West and Stanovich (1982), that if one is interested in studying context effects on word recognition, the naming task is preferable.

The study of context effects in visual word recognition has received much attention recently. This area of research has become known as 'priming'. Mostly, incomplete sentences (e.g., Fischler & Bloom, 1978, 1979; Forster, 1981; Perfetti & Roth, 1981; Schuberth & Eimas, 1977; Stanovich & West, 1979, 1981; West & Stanovich, 1978, 1982) or single words (e.g., De Groot, Thomassen & Hudson, 1982; De Groot, in press; Fischler, 1977; Neely, 1976, 1977; Warren, 1977) have been presented as context for a subsequent word. The two tasks that have been used most frequently in these studies are lexical decision and word naming. In a lexical-decision task the subjects decide for each of the stimuli to which they have to respond (these stimuli will henceforth be called 'targets') whether it is a word or a letter string that does not spell a word. In a naming task the subjects read the target aloud. The naming task seems the more 'natural' of the two tasks, with a straightforward and presumably automatic connection between recognition of the target and execution of the response.

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Despite the naturalness of the naming task, its appropriateness as a tool for studying word recognition and the way it is affected by contextual information has been questioned on the grounds that words with regular pronunciations can be named via a route that bypasses the lexicon, where word recognition is assumed to take place.[1] In the same way fluent readers can pronounce meaningless strings of letters that have no lexical representation. Naming via a non-lexical route comes about via a process of mapping graphemic units onto phonemic units, and blending the latter into sound structures of whole words or pseudowords. Lexically based naming occurs by a process of accessing the stimulus' lexical representation and retrieving the stimulus' sound structure from this representation (Forster & Chambers, 1973; Frederiksen & Kroll, 1976). To the extent that prior context affects lexical access of subsequent targets, the naming task may be relatively insensitive for detecting contextual influences on word recognition as compared to a task that always requires lexical access. Lexical decision, being such a task, may therefore be considered better suited to study context effects on word recognition.

If in a lexical-decision task a stimulus is to be identified correctly as a word, the subjects must access the mental lexicon and find that the stimulus has an associated word representation stored there. From the viewpoint of studying word recognition the lexical-decision task has the disadvantage that, after lexical access and recognition, the outcome of the access stage must be translated into the appropriate response. It is generally assumed (e.g., Theios & Muise, 1977) that this post-lexical stage is relatively complex and that, therefore, it takes longer than to convert lexical access into a naming response. This is presumably the reason why reaction times in lexical decision are usually longer than in naming (Forster, 1981; Forster & Chambers, 1973; West & Stanovich, 1982). If this additional processing complexity of lexical decision simply adds a constant to the actual word recognition times, it may conveniently be ignored or corrected for. Unfortunately, it appears that the duration of the post-access response-selection stage is sensitive to certain manipulations, for instance, to the type of the preceding context.

West and Stanovich (1982) reported two experiments in which they compared naming and lexical-decision responses to word targets preceded by congruous, neutral, and incongruous sentence contexts.[2] They call a sentence context congruous if it is completed by the target into a semantically and syntactically appropriate sentence. Incongruous combinations of sentence context and target word were formed by repairing contexts and targets from congruous sentences such that the targets in the newly formed sentences were very unlikely and presumably often semantically inappropriate completions of the preceding sentence fragment. As context in the neutral condition they always presented the sentence fragment: *They said it was the....* This neutral context hardly restricts the number of possible completions and does not contain any word semantically or associatively related to the target. This latter property of the neutral context should prevent any preparation for the recognition of the target word through automatic spreading activation in semantic memory (Fischler, 1977; Neely, 1977; Warren, 1977). In the West and Stanovich study only the lexical-decision task displayed inhibition from an incongruous sentence context, while lexical decision and naming produced equal amounts of facilitation for word targets preceded by a congruous sentence context. Facilitation and inhibition were assessed from the response time (RT) to the targets in the neutral condition as a baseline.

West and Stanovich consulted Forster's (1979) language-processing system to illustrate how this inhibition in the lexical-decision task might have come about. This system contains three subsystems: a lexical processor that accesses the lexical representation of the target as well as those of the words in the sentence context, a syntactic processor that assigns a syntactic structure to the words composing the sentence, and a message processor that assigns meaning to the syntactic structure. A decision-making mechanism accesses the output of all three components of the language processor. The inhibition in lexical decision of word targets incongruous with the sentence context may be caused by the decision-making mechanism receiving conflicting information from the three subsystems before the complex process of selecting the appropriate *yes* decision has been completed. If and when the lexical processor has recognized the target as a word, but the *yes* decision has not been made yet, the message processor may note the incongruence between sentence context and target word, and may send out a *no* response. This negative output from the message processor may bias the decision maker towards a *no* decision. In order to arrive at the appropriate answer, this bias must be overcome. Consequently, correct *yes* responses to incongruous word targets will be relatively slow. In other words, an incongruous sentence context preceding a word target lengthens the post-lexical response-selection stage relative to the duration of this stage in the neutral-context condition. Similarly, a congruous sentence context preceding a word target shortens this post-lexical stage because a positive output from the message processor should bias the decision maker towards the correct *yes* decision.[3] It is therefore surprising that the relatively large inhibition for incongruous targets in lexical decision in the experiments of Stanovich and West (1982) is not mirrored in a relatively large facilitation for congruous targets in that task. In contrast, Forster (1981) who also compared the two tasks in a single study, obtained more facilitation for one particular type of congruous target with lexical decision than with naming. In fact, the sentence contexts that produced facilitation in lexical decision did not exert any effect on subsequent target naming. Furthermore, as West and Stanovich, Forster obtained more inhibition in lexical decision than in naming. He also attributed the differences in contextual effects displayed by the two tasks to post-lexical processing in lexical decision. The apparent inconsistency between the results of West and Stanovich and those of Forster were presumably caused by differences in the experimental materials, for instance the choice of the neutral sentence context (Forster, 1981).

If, in addition to the two studies mentioned above, we consider a number of other sentence-context studies that did not compare the two tasks in a single study, but that have either used naming times (Perfetti & Roth, 1981; Stanovich & West, 1979, 1981; West & Stanovich, 1978) or lexical-decision times (Fischler & Bloom, 1979, 1980; Schuberth & Eimas, 1977; Schuberth, Spoehr & Lane, 1981) as the dependent variable, the finding that lexical decision and naming differentially affect the influence of a preceding sentence context on subsequent target processing appears to be very general.

In several lexical-decision studies that used single words rather than incomplete sentences as context for a subsequent word target (De Groot, in press, Note 1; De Groot, et al., 1982, Note 2) we have also suggested a post-lexical context effect. Following Forster (1981) we shall refer to such a word context by the term 'lexical context'. The strongest indication from our data for such a post-lexical effect (De Groot et al., 1982) was the finding that word targets unrelated to the preceding lexical context were inhibited, even though none of the targets in the complete set of materials was in any sense related to its context word. The absence of related word pairs must have discouraged the subjects from using an attentional strategy (see below) that, apart from post-lexical processing, could have caused the inhibition for unrelated word targets (Neely, 1976, 1977; Posner & Snyder, 1975). A second indication for a post-lexical context effect in lexical decision came from a study (De Groot et al., Note 2) in which the stimulus-onset asynchrony (SOA) of context word and target word was systematically varied. It appeared from this study that word targets following an unrelated lexical context are inhibited with SOAs as short as 100 msec. Although with very short SOAs the subjects may have a general expectancy that some related word will occur as target, they will presumably not have sufficient time to generate, prior to target presentation, one or more words that are related to the context word and that could possibly occur as target (Neely, 1977). Such context-induced expectations would, in case they would be wrong, inhibit target processing (Neely, 1976, 1977). In contrast, the present post-lexical inhibition process is less dependent upon SOA duration. It can presumably operate whenever both prime and target have been perceived consciously by the subjects. If, for instance due to backward masking, conscious perception of the prime is prevented (De Groot, in press; Fowler, Wolford, Slade & Tassinary, 1981; Marcel, in press), this post-lexical process cannot operate. Support for this view comes from one of these masking studies (De Groot, in press) in which, for once, unrelated targets were not processed slower than targets preceded by a neutral prime.

More direct evidence for post-lexical effects of a lexical context in lexical decision would be obtained from an experiment that, as Forster (1981) and West and Stanovich (1982) did for sentence contexts, compared naming and lexical decision to the same targets under the same experimental circumstances. The present experiment was run in order to provide these data. The differences in context effects that are obtained between the two tasks will be attributed to the complex post-lexical response-selection stage in lexical decision. The context effects occurring in the naming sub-experiment will be ascribed to processes affecting lexical access itself (or to earlier stages). Only these are truly 'priming' processes in the sense that they prepare word recognition.

Two types of actual priming processes have been proposed, viz., automatic spreading activation in lexical memory and context-induced attentional processing (Neely, 1976, 1977; Posner & Snyder, 1975). Automatic spreading activation in lexical memory comes about when the representation of a word, say of the context word, is contacted in lexical memory. The activation originating in this lexical entry is said to spread to 'nearby' word representations. If lexical memory is organized such that the representations of related words are stored close to one another (or according to principles that are functionally the same as spatial proximity, for instance, with more or better accessible links between representations of related words than between those of unrelated words), then these nearby representations receiving activation from the context word's representation will be those of related words. When a target corresponds to one of these pre-activated memory representations, relatively little stimulus information suffices for it to be recognized (Morton, 1969). The strongest support for such automatic spreading activation in lexical memory comes from the studies, mentioned above, in which the context word was masked in such a way that it could not be perceived consciously by the subjects. Nevertheless, the context word facilitated processing of the subsequent related target.

The second priming process, context-induced attentional processing, implies the subjects' use of the context word to direct their attention to the memory representations of one or more words. If one of these 'expected' words is subsequently presented as target, it will be recognized relatively fast. The idea that such attentional processing causes lexical-context effects on subsequent word recognition is supported by the fact that the size of this effect varies with the proportion of trials on which the context word and target word are related (De Groot, Note 1; Tweedy, Lapinski & Schvaneveldt, 1977; Tweedy & Lapinski, 1981).

Apart from the difference in the type of contextual information that is provided, viz., lexical vs. sentential, the present study differs from the previously mentioned sentence-context studies in two respects. First, instead of including both related (congruous) and unrelated (incongruous) lexical contexts, we only used related context words besides the neutral context. Second, unlike the above sentence-context studies, we systematically varied the SOA of context word and target word. The first of these two differences between the two types of context studies was based on the results of a lexical-context pilot study, with naming responses as the dependent variable. This study, which *did* include pairs of unrelated context and target words, produced equal amounts of facilitation and inhibition, that were both too small to approach statistical reliability. Only the 'overall' context effect, that is, the difference between the related and unrelated conditions, was significant.[4] Although this overall effect clearly showed that the lexical context had exerted an influence on subsequent target naming, the unreliability of both facilitation and inhibition complicates the interpretation of this effect in terms of underlying processes. Subjects' reports indicated that the inclusion of (relatively few) 'catch' trials in the form of unrelated word pairs kept them from anticipating the target. In order to obtain statistical reliability of at least one of the relevant context effects, namely, the facilitatory effect, we replaced the unrelated word pairs of the pilot experiment by related pairs in the present experiment. We thereby eliminated the subjects' uncertainty as to which type of target was to follow a non-neutral context word, and, consequently, we increased the subjects' use of context-induced attentional strategies. In view of our goal to find a difference between word naming and lexical decision in a lexical context, the removal of unrelated word pairs carries the risk of not finding any differences at all. Recall that, whereas the inhibition of unrelated targets preceded by a sentence context has generally been found to be larger in lexical decision than in word naming, the facilitatory effect of a sentence context on related targets has at least once been found not to differ across the two tasks (West & Stanovich, 1982). Yet, the explanation provided above of the differential effects of the two tasks in terms of a post-lexical biasing of the decision maker does not only predict more inhibition for unrelated targets in the lexical-decision task than in naming, but it also predicts more facilitation for related targets.

The second difference between the present lexical-context study and the previous sentence-context studies, i.e., the SOA manipulation, served to obtain stronger support for context-induced attentional processing in lexical-context studies than is currently available. Generally, in lexical-decision experiments in which the subjects are encouraged to attend to words related to the context word (but see Neely, 1977), both the presence of inhibition for unrelated targets (Neely, 1976, 1977) and of an effect of varying the proportion of related word pairs in the set of materials (Tweedy et al., 1977; Tweedy & Lapinski, 1981) have been regarded as indicative of such attentional processing in lexical-context studies. But, as argued above, post-lexical processes may also produce inhibition for unrelated targets in lexical decision. Furthermore, we have to consider the possibility that post-lexical as well as context-induced attentional processes are sensitive to proportion manipulations. Therefore, neither the presence of an inhibitory effect for unrelated targets nor the sensitivity of the priming effects to the proportion of related word pairs in these lexical-decision studies are unambiguous evidence of context-induced attentional processing.

It was mentioned in passing that the duration of the SOA of context word and target word is critical if the subjects are to generate specific expectations about the identity of the target prior to its presentation. Therefore, with very short SOAs such attentional processing cannot facilitate the recognition of a subsequent related word. In lexical-decision studies such as the present one in which the subjects are encouraged to direct their attention to representations of words related to the prime, the facilitatory effects of automatic spreading activation, of post-lexical processing, and of context-induced attentional processing are confounded. Since the former two processes can exert an effect on subsequent target processing with relatively short SOAs (see Neely, 1977, and Warren, 1977, for the onset time of automatic spreading activation in lexical memory), the fact that we do find facilitation with very short SOAs is not surprising. What *Is* surprising, however, is that, even when the composition of the stimulus set encourages the use of context-induced attentional processing, the amount of facilitation does not always increase significantly over a range of increasing SOAs (De Groot, Note 1), since the use of attentional processing predicts such growth. This suggests that the development of attentional facilitation may be overruled by the effects of the remaining two processes. In that case, removing any effect of post-lexical processing by switching to the naming task might reveal a growth of facilitation over SOAs. Since we may expect (Neely, 1977) the effects of automatic spreading activation to decrease over the range of SOAs that we have adopted, from 240 msec to 1040 msec, any growth of facilitation in the naming task would have to be attributed to context-induced attentional processing and its increased effectivity. This would provide stronger evidence of context-induced attentional processing than is presently available from lexical-decision studies. Warren (1977) also ran a naming experiment in which he systematically varied the SOA of context word and target word. But since he chose a range of SOAs over which presumably only automatic spreading activation was effective, namely from 75 msec to 225 msec, his study cannot provide us this information.

Finally, one feature of the materials used in the present experiment deserves some attention. The materials used in the lexical-decision sub-experiment differ from those used in the naming sub-experiment in that we have not included nonword targets among the naming materials. The purpose of this was to enhance lexical processing in the naming task. As was mentioned before, regular words can be named via a non-lexical process of grapheme-phoneme translation as well as via lexical access. The use of word targets only in the naming sub-experiment presumably encourages the subjects to use the lexically based route to the naming response (Frederiksen & Kroll, 1976). But due to this feature of the materials, the predictability of the target is larger in the naming sub-experiment than in the lexical-decision sub-experiment. Therefore, we may expect more context-induced attentional processing and larger effects of this process in the present naming task than in the lexical-decision task. Such a result would, however, run counter to the predicted larger effects in lexical decision than in naming, due to the complex post-lexical processing in the former. If we nevertheless find that lexical decision displays more facilitation than naming does, the notion of post-lexical effects in lexical decision as proposed here will be even more strongly supported than with equal predictability in both tasks.[5]

Method

Materials. The test materials of the naming sub-experiment consisted of 120 pairs of context word and target word. Henceforth, the context word will be called 'prime'. In eighty of these pairs, the prime was a stimulus word taken from Dutch association norms (De Groot, 1980) and the corresponding target was the word that had occurred as the primary associate to this stimulus word in the norms. All primes and targets in these 80 related pairs were nouns. The prime in the remaining 40 prime-target pairs was the Dutch equivalent of the word *blank* (*blanco*). The targets in these pairs were nouns, a different noun in each pair. These *blank*-noun pairs served as neutral pairs from which facilitation for the related pairs was to be determined. Of the 80 related pairs, only 20 were regarded as critical. Similarly, of the 40 neutral pairs only 20 were considered critical. The remaining 60 related and 20 neutral pairs were regarded as fillers and were not included in the analyses below.[6] The mean association frequency of the target to the prime in the 20 critical related prime-target pairs was 65.7%, with a standard error of 2.8. The overall mean association frequency of the target to the prime across all 80 related pairs was 56.8%, with a standard error of 2.1. Across the two groups of critical pairs the targets were balanced on language frequency (Uit den Boogaart, 1975), length in letters, and number of syllables. The mean language frequencies were 75.3 (per 600,000 words) for the targets in the critical related prime-target pairs and 75.7 for the critical targets following the neutral prime *blank*. The corresponding standard errors were 17.5 and 18.3, respectively.

Besides the test materials, 25 practice prime-target pairs were included in the set of materials of the naming sub-experiment. Among the practice materials, related and neutral pairs appeared in about the same proportion as among the test materials. With the exception of the word *blank* all the words in the complete set of materials, practice and test sets combined, occurred only once, either as prime or as target.

The 120 positive prime-target pairs (their target being a word) of the test materials that were presented in the lexical-decision sub-experiment were the same as the prime-target pairs of the naming sub-experiment. Apart from these positive pairs, the lexical-decision test materials included 120 negative prime-target pairs (their target being a nonword). All targets in these negative pairs were pseudowords, i.e., nonwords that, however, were orthographically permissible Dutch letter sequences. They were derived from nouns, all different from those used as prime or as target in the positive materials, by changing, adding or deleting one or two letters. Eighty of these negative pairs had a noun as prime, a different noun in each pair. The remaining 40 negative pairs had the word *blank* as prime. The primes in the noun-pseudoword pairs were from the same population of words as those in the noun-word pairs.

Besides the test materials, 86 practice prime-target pairs were included in the set of materials of the lexical-decision experiment. Among the practice materials, all types of prime-target pairs appeared in about the same proportion as among the subsequent test materials.

Subjects, Apparatus and Procedure. In this experiment 96 students of the University of Nijmegen participated as subjects, 48 in each of the two sub-experiments. They were paid 6.50 guilders. All subjects in the naming sub-experiment were presented the total naming set of 25 practice and 120 test pairs. All subjects in the lexical-decision sub-experiment were presented the total lexical-decision set of 86 practice and 240 test pairs. In order of arrival, the 48 subjects in each of the sub-experiments were assigned to one of three groups. A group consisted of 16 subjects all of whom were tested under the same SOA condition (see below).

The subjects in the naming sub-experiment were individually tested in a normally lit room. They sat at a comfortable reading distance in front of a TV monitor on which the stimuli were presented in uppercase (white on grey). Stimulus presentation and RT recording were performed by a program called LEXSYS (Hudson, Maarse & Bouwhuisen, Note 3). The subjects were told that pairs of words were going to be presented on the monitor, one word after the other, and that they had to read aloud the second word of each pair as quickly and as accurately as possible. The naming response was registered by a microphone that activated a voice-operated switch. RTs were measured starting from target onset. The experimenter was seated next to the subject and recorded actual reading errors, premature sounds that triggered the voice switch before the target had appeared, and failures of the voice switch to respond to an utterance because it was not loud enough. The subjects were not informed about the presence of associatively related prime-target pairs among the experimental materials until after the experiment.

Prior to every first letter string of a pair (the prime), a fixation star appeared for one second, slightly above and to the left of the place at which the prime would appear. The prime replaced the fixation star immediately. Prime exposure depended upon the particular SOA condition in which the subject participated. There were three SOA conditions: 240, 540 and 1040 msec. In these conditions the prime was presented for 200, 500 and 1000 msec, respectively. Following prime offset and prior to the presentation of the second letter string (the target) the screen was empty for 40 msec. The target then appeared slightly below the position where the prime had been, and remained on the screen until the subject initiated the naming response. Latencies were recorded on-line. After every trial the subject received feedback about speed and accuracy. If a reading error had been made, this was notified to the subject by the experimenter. The word *slow* occurred on the screen whenever a response exceeded a preset 900-msec deadline. The test materials were presented in five blocks of 24 prime-target pairs each. After each block the mean RT for that block was presented on the screen. After a forced rest of at least 10 sec the subjects initiated the presentation of a new block by pressing a key in front of them. Prior to the test materials the practice materials were presented in one block of 25 trials.

The data of the lexical-decision sub-experiment were collected using the same apparatus and procedure. The only procedural difference from the naming sub-experiment was that the subjects, instead of naming the target, responded to the target by pressing, with their right forefinger, the positive response key on the right-hand side of the keyboard in front of them in case the target was a Dutch word. When the target was not a word they were to press the negative response key on the left-hand side of the keyboard with their left forefinger. Some further, minor, differences between the two sub-experiments were that in the lexical-decision sub-experiment, instead of being told that pairs of words were going to be presented on the screen, the subjects were told that pairs of letter strings were going to be presented, the experimenter was not seated next to the subject, that all errors were recorded on-line and that error feedback was provided on the screen instead of by the experimenter. Furthermore, the test materials of the lexical-decision sub-experiment were presented in 10 blocks of 24 prime-target pairs each. After each block not only the mean RT, but also the number of errors made in that block were shown on the screen. The practice materials were presented in three blocks of 24 prime-target pairs each and in one last block of 14 pairs.

Results

Table 1 presents, for both sub-experiments, the mean RTs, the mean subjects' standard deviations (collapsed across items) and error rates for the two groups of critical prime-target pairs in all three SOA conditions. The error rates for the naming sub-experiment include actual reading errors, responses that were too soft to trigger the voice switch, and detections of premature sounds by the voice switch. The error rates for the lexical-decision sub-experiment include RTs longer than 1,400 msec. These long RTs occurred on less than one percent of the trials. In the naming sub-experiment such long RTs did not occur at all. For each SOA condition, Table 1 also shows the facilitatory effect, that is, the difference between the two prime-type conditions.

Table 1

Mean Response Times (in Milliseconds), Standard Deviations, and Error Rates (in Percentages) for the Critical Prime-Type Conditions

task	prime type	SOA (msec) 240 RT	SD	ER	540 RT	SD	ER	1040 RT	SD	ER	X
lexical decision	related	480	103	0.9	442	102	0.6	432	123	1.6	451
	neutral	533	117	2.8	510	114	2.5	505	90	1.3	516
	facilitation	53			68			73			65
	(percent)	(9.9)			(13.3)			(14.5)			(12.6)
naming	related	419	64	2.2	412	74	2.5	364	77	3.4	398
	neutral	434	73	1.6	443	74	2.8	430	87	1.6	436
	facilitation	15			31			66			38
	(percent)	(3.5)			(7.0)			(15.3)			(8.7)

The total number of errors in the naming sub-experiment was 45, of which 26 were made on related prime-target pairs and 19 on the neutral pairs. Of the 26 errors on related pairs, 19 were due to failure of the voice switch to detect the naming response, 2 were due to a premature sound that activated the voice switch and 5 were actual reading errors. All 5 reading errors indicated that the subjects anticipated the presentation of particular targets (e.g., after the prime *fork*, *spoon* was read as target rather than the actual target *knife*). Of the 19 naming errors on neutral pairs, 9 were due to the fact that the response was too soft to trigger the voice switch, 8 were caused by premature sounds uttered by the subjects, and 2 were actual reading errors. Although slightly more errors were made on targets in the related pairs, the distribution of errors over the different types of errors shows that it is very unlikely that the subjects have traded off speed for accuracy. Since very few errors were made in the naming sub-experiment (2.4% overall), and even less errors were made in the lexical-decision sub-experiment (1.6% overall), errors were not subjected to further analysis.

In order to test the significance of the facilitatory effects, the subjects' mean naming RTs to the targets in both groups of critical prime-target pairs of each SOA condition separately were subjected to a 2 (prime type: related and neutral) by 16 (subjects) ANOVA, treating prime type as a within-subjects factor. Error responses were not included in these analyses, nor were they included in the overall analyses reported below. Furthermore, for each SOA condition a 2 (prime type) by 20 (items) ANOVA was performed on the item means, collapsed across subjects. In these item analyses prime type was treated as a between-items variable. These same analyses were performed on the subject and item means of the lexical-decision data. The effect of prime type was significant on all these analyses ($p < .05$, or better). Finally, for all three SOA conditions in both sub-experiments a minF' (Clark, 1973) was calculated, combining the F-values of the subject and item analyses within each SOA condition. MinF' was statistically reliable in all cases ($p < .05$ or better).

As can be seen in Table 1, the facilitatory effect in the naming sub-experiment increased considerably over the three SOAs (51 msec), whereas this growth in the lexical-decision sub-experiment was relatively small (20 msec). To see whether these increases were significant, for each of the two sub-experiments separately a 2 (prime type) by 3 (SOA) by 16 (subjects) ANOVA and a 2 by 3 by 20 (items) ANOVA was performed on the subject and item means of the critical prime-target pairs. On the subject analyses prime type was treated as a within-subjects variable and SOA was treated as a between-subjects variable. On the item analyses prime type was treated as a between-items variable and SOA was treated as a within-items variable. On the analysis of the naming data the interaction between prime type and SOA was statistically reliable [F_s (2,45) = 10.38, p <.01; F_i (2,76) = 20.79, p < .01; *minF'* (2,88) = 6.93, p < .01], showing that the facilitatory effect increased over SOAs. In contrast, this interaction was insignificant in the analysis of the lexical-decision data [F_s (2,45) < 1; F_i (2,76) = 1.93, p > .10]. The finding that the facilitatory effect of a related prime increases over SOAs in the naming sub-experiment is suggestive of prime-induced attentional processing and shows that such processing can indeed contribute to context effects in visual word recognition. The absence of such increase in the lexical-decision sub-experiment indicates that an effect of attentional processing is overwritten by a facilitatory effect of post-lexical processing.

As could be expected from the results of the analyses performed on the data for the separate SOAs, the main effect of prime type was significant both for the naming data [F_s (1,45) = 66.77, p < .01; F_i (1,38) = 52.90, p < .01; *minF'* (1,79) = 29.52, p < .01] as for the lexical-decision data [F_s (1,45) = 119.59, p < .01; F_i (1,38) = 66.25, p < .01; *minF'* (1,72) = 42.63, p < .01]. Furthermore, on the analysis of the naming data the main effect of SOA was significant on the item analysis, but it just failed to reach significance on the subject analysis [F_s (2,45) = 2.52, .05 < p < .10; F_i (2,76) = 37.22, p < .01]. On the analysis of the lexical-decision data the main effect of SOA was only significant on the item analysis [F_s (2,45) = 1.96, p > .10; F_i (2,76) = 28.51, p < .01]. Since these main effects are not relevant with respect to the purposes of the present experiment, they will not be discussed here.

In order to directly compare the effect of a related prime on subsequent lexical decision on the one hand and on subsequent naming on the other, the combined naming and lexical-decision data were subjected to two overall analyses, one treating subjects as the unit of analysis and one treating items as the unit of analysis. In the 2 (task) by 2 (prime type) by 3 (SOA) by 16 (subjects) analysis, prime type was treated as a within-subjects variable and task and SOA were regarded as between-subjects variables. In the 2 by 2 by 3 by 20 item analysis, task and SOA were treated as within-items variables and prime type was treated as a between-items variable. The relevant questions to be answered in these overall analyses are the following two: First, do lexical decisions take longer than naming responses? If lexical decisions require relatively complex post-lexical processing, this question should be answered affirmatively. Second, is the size of the facilitatory effect of a related lexical context on subsequent lexical decision larger than it is on subsequent word naming? If indeed in lexical decision the facilitation due to actual pre-lexical priming processes is augmented by a post-lexical facilitatory biasing mechanism, this question should also be answered affirmatively. Of the present overall analyses only the relevant effects, that is, the main effect of task and the interaction between task and prime type will be reported.

The main effect of task was reliable on both analyses [F_s (1,90) = 40.62, p < .01; F_l (1,38) = 303.68, p < .01; *minF'* (1,110) = 35.83, p < .001]. As predicted, the overall mean RT in the naming sub-experiment was shorter (417 msec) than that in the lexical-decision sub-experiment (483 msec). This finding suggests that the size of facilitation can be expressed more appropriately in terms of gain in percentages relative to targets in the neutral condition than as absolute differences between the mean RTs of the two prime-type conditions. Both measures of facilitation are shown in Table 1.

The interaction between the variables task and prime type was also reliable both on the subject and the item analysis [F_s (1,90) = 13.11, p < .01; F_l (1,38) = 12.18, p < .01; *minF'* (1,103) = 6.31, p < .05], with a larger difference between the two prime-type conditions in lexical decision than in naming. In other words, the lexical-decision task indeed displays more facilitation (65 msec collapsed over SOAs) than the naming task does (38 msec collapsed over SOAs).

SUMMARY AND DISCUSSION

The results of the present experiment can be summarized in three points, of which the first two support the notion of a relatively complex post-lexical stage in lexical decision, and the sensitivity of this stage to the type of contextual information. First, lexical decisions to word targets preceded by a word context took longer (66 msec overall) than naming responses to these same targets. Second, collapsed across three SOAs the facilitatory effect of a related context word on subsequent lexical decisions to word targets was 27 msec larger than on subsequent naming of word targets. Third, whereas the magnitude of the facilitatory effect was virtually unaffected by the SOA of prime and target in the lexical-decision sub-experiment, it increased linearly with SOA in the naming sub-experiment.

The first of these findings supports the view set forth above that lexical decisions require relatively complex post-lexical processing. The extra time taken by the additional processing complexity in lexical decision can be assessed from the naming and lexical-decision times to targets in the neutral condition. The overall RT to targets in the neutral lexical-decision condition was 516 msec; that in the neutral naming condition was 80 msec faster, namely 436 msec.

The second of the above results suggests that the duration of the additional post-lexical processing time in lexical decision can be influenced by the type of contextual information: When context and target words are associatively related, the extra processing time in lexical decision is shorter than when a neutral context word precedes the target. Whereas the overall difference between naming and lexical-decision times in the neutral condition was 80 msec, this difference was only 53 msec in the related condition (see Table 1). This finding extends the results of West and Stanovich (1982) who found more inhibition for targets preceded by an incongruous sentence context in lexical decision than in naming. They interpreted this result in terms of a lengthening of the post-lexical response-selection stage in lexical decision due to the detection by the message processor of the incongruent relation between context and target, and the consequent *no* output that it sends off to the decision maker (see introduction).

The present findings may have considerable consequences for the interpretation of 'priming' effects in lexical-decision tasks. Very often the facilitatory and inhibitory effects observed in lexical-decision experiments are well below

30 msec. The present study shows that such effects may be totally due to variations in post-lexical processing time. In other words, even if real priming processes such as automatic spreading activation in lexical memory or prime-induced attentional processing do not exert any influence on subsequent word recognition, lexical decisions to targets related to the context word can be about 30 msec faster than those to targets preceded by a neutral prime, and lexical decisions to unrelated targets can be about 30 msec slower than those to targets in the neutral condition.

The present naming data, not being confounded by post-lexical processing variability, provide evidence of real priming effects of lexical contexts on actual word recognition, and of the dependence of these effects upon the SOA of context word and target word. Since automatic spreading activation presumably decreases over the range of SOAs that we have used (Neely, 1977), increased effectivity of prime-induced attentional processing is probably responsible for the increase of facilitation over SOAs. In the introduction to this paper it was suggested that the effects of such attentional processing in the lexical-decision task may be overshadowed by those of post-lexical processing operations, and that for this reason the magnitude of facilitation in lexical decision is sometimes unaffected by the SOA manipulation, as it is in the present experiment. Of course, an alternative interpretation of the small and insignificant growth of the facilitatory effect in the present lexical-decision sub-experiment is that, due to the fact that the predictability of the target was less than in the naming sub-experiment (see introduction), the subjects were less engaged in prime-induced attentional processing. This view is supported by the fact that the 1040-msec SOA condition displays slightly more facilitation in the naming sub-experiment than in the lexical-decision sub-experiment, even though only in the lexical-decision task the amount of facilitation is supposedly augmented by post-lexical processes.

In the light of the present results some of our own earlier data need to be reconsidered. In a lexical-decision experiment (De Groot et al., 1982) in which we tested the effect of a word context on word targets that were 'strong' or 'weak' associates of the context word (the mean association frequency of the target to the prime being 37.4% and 1.9%, respectively) or that were unrelated to the context word, we found that strongly associated targets were processed 19 msec faster than targets in the neutral condition (in which, as in the present experiment, the word *blank* was used as prime), that unrelated targets were responded to 22 msec slower and that weak associates were processed equally fast as targets in the neutral condition. Two possible interpretations were provided for this finding. The first was in terms of Posner and Snyder's (1975) theory of attention in which both of two processes, similar to automatic spreading activation and prime-induced attentional processing as set forth above, are assumed to affect actual word recognition. We suggested that both these processes facilitate lexical decisions to strong associates, but that they might cancel each other's effect on weak associates. The inhibition of unrelated targets was considered to be caused by the attentional priming process. The second interpretation of the results denied the operation of a prime-induced attentional priming process. According to this conception, the facilitation of related targets was caused by automatic spreading activation, and the inhibition of unrelated targets was thought to be the result of a post-lexical process similar to the present one. However, at that time we assumed the latter process only to affect unrelated targets; the neutral times for weak associates were thought to indicate that neither automatic spreading activation nor this post-access process had affected them. The present data suggest a simpler and therefore more elegant interpretation of our earlier data, namely that both the facilitation for strong associates and the inhibition for unrelated targets were caused by a single process: the present post-lexical biasing by the message processor. The neutral times for weak associates indicate that the message processor can more readily detect incongruence and 'obvious' congruence (in case of strong associates) than it can detect less obvious congruence (in case of weak associates), and that the congruence between weak associates is discovered too late to bias the decision maker. This reinterpretation of our earlier data is not meant to suggest that automatic spreading activation and attentional priming never play a role in lexical-decision tasks. As the masking experiments (see introduction) of Fowler et al. (1981), of Marcel (in press) and of ourselves (De Groot, in press) indicate, a process like automatic spreading activation must sometimes be assumed in order to explain the facilitatory effect. Also, since the present naming data show that, under certain circumstances, attentional priming processes can indeed affect word recognition in lexical-context studies, a conclusion that could not easily be inferred from lexical-decision studies alone (see introduction), we are free to assume that attentional priming can also be operative in lexical-decision studies. The present interpretation only suggests that these priming processes are less general and have less impact on lexical-decision times than is commonly assumed.

In view of the present data, one further earlier result (De Groot, Note 1) needs to be reconsidered. In that lexical-decision experiment the magnitude of facilitation depended upon the proportion of related prime-target pairs in the set of materials. This was equally true for an SOA of 240 msec as for longer SOAs. We attributed the sensitivity to the proportion manipulation to prime-induced attentional processing. Consequently, the effect of proportion in the 240-msec SOA condition led us to suggest that such attentional processing is already fully effective with this short SOA. The naming data reported here indicate that this is not the case, and that therefore not only attentional processing, but also the post-lexical response-selection stage must be sensitive to the proportion manipulation.

Summing up the results reported here, we can say that the data clearly support the model of post-lexical processing in lexical decision as set forth in the introduction to this paper, and that we agree with West and Stanovich that "If the goal of an investigation is to study sentence context effects (and word-context effects, adg) on the process of word recognition, the naming task is probably preferable (West & Stanovich, 1982, p. 385)".

REFERENCE NOTES

1. De Groot, A.M.B. Primed lexical decision: Combined effects of the proportion of related prime-target pairs and of the stimulus-onset asynchrony of prime and target. Paper submitted for publication.
2. De Groot, A.M.B., Thomassen, A.J.W.M., & Hudson, P.T.W. Primed lexical decision: The effect of varying the stimulus-onset asynchrony of prime and target. Paper submitted for publication.
3. Hudson, P.T.W., Maarse, F.J.M., & Bouwhuisen, C. LEXSYS: A real-time multi-subject system for psycholinguistic experiments. Report. Department of Experimental Psychology, University of Nijmegen, P.O. Box 9104, Nijmegen 6500 HE, The Netherlands.

REFERENCES

Clark, H.H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior*, 1973, *12*, 335-359.

De Groot, A.M.B. *Mondelinge Woordassociatie Normen: 100 Woordassociaties op 460 Nederlandse Zelfstandige Naamwoorden*. Lisse, The Netherlands: Swets & Zeitlinger, 1980.

De Groot, A.M.B. The range of automatic spreading activation in word priming. *Journal of Verbal Learning and Verbal Behavior*, in press.

De Groot, A.M.B., Thomassen, A.J.W.M., & Hudson, P.T.W. Associative facilitation of word recognition as measured from a neutral prime. *Memory and Cognition*, 1982, *10*, 358-370.

Fischler, I. Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 18-26.

Fischler, I., & Bloom, P.A. Automatic and attentional processes in the effects of sentence context on word recognition. *Journal of Verbal Learning and Verbal Behavior*, 1979, *18*, 1-20.

Fischler, I., & Bloom, P.A. Rapid processing of the meaning of sentences. *Memory and Cognition*, 1980, *8*, 216-225.

Forster, K.I. Levels of processing and the structure of the language processor. In W.E. Cooper & E. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett*. Hillsdale, N.J.: Erlbaum, 1979.

Forster, K.I. Priming and the effects of sentence and lexical contexts on naming time: Evidence for autonomous lexical processing. *Quarterly Journal of Experimental Psychology*, 1981, *33A*, 465-495.

Forster, K.I., & Chambers, S.M. Lexical access and naming time. *Journal of Verbal Learning and Verbal behavior*, 1973, *12*, 627-635.

Fowler, C.A., Wolford, G., Slade, R., & Tassinary, L. Lexical access with and without awareness. *Journal of Experimental Psychology: General*, 1981, *110*, 341-362.

Frederiksen, J.R., & Kroll, J.F. Spelling and sound: Approaches to the internal lexicon. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, *2*, 361-379.

Marcel, A. Conscious and unconscious reading: The effects of visual masking on word perception. *Cognitive Psychology*, in press.

Morton, J. Interaction of information in word recognition. *Psychological Review*, 1969, *76*, 165-178.

Neely, J.H. Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. *Memory and Cognition*, 1976, *4*, 648-654.

Neely, J.H. Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General*, 1977, *106*, 226-254.

Perfetti, C.A., & Roth, S. Some of the interactive processes in reading and their role in reading skill. In A.M. Lesgold & C.A. Perfetti (Eds.), *Interactive processes in reading*. Hillsdale, N.J.: Erlbaum, 1981.

Posner, M.I., & Snyder, C.R.R. Attention and cognitive control. In R.L. Solso (Ed.), *Information Processing and Cognition: The Loyola Symposium*. Hillsdale N.J.: Erlbaum, 1975.

Schuberth, R.E., & Eimas, P.D. Effects of context on the classification of words and nonwords. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 27-36.

Schuberth, R.E., Spoehr, K.T., & Lane, D.M. Effects of stimulus and contextual information on the lexical decision process. *Memory and Cognition*, 1981, *9*, 68-77.

Stanovich, K.E., & West, R.F. Mechanisms of sentence context effects in reading: Automatic activation and conscious attention. *Memory and Cognition*, 1979, *7*, 77-85.

Stanovich, K.E., & West, R.F. The effect of sentence context on ongoing word recognition: Tests of a two-process theory. *Journal of Experimental Psychology: Human Perception and Performance*, 1981, *7*, 658-672.

Theios, J., & Muise, J.G. The word identification process in reading. In N.J. Castellan, D.B. Pisoni, & G.R. Roth (Eds.), *Cognitive theory* (Vol. 2). Hillsdale, N.J.: Erlbaum, 1977.

Tweedy, J.R., & Lapinski, R.H. Facilitating word recognition: Evidence for strategic and automatic factors. *Quarterly Journal of Experimental Psychology*, 1981, *33A*, 51-59.

Tweedy, J.R., Lapinski, R.H., & Schvaneveldt, R.W. Semantic-context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context. *Memory and Cognition*, 1977, *5*, 84-89.

Uit den Boogaart, P.C. (Ed.). *Woordfrequenties in Geschreven en Gesproken Nederlands*. Utrecht, The Netherlands: Oosthoek, Scheltema & Holkema, 1975.

Warren, R.E. Time and the spread of activation in memory. *Journal of Experimental Psychology: Human Learning and Memory*, 1977, *3*, 458-466.

West, R.F., & Stanovich, K.E. Automatic contextual facilitation in readers of three ages. *Child Development*, 1978, *49*, 717-727.

West, R.F., & Stanovich, K.E. Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 1982, *5*, 385-399.

FOOTNOTES

[1]In the present paper the term 'word recognition' is implicitly defined as the identification of the stimulus as a word. According to our definition, word recognition does not necessarily imply that meaning is attributed to the stimulus. That is, a stimulus can be recognized as a word even though its meaning is unknown. Also, with the term 'word recognition' we do not refer to the process leading to actual word recognition, but to the product of this process.

[2]With 'sentence context' we mean an *incomplete* sentence that serves as the context for the subsequent target.

[3]Whereas word recognition per se as we defined it (see Footnote 1) does not imply that meaning is assigned to the stimulus, the message processor that produces context effects in the post-access response-selection stage operates on word meanings.

[4]In this pilot study three out of each six context-target pairs consisted of related words, two consisted of a neutral context followed by a word, and one consisted of unrelated words. Equal numbers of related, neutral and unrelated context-target pairs were considered as critical. The overall mean RTs for the targets in the critical related, neutral and unrelated conditions of this pilot experiment were 434, 454 and 476 msec, respectively. The SOA of context word and target word was 540 msec.

[5]The lexical-decision data of the present experiment were also reported as part of the data of an earlier experiment in which we varied both the SOA of context word and target word and the proportion of related word pairs in the set of materials (De Groot, Note 1). Since these lexical-decision data were collected under exactly the same circumstances, drawing from the same popu-

lation of subjects, and using the same set of materials as the newly reported naming data, both sets of data are treated as obtained in a single experiment.

[6]The large number of fillers were due to the fact that the present set of materials was developed for an experiment different from the one reported here (see Footnote 5).

CHAPTER VI

Chapter VI

DISCUSSION IN RETROSPECT

This thesis is concerned with the influence of a visually presented context word on the recognition and further processing of a subsequent word that is also presented visually. In the typical experiment reported here the context words (the primes) are followed by letter strings (the targets) for which the subjects have to decide whether they are words or nonwords. It is generally found that such decisions, which are referred to as 'lexical decisions', are made faster when the target word follows shortly after an associatively related context word than when it is preceded by an unrelated word. The influence of a prime on the processing of a target is generally called 'priming effect'. The present research aims at specifying the conditions under which this associative priming effect occurs, and at providing insight into the underlying processes and the memory structure on which they operate. It is closely related to the research on the effects of sentence fragments on subsequent visual word recognition. Studies of the latter type, and to a certain extent also the current word-context studies, throw light on how context is used during the reading of text.

During the past decade, the views on the use of contextual information in reading have been changed radically. In the early seventies the 'top-down' models of reading (Goodman, 1976; Smith, 1971) were received enthusiastically, presumably because of their promise from an educational point of view. According to proponents of this model, context facilitates word recognition because contextual redundancy reduces the amount of information that must be extracted from the word stimulus to recognize it. In the top-down models it was often assumed that acquiring reading fluency involves an increasing ability of the reader to use context for building specific expectancies about subsequent words. Fluent readers were thought to differ from less-fluent readers in making more use of the context. Consequently, educationalists tackled reading deficiency by training less-skilled readers in using contextual information. But contrary to this top-down conception of reading, an abundance of recent sentence-context studies (e.g., Perfetti, Goldman & Hogaboam, 1979; Stanovich, West & Freeman, 1981; West & Stanovich, 1978) have indicated that less-fluent readers in fact rely *more* on context than fluent readers do: On the whole, the magnitude of context effects correlates negatively with reading skill. This finding has been attributed to differences in bottom-up word recognition skills between skilled and less-skilled readers. In skilled readers word recognition has become highly automatized and comes about extremely fast. The slower this process, the more it is influenced by context. This is why less-skilled readers, in whom bottom-up word recognition takes much longer, show larger context effects. According to the 'interactive-compensatory model' of Stanovich (1980), the reason why less-skilled readers rely more on context is to compensate their deficient word-recognition skills.

In the experiments reported in this thesis we have not as a rule investigated the relationship between reading proficiency and the size of contextual effects (but see the post-hoc analyses on two groups of subjects that apparently differ in reading proficiency in the 'masked-prime' experiments in Chapter II). Only highly skilled readers, university students, have participated as subjects in our experiments. The context effects will therefore presumably be relatively small. In some experiments we have tried to increase these effects by encouraging the subjects to engage actively in contextually based processing. This active engagement may imply that the subjects direct their attention to the memory representations of certain words prior to the presentation of the target. In order to bring about this activity on the part of the subject, we manipulated the proportion of associatively related prime-target pairs among the set of experimental materials (Chapter IV), and the associative strength between prime and target within related pairs. However, not all context effects result from the above adaptive, attentional strategy. Data from sentence-context as well as word-context studies indicate that part of these effects are due to a process that operates automatically. Chapter II investigates the impact of this process. Furthermore, depending upon the particular task being used, a third, post-lexical, process may cause context effects in visual word recognition. It appears that this process effectively influences the responses in a lexical-decision task but not in another, more straightforward task concerned with word recognition, viz., word naming. These three contextual processes and their workings run through this thesis like a continuous thread. The major part of the present discussion is devoted to following this thread. At first, however, we will dwell on the importance of including a neutral condition in the priming experiment to serve as a baseline from which context effects can be assessed. As will be seen below, context can facilitate or inhibit subsequent target processing. The type of context effect, facilitation or inhibition, provides information as to what process could have caused it. If no neutral condition is included in the experiment, facilitation and inhibition cannot be distinguished. This complicates an analysis of priming effects in terms of underlying processes. In Chapter I the adequacy of several different neutral primes is tested. As a consequence of the results of these investigations, the Dutch equivalent of the word *blank* (*blanco*) is used as prime on all neutral trials in all experiments reported in Chapters II through V.

In much of the early priming research, lexical-decision times to targets following unrelated words (that are only presented once during the course of the experiment) have been tacitly accepted as the baseline to assess the presence and the size of a priming effect on prime-related targets. Consequently, the difference between the response times to related and unrelated targets was taken as evidence that the former are facilitated rather than that the latter were thought to be inhibited. Later studies, however, have shown that under certain circumstances primes may not only facilitate responses to subsequent related words, but also inhibit responses to subsequent unrelated words. Therefore, response times to targets following unrelated-word primes do not constitute a proper baseline for assessing priming effects. What is required is the inclusion in the experiment of a neutral condition in which the prime does not influence subsequent target processing through one or more of the above priming processes. Also, neutral primes should, ideally, have the same alerting properties and require the same processing as non-neutral primes. As indicated at various places in this thesis, these conditions are not easily satisfied. Commonly, the same stimulus is presented as prime in all neutral prime-target pairs. This repeated presentation is to render the prime uninformative as to what target may follow, thereby discouraging the subjects to anticipate the target on trials on which such an uninformative prime is presented. A repeated stimulus, however, is recognized faster than novel, non-repeated stimuli. Therefore, more processing capacity can be devoted to a target following a repeated neutral prime than to one that follows a non-neutral prime, and, consequently, the target may receive a relatively rapid response. Thus, the facilitation of related targets as measured from a baseline involving such a neutral prime will be systematically underestimated and the inhibition of unrelated targets will be overestimated. On the other hand, a familiar, repeated neutral prime, having less novelty value than a non-neutral prime that only occurs once, will presumably be less alerting than a non-neutral prime, and will, for this reason, be responded to slower. This causes an effect opposed to the one above, i.e., facilitation to be overestimated and inhibition to be underestimated.

Not only the repetition of the neutral-prime stimulus, but also the particular choice of a stimulus as the prime in the neutral condition may bias the data. For instance, a row of *Xs*, or a word that evokes few associates (e.g., *neutral* or *blank*), have often been adopted as neutral, repeated, prime. It appears from the data reported in Chapter I that, relative to neutral-word primes, a row of *Xs* slows down responses to the subsequent targets. This finding is interpreted in Chapter I as the consequence of the non-linguistic nature of the *Xs* prime: If subjects are to process a word stimulus following an *Xs* prime they must first switch into a 'linguistic mode', or, less spectacularly, they may simply tend to wait for the second *linguistic* event as they do in the majority of the trials, which have a word as the prime. An alternative, more parsimonious interpretation is that the subjects tend to interpret the familiar stimulus that is presented as prime on all neutral trials as another fixation stimulus (in addition to the fixation stimulus that usually precedes the prime), that they take the target on these neutral trials for the prime and wait until a second *new* event is presented. Such a strategy would not only inhibit responses to targets following *Xs* primes, but also those following repeated neutral primes that are words, such as our *blank* prime. In that case, the systematic difference between responses to the targets following the two types of 'neutral' primes indicates that the tendency to regard the prime as an additional fixation stimulus is stronger with *Xs* primes than with neutral-word primes. This is a plausible assumption, since an *Xs* prime is more like the common fixation stimuli than is a neutral-word prime. Finally, Chapters III and IV provide evidence that the response times to targets in the neutral condition vary with changes in the stimulus-onset asynchrony (SOA) of prime and target and with changes in the proportion of related prime-target pairs in the set of materials. Besides comparing the effects of a number of different 'neutral' primes on subsequent target processing, Chapter I also shows that the proportion of neutral prime-target pairs in an experiment has a systematic effect on target processing: The response delay caused by *Xs* primes turns out to be particularly large when the number of neutral prime-target pairs among the experimental materials is relatively small.

As was mentioned above, all through this thesis, three contextual processes recur that are assumed to underly priming effects in lexical decision. These will be referred to as 'automatic spreading activation in the mental lexicon', 'prime-induced attentional processing', and 'post-lexical coherence checking'. The first two of these processes are presumably genuine 'priming' processes in the sense that they prepare target recognition, but the third operates on the meanings of both prime and target *after* they have been recognized. Presumably the third process affects, in lexical decision, the duration of the response-selection stage subsequent to target recognition. In one form or other, automatic spreading activation and prime-induced attentional processing are regarded as causes of priming effects in a large number of papers (e.g., Posner & Snyder, 1975). The present research provides additional support for these 'classical' priming processes and it delimits their workings. We postulated post-lexical coherence checking to be able to deal with some of our own findings in a more satisfactory way than could be achieved with the other two contextual processes. A direct test of this post-lexical process is provided in Chapter V.

Automatic spreading activation in lexical memory is said always to come about when, after the presentation of the prime word, its lexical representation is contacted. The activation that consequently arises in the corresponding memory location spreads to 'nearby' word representations. If the organization in lexical memory reflects word relatedness, these nearby representations will be those of related words. If a prime-related word that corresponds to one of these pre-activated representations is subsequently presented as target, either relatively little target information will suffice for its recognition or this pre-activation will enable more efficient target analysis. Automatic spreading activation is commonly assumed, (i) to come about rapidly, (ii) to facilitate the recognition of words associated with memory locations that it encounters without negatively affecting the recognition of words that correspond to representations not met by the activation wave, and, (iii) not to require the commitment of attention by the subjects. Strong support for an automatic priming process of this kind is provided in Chapter II, in which a number of masked-prime experiments are reported (Chapter II, Experiments 5 and 6). In these experiments the prime was masked such that it could be reported (and, therefore, identified) only occasionally by some of the subjects and never by others. Yet, *all* subjects, even those who had never identified the prime, showed facilitation of prime-related targets. As will be argued later, the remaining two contextual processes require identification of the prime. Therefore, the facilitation in these masked-prime experiments is presumably caused by automatic spreading activation.

The second process that can facilitate lexical decisions to prime-related targets, prime-induced attentional processing, implies the subjects' use of the prime to direct their attention to memory locations of one or more prime-related words prior to the occurrence of the target. If one of these 'expected' words is subsequently presented as the target, it will be recognized relatively fast. In contrast to automatic spreading activation, this process is considered to be slow acting, to require attentional commitment, and to inhibit the recognition of words that correspond to unattended memory locations. The magnitude of priming effects is commonly shown to vary with the proportion of related prime-target pairs (Chapter IV). This finding as well as the presence of inhibition of unrelated targets is usually regarded as evidence for prime-induced attentional processing. It will be argued below that both these findings provide rather weak support for this process, since they may also be explained in terms of post-lexical coherence checking.

The first indication that automatic spreading activation and prime-induced attentional processing cannot completely account for the pattern of results in primed lexical-decision experiments comes from an experiment (Chapter I, Experiment 3) in which inhibition was obtained for unrelated targets even though no related prime-target pairs were included in the set of experimental materials. Consequently, directing attention to particular memory representations prior to target occurrence would be an unprofitable and, therefore, unlikely strategy on the part of the subjects. Furthermore, in an experiment in which we systematically varied the SOA of prime and target (Chapter III) we obtained inhibition for unrelated targets with SOAs as short as 100 msec. The fact that prime-induced attentional processing is slow acting defies an interpretation of this inhibition in terms of such process. If the above assumption, that automatic spreading activation never inhibits the processing of unrelated targets, is correct, a third process is needed to explain the inhibition in the above two experiments. Indeed we have postulated a third contextual process that can explain this inhibition. In this thesis we have variously called this process 'set for coherence', 'search for meaningfulness' and 'post-lexical coherence checking'. The names have changed concurrently with our views on the precise workings of this process. However, the main assumed property of this process, namely, that it is executed in a post-lexical stage of processing, has remained the same.

In our original conception (Chapter I) coherence checking involves a tendency of the subjects always to try and relate the meanings of prime and target after both have been recognized as words. This process may continue after the appropriate *yes* response has already been selected, and it may postpone response execution. If response execution is indeed held up until coherence checking has discovered relatedness, or, in the case of unrelated words, until this unrelatedness has been discovered, or until some deadline is exceeded, this process would delay lexical decisions to targets not only in unrelated prime-target pairs, but, to a lesser degree, also in related pairs. The facilitation observed on the latter should then be taken as the net effect of such inhibitory post-lexical coherence checking and facilitatory automatic spreading activation. Chapter II holds on to this original conception of the post-lexical process, but provides data requiring the additional assumption that in case of relatedness this process is enacted too rapidly to entail any noticeable cost for associatively related word pairs or for 'mediator pairs'. The latter are pairs of words only indirectly related to one another via an intermediate, not overtly presented, word association (e.g., *bull*-(*cow*)-*milk*).

Influenced by some very recent interpretations of priming effects in lexical-decision studies with sentence fragments instead of single words as primes (Forster, 1981; West & Stanovich, 1982), our views on post-lexical coherence checking in lexical decision are modified in Chapters III through V. The process is no longer considered only to cause inhibition for targets unrelated to the prime, but it is now thought of as being facilitatory to prime-related targets as well. The new version does not consider the possibility that coherence checking holds up the execution of the response after it has been selected already, but assumes that this process influences the duration of the response-selection stage in lexical decision: The discovery of a meaningful relation between prime and target shortens the response-selection stage, whereas the conclusion of unrelatedness lengthens it. Basically, post-lexical coherence checking assumes the operation of a 'message processor' that sends off a *yes* output whenever it discovers a meaningful relation between prime and target, and a *no* output when it discovers unrelatedness. These outputs are received by a decision-making mechanism that is also in charge of making lexical-decision responses and that for this purpose also receives the output from a lexical processor. A *yes* output from the message processor thus biases the decision maker towards a *yes* response, thereby shortening *yes* responses to related word targets. A *no* output biases the decision maker towards a *no* response, thereby lengthening *yes* responses to unrelated word targets. This post-lexical influence on response selection is thought to be effectuated in lexical decision due to the fact that the response-selection stage in this task is relatively time consuming. More detailed information about this post-lexical process is given in Chapter V. In that chapter the revised model is tested in a comparison of priming effects in lexical decision and in word naming, in the latter of which the connection between target recognition and response is much more straightforward than in the former. It is assumed that post-lexical coherence checking cannot affect response times in word naming because response selection is already completed at the time that the output from the message processor becomes available.

The acceptance of a post-lexical process that produces facilitation for related targets and inhibition for unrelated targets allows some elegant reinterpretations of the data obtained in our earlier experiments. For instance, Experiment 2, Chapter I, displays facilitation for targets moderately related to the prime (their mean association frequency to the prime being 37.4%), and inhibition for unrelated targets. Very weak associates of the prime (their mean association frequency to the prime being 1.9%) are responded to equally fast as targets following the neutral prime *blank*. The first interpretation we provided for these results assumed the combined operation of automatic spreading activation and of prime-induced attentional processing that both produced facilitation on the moderate associates, and that cancelled out each other's effect on weak associates. The inhibition of unrelated targets was thought to be caused solely by prime-induced attentional processing. Although not uncommon in the literature, the assumption of opposing processes is not very elegant.

In an alternative attempt to interpret the above results we denied the operation of prime-induced attentional processing, and we assumed the pattern of results to be caused by the joint operations of automatic spreading activation and post-lexical coherence checking. As was already mentioned above, we originally (Chapter I) assumed that coherence checking takes place after the appropriate lexical-decision response has already been selected, but before the response is executed, and that it postpones the latter. In other words, the effect of this process was regarded always to be inhibitory, for related as well as unrelated targets. Consequently, this process could only explain the *inhibitory* effects that were observed in Experiment 2, Chapter I. Since the net effect for moderately related targets was positive (that is, they showed facilitation) it was concluded that for these targets the inhibition due to post-lexical coherence checking was overruled by a second, facilitatory process. We thought this process to be automatic spreading activation.

But more attractive than either of the above two interpretations of the response pattern in Experiment 2, Chapter I, would be one in terms of a single process. As set forth in Chapter V, our final conception of post-lexical coherence checking can deal with the above results on its own, since it is at the same time facilitatory to related targets and inhibitory to unrelated targets. The facilitation of strong associates was suggested to be totally due to a *yes* output from the message processor to the decision maker, shortening, in lexical decision, the response-selection stage subsequent to target recognition. The inhibition of unrelated targets was thought to be caused by a *no* output from the message processor biasing the decision maker towards a *no* response that has to be overcome, and that causes the response-selection stage to be lengthened. If this interpretation is correct, the neutral response times for the weak associates indicate that the discovery of a weak semantic relationship between words requires more time than that of stronger relationships (in the moderately related pairs) or of the absence of any relationship (in the unrelated pairs), and that it comes too late to influence the duration of the response selection.

Not only the absence of any effect on weak associates, but also the null-effect for mediated targets (Chapter II, Experiments 1 and 2) that are indirectly related to their prime via an implicit word association to the prime can be explained in this way. Neither relatedness nor unrelatedness is obvious in these pairs, and, consequently, the message processor does not send off its output in time to bias the decision maker. Furthermore, this post-lexical process may explain the null-effect for targets that are not given as word associates to the prime in an association test, but that are nevertheless semantically related to their primes (e.g., *grass-hair*; Hudson, de Groot & Thomassen, Note 1). All in all, it appears that post-lexical coherence checking provides a relatively simple explanation for many of the data obtained in lexical-decision experiments.

Beyond our own results, the following example illustrates how the acceptance of this post-lexical process questions current interpretations of 'priming' effects in lexical decision. Fischler (1977) found that the lexical-decision time for the only prime-related target among otherwise unrelated targets was shorter than those to unrelated targets. No neutral prime-target pairs had been included in his set of materials. Fischler only considered automatic spreading activation and prime-induced attentional processing as priming processes, and concluded that, since the subjects were not encouraged to use the attentional strategy, automatic spreading activation alone must have caused the facilitation for the prime-related target. This finding has been widely accepted as support for automatic spreading activation (indeed, we have, in this thesis, also referred to it as evidence of such a process). But the current acceptance of post-lexical coherence checking throws doubt on this interpretation, since it shows that automatic spreading activation is not the only process capable of causing facilitation in situations that discourage the subjects from using prime-induced attentional processing. In fact, since post-lexical coherence checking can both be facilitatory to related targets and inhibitory to unrelated targets, it is not at all certain that the difference between the response times to related and unrelated targets in Fischer's experiment is due to facilitation of related targets; it may also be that this difference is composed of both facilitation and inhibition, or that it is solely due to inhibition of unrelated targets. Since no neutral condition was included in his experiment, this question cannot be answered.

Although post-lexical coherence checking on its own can in principle explain *all* priming effects in some lexical-decision experiments, e.g., in the above experiment that included moderate and weak associates (Chapter I, Experiment 2), in other experiments it is still necessary to assume also the workings of one or both of the remaining two priming processes. For instance, it was mentioned above that we found facilitation for prime-related targets in two experiments in which the prime was masked in such a way that the subjects could not report it (Chapter II, Experiments 5 and 6). We have taken automatic spreading activation to be the source of this effect. It is obvious that the subjects cannot engender prime-induced attentional processing when they cannot report the prime, and that therefore this priming process cannot have contributed to the context effects in the masked-prime studies. But the further assumption that also post-lexical coherence checking cannot operate under masked-prime circumstances, and therefore has not contributed to these effects either, is less evident. According to several investigators (Fowler, Wolford, Slade & Tassinary, 1981; Marcel, in press) the effect of a (pattern) mask is to prevent conscious perception of the prime after its graphic (or, in case the stimulus is auditorily presented, the phonetic) properties have been unconsciously perceived. It is imaginable that coherence checking is a fully automatic process that operates on words that have only been perceived at the unconscious level. However, the response times to the unrelated targets in the masked-prime experiments suggest that this is not the case: The unrelated targets in the masked-prime experiments were not inhibited, which they should have been if post-lexical coherence checking had taken place. This suggests that the message processor can only operate on sets of consciously perceived words, and leaves us with the conclusion that automatic spreading activation is the only cause of facilitation in the masked-prime studies. Summing up this line of argument, it appears that prime-induced attentional processing and coherence checking both require that the prime is consciously perceived, whereas for automatic spreading activation unconscious prime perception suffices.

It was set forth above that post-lexical coherence checking on its own can explain the complete pattern of context effects in a number of priming experiments, for instance, in the experiment that compared the effect of a prime on moderately and weakly associated targets (Chapter I, Experiment 2). The present description of the masked-prime experiments serves to illustrate that sometimes the explanation of priming effects necessitates the assumption of the operation of one or both of the remaining two contextual processes. If our final interpretation of the response pattern in Experiment 2, Chapter I, as being caused solely by post-lexical coherence checking is correct, (and having shown, in the masked-prime experiments, that indeed a process such as automatic spreading activation in lexical memory can contribute to priming effects), the question arises why automatic spreading activation has not influenced target processing in that experiment. We think that the answer to this question lies in the strength of the associative connection between prime and target in the related pairs. It may be that automatic activation in lexical memory only spreads to representations of words that are exceptionally strongly related to the prime. This was true for at least one of the two masked-prime experiments (Chapter II, Experiment 5), in which the targets in the related pairs were all very strong primary associates of their primes, with a mean association frequency of 64.5%. This is considerably higher than the association frequency of the targets to the primes in the set of moderate associates in Experiment 2, Chapter I (37.4%).[1] The assumption that automatic activation spreading from a prime word's lexical representation only affects the recognition of targets that are strong associates of the prime moderates the role of this process in the preparation of subsequent word recognition. The role of automatic spreading activation in the priming of word recognition is also mitigated by the main result of Chapter II, namely, that automatic activation in lexical memory does not spread beyond the immediate neighbours of the prime's representation. On the basis of this result a memory structure is proposed consisting of word representations that are much less interlinked than those in classical network models are.

The experiment reported in Chapter IV was run to obtain evidence for prime-induced attentional processing. In this lexical-decision experiment both the SOA of prime and target and the proportion of related prime-target pairs in the set of materials were varied. The latter variable has been found to influence the magnitude of priming effects, and this finding is commonly regarded as support for prime-induced attentional processing. Whereas it is likely that the proportion of related pairs determines whether or not and to what extent the subjects are engaged in prime-induced attentional processing, the SOA determines the *effectivity* of this process. In the experiment reported in Chapter IV we found indeed that the size of the facilitatory effect, but not of the inhibitory effect, was sensitive to manipulation of the proportion related pairs. Since it appeared from the data that this was about equally the case at the shortest SOA (240 msec) as at the two much longer SOAs (540 and 1040 msec), we suggested that prime-induced attentional processing might already be about fully effective with 240-msec SOA. In Chapter III, in which a lexical-decision experiment is presented that explores the influence of SOA on the size of priming effects over a wide range of SOAs, we also come to this conclusion. However, the word-naming data in Chapter V necessitate a revision of this view. It is argued there that by changing from lexical decision to the naming task the effective influence of post-lexical coherence checking is prevented. By doing so we obtained over three SOAs ranging from 240 msec to 1040 msec a considerably larger increase of facilitation (the only priming effect that is investigated in Chapter V) than we did with lexical decision. In the word-naming task this effect increased linearly from 15 msec at the shortest SOA to 66 msec at the longest SOA. In the lexical-decision task the corresponding values were 53 and 73 msec, respectively. Since the effect of automatic spreading activation decreases rapidly over SOAs, and since furthermore post-lexical coherence checking, although operative, cannot influence response times in naming, the increase of the facilitatory effect in this task must be due to (increased effectivity of) prime-induced attentional processing. Therefore, the word-naming data indicated that, contrary to our earlier suggestion, prime-induced attentional processing is *not* yet fully effective at 240-msec SOA. Consequently, the above sensitivity in lexical decision of the facilitatory effect to the proportion manipulation in the 240-msec SOA condition had to be attributed to another process, and we suggested post-lexical coherence checking as the best candidate. Earlier we have inferred that this post-lexical process only operates on word meanings that have been consciously perceived by the subjects. Now that it appears that this process is sensitive to the proportion of related pairs in the set of materials, we can add that it looks as if this process can be controlled by the subjects. However, the fact that post-lexical coherence checking seems to exert an effect under *all* circumstances, also when none of the prime-target pairs in the set of materials is related (Chapter I, Experiment 3; see above) indicates that the amount of control that the subjects have over it is limited.

So far we have shown that neither of the two 'classical' indicators of prime-induced attentional processing, viz., the sensitivity of priming effects to manipulations of the proportion of related word pairs and the presence of inhibition of unrelated targets, provide unambiguous support for such processing, since both phenomena may be due to post-lexical coherence checking as well. If we are to hold on to the notion of prime-induced attentional processing in priming experiments, we need a new source of evidence to support it; a source that, hopefully, does not confound the effects of different processes. At several places in this thesis (Chapters I, III and IV) an analysis of the pseudoword data is provided mainly to fulfil this need.

The current conceptions about the way in which prime-induced attentional processing is enacted predict a systematic difference in processing time for pseudowords that follow non-neutral primes and those following neutral primes. According to the so-called limited-capacity interpretation of such attentional processing, lexical decisions to pseudowords preceded by neutral primes must be shorter than those to pseudowords preceded by non-neutral primes, because, more so than neutral primes, non-neutral primes set off processes that deplete the resources of a limited-capacity system. What actually happens, however, is quite the opposite: *If* a difference is obtained between the two pseudoword conditions (but see Chapter I), responses to pseudowords following neutral primes are found to be *longer* (Chapters III and IV). This finding has led to the assumption (e.g., Neely, 1976) of a predict-and-match strategy by the subjects, who, after having used the prime to direct their attention towards representations of words related to the prime, match these 'expectations' onto the actual target. A successful match biases the subjects towards a *yes* response and an unsuccessful match biases them towards responding *no.* Such a strategy would facilitate both positive lexical decisions to 'expected' word targets and negative decisions to pseudoword targets, but it would inhibit correct *yes* responses to unrelated word targets. Note that this strategy, although the matching part of it may also be enacted post-lexically, is different from the post-lexical biasing strategy set forth above that cannot start until both prime and target have been recognized. The present strategy can start to operate immediately after the prime has been recognized. But whatever way prime-induced attentional processing is enacted, it may be expected, under appropriate SOA conditions, to cause a difference in processing time between the two pseudoword conditions. Conversely, the absence of any such difference under SOA conditions long enough for this process to be effective (e.g., Chapter I, Experiments 2 and 3), may be regarded as indicating that this attentional process is not operative. Such a difference is not predicted by the workings of post-lexical coherence checking, since this process requires the input of (at least) two *word meanings*. In short, we regard the facilitation of pseudowords preceded by non-neutral primes as indicative of prime-induced attentional processing. Whether or not such a strategy is used presumably depends upon the associative strength between the words in related prime-target pairs (which is considerably larger in the experiments reported in Chapters III and IV than in those reported in Chapter I), and upon the proportion of these pairs among the set of experimental materials.

It was mentioned above that prime-induced attentional processing is presumably a true (pre-lexical) priming process that prepares the recognition of

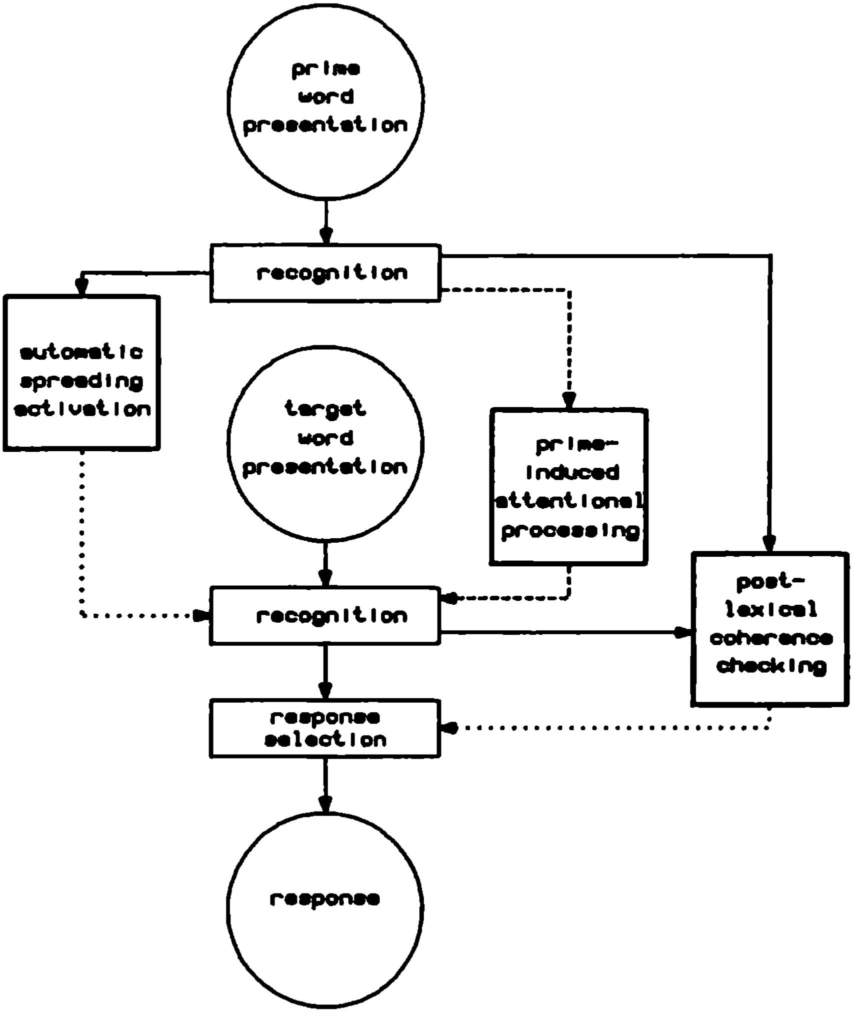

Figure 1. Schematic representation of the processes by which context can influence performance in word recognition tasks. The three different context processes are represented by the bold-faced square boxes. The vertical dimension gives an approximate indication of the time course of events. Solid lines denote the unconditional nature of automatic spreading activation and of post-lexical coherence checking. Dotted lines indicate that processes may not actually affect performance. Dashed lines suggest the optionality of prime-induced attentional processing.

the target. The present predict-and-match view of this process suggests that it might just as well affect the decision stage subsequent to word recognition.

Table 1

	required depth of prime processing	automatic vs. controlled processing	facili- tation	inhibi- tion
automatic spreading activation	unconscious	automatic	yes	no
prime-induced attentional processing	conscious	controlled	yes	yes
post-lexical coherence checking	conscious	automatic but controllable	yes	yes

However, the true priming nature of prime-induced attentional processing is suggested by the word-naming data of Chapter V. It is argued there that in word naming the connection between target recognition and response is much more straightforward than in lexical decision and presumably not influenced by post-lexical coherence checking that biases the decision maker. It is equally probable that in word naming the present predict-and-match strategy also cannot be executed fast enough to bias the decision maker post-lexically. We therefore think that the facilitatory effect of a related prime that is observed in the word-naming data in Chapter V is a genuine pre-lexical priming effect. It is mentioned there that the effect of automatic spreading activation decreases over the range of SOAs being tested. Yet, the facilitation increases over SOAs, prompting the conclusion that prime-induced attentional processing must cause this increase, and that, consequently, this process must influence word recognition per se. Of course, it remains possible that, in lexical decision, prime-induced attentional processing, on top of affecting actual word recognition, *also* affects post-lexical response selection.

Figure 1 and Table 1 sum up the exposition presented in this chapter. Figure 1 schematically shows the three context processes (squares) in relation to the input and output stages that can be distinguished in primed word-recognition tasks (circles), and to the processing stages of prime and target (rectangles). The solid arrows feeding into the boxes representing automatic spreading activation and post-lexical coherence checking indicate the unconditional, automatic nature of these processes, whereas the dashed line feeding into the box that represents prime-induced attentional processing suggests its optional, attentional character. The arrows leaving the boxes of the two unconditional processes are dotted in order to indicate that these processes may not actually affect performance. For instance, if automatic spreading activation is to influence target recognition, the prime word and target word should be related, and relatively strongly so. Post-lexical coherence checking only seems to affect response times to targets that can be determined as related or unrelated to the prime in time to influence response selection. The dashed line leaving the box representing prime-induced attentional processing is also meant to suggest that this optional process, even if it is operative, is not always effective. As was argued above, the effectivity of this process depends upon the SOA of prime and target. Of course, this is also the case for automatic spreading activation. But, with respect to their effectivity, these two processes differ from one another in that under appropriate SOA conditions automatic spreading activation may still not influence target recognition (for instance, if an unrelated or too weakly related word is presented as target), whereas, again under appropriate SOA conditions, prime-induced attentional processing will always affect response times. Depending upon whether or not the target is among the expected set, the effect of this process on target processing is facilitatory or inhibitory. In order to suggest this difference between automatic spreading activation (and, for that matter, post-lexical coherence checking) on the one hand, and prime-induced attentional processing on the other, the arrows leaving their boxes are distinguished.

The first column of Table 1 shows the level of prime processing that is minimally required by each of the three contextual processes if it is to operate. The second column distinguishes the three processes with respect to their controllability by the subjects. The description 'automatic but controllable' for post-lexical coherence checking indicates that this process takes place even when the set of materials does not contain any related prime-target pair (automatic), but nevertheless appears to be influenced by manipulations of the proportion of related pairs in the stimulus set (controllable). The third and fourth columns point out whether each single contextual process can cause facilitation (for related targets), inhibition (for unrelated targets), or both.

REFERENCE NOTES

1. Hudson, P.T.W., de Groot, A.M.B., & Thomassen, A.J.W.M. Semantic and associative facilitation in lexical decision. In preparation.

REFERENCES

Becker, C.A. Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory and Cognition*, 1980, *8*, 493-512.

De Groot, A.M.B. *Mondelinge Woordassociatie Normen: 100 Woordassociaties op 460 Nederlandse Zelfstandige Naamwoorden*. Lisse, The Netherlands: Swets & Zeitlinger, 1980.

Fischler, I. Associative facilitation without expectancy in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, *3*, 18-26.

Forster, K.I. Priming and the effects of sentence and lexical contexts on naming time: Evidence for autonomous lexical processing. *Quarterly Journal of Experimental Psychology*, 1981, *33A*, 465-495.

Fowler, C.A., Wolford, G., Slade, R., & Tassinary, L. Lexical access with and without awareness. *Journal of Experimental Psychology: General*, 1981, *110*, 341-362.

Goodman, K.S. Reading: A psycholinguistic guessing game. In H. Singer & R. Ruddell (Eds.), *Theoretical models and processes of reading*. Newark, Del.: International Reading Association, 1976. 2nd. ed.

Marcel, A. Conscious and unconscious reading: The effects of visual masking on word perception. *Cognitive Psychology*, in press.

Neely, J.H. Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes. *Memory and Cognition*, 1976, *4*, 648-654.

Perfetti, C.A., Goldman, S.R., & Hogaboam, T.W. Reading skill and the identification of words in discourse context. *Memory and Cognition*, 1979, *7*, 273-282.

Posner, M.I., & Snyder, C.R.R. Attention and cognitive control. In R.L. Solso (Ed.), *Information processing and cognition: The Loyola symposium*. Hillsdale, N.J.: Erlbaum, 1975.

Smith, F. *Understanding Reading*. New York: Holt, Rinehart, & Winston, 1971.

Stanovich, K.E. Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly*, 1980, *16*, 32-71.

Stanovich, K.E., & West, R.F. Mechanisms of sentence context effects in reading: Automatic activation and conscious attention. *Memory and Cognition*, 1979, *7*, 77-85.

Stanovich, K.E., & West, R.F. The effect of sentence context on ongoing word recognition: Tests of a two-process theory. *Journal of Experimental Psychology: Human Perception and Performance*, 1981, *7*, 658-672.

Stanovich, K.E., West, R.F., & Feeman, D.J. A longitudinal study of sentence context effects in second-grade children: Tests of an interactive-compensatory model. *Journal of Experimental Child Psychology*, 1981, *32*, 185-199.

West, R.F., & Stanovich, K.E. Automatic contextual facilitation in readers of three ages. *Child Development*, 1978, *49*, 717-727.

West, R.F., & Stanovich, K.E. Source of inhibition in experiments on the effect of sentence context on word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 1982, *5*, 385-399.

FOOTNOTE

[1]The data of the second masked-prime experiment that includes related word pairs among its experimental materials (Chapter II, Experiment 6) appears to defy this interpretation. According to the association norms that we have used (De Groot, 1980) the overall associative strength between primes and targets within the related pairs in this experiment was very low. Nevertheless facilitation is observed for the related targets, which, again, must be attributed to automatic spreading activation. We think, however, that our association norms largely underestimate the associative strength within the related word pairs in Experiment 6, Chapter II. In these pairs all primes are nouns and all targets are verb-infinitives. In our association norms *all* 460 stimulus words are nouns. All of the subjects who provided the association-norm data had been given 230 nouns as stimulus words. It is very plausible that, under these circumstances, the subjects are strongly biased towards providing nouns as word associations to the stimulus words. Therefore, the associative strength between the primes and targets within the related pairs in Experiment 6, Chapter II, is likely to be largely underestimated. Indeed this is suggested by a glance at the materials (see Appendix B, Chapter II).

HET EFFECT VAN EEN LEXICALE CONTEXT OP VISUELE WOORDHERKENNING

SAMENVATTING

In de experimenten die in dit proefschrift worden gerapporteerd wordt het effect onderzocht van een visueel aangeboden contextstimulus op de herkenning en de verdere verwerking van een tweede stimulus, die eveneens visueel wordt aangeboden. In al deze experimenten op een na werden de contextstimuli gevolgd door letterreeksen (doelstimuli) waarover de proefpersonen moesten beslissen of het woorden of niet-woorden waren. Dergelijke experimenten worden 'lexicale-decisie-experimenten' genoemd. Het resterende experiment bestond uit twee sub-experimenten. Een hiervan was opnieuw een lexicale-decisie-experiment. In het tweede sub-experiment moesten de proefpersonen de doelstimuli, die nu allemaal woorden waren, hardop lezen. We zullen deze taak 'hardop lezen' noemen. Dikwijls wordt in deze beide typen experimenten sneller gereageerd wanneer de contextstimulus en de doelstimulus woorden zijn waartussen een associatieve relatie bestaat (bv. *veulen-paard*) dan wanneer de doelstimulus een woord is dat wordt voorafgegaan door de een of andere neutrale contextstimulus. Onder bepaalde omstandigheden wordt bovendien langzamer gereageerd op woorden die worden voorafgegaan door ongerelateerde woorden (bv. *paard* voorafgegaan door *mes*) dan op woorden die volgen op een neutrale contextstimulus. In het onderhavige onderzoek werd geprobeerd om de condities te specificeren waaronder deze contexteffecten optreden en om inzicht te verschaffen in de processen die eraan ten grondslag liggen en de geheugenstructuur waarop ze opereren. Het is nauw verwant aan onderzoek naar de invloed van onvolledige zinnen op de visuele herkenning van later aangeboden woorden. Dergelijke studies, en in zekere mate ook de onderhavige onderzoeken waarin losse

woorden als contextstimulus worden gebruikt, kunnen verduidelijken hoe bij het lezen van teksten gebruik wordt gemaakt van contextuele informatie.

In dit proefschrift wordt verondersteld dat er drie processen ten grondslag liggen aan bovengenoemde contexteffecten, nl. (i) automatisch spreidende activatie in het mentale lexicon, (ii) door de context geïnduceerde aandachtsturing, en (iii) post-lexicale koppeling van woordbetekenissen. De eerste twee processen beïnvloeden waarschijnlijk, zowel bij lexicale decisie als bij hardop lezen, de herkenning van de doelstimulus als woord, terwijl het derde opereert op groepen van minimaal twee woordbetekenissen en pas op gang komt nadat zowel de contextstimulus als de doelstimulus als woord zijn herkend. Het beïnvloedt vermoedelijk de duur van het stadium van responsie-selectie bij lexicale decisie waarin de woordherkenning van de doelstimulus wordt vertaald in een *ja*-responsie, maar heeft geen effect op het post-lexicale stadium bij hardop lezen. Alvorens de inhoud samen te vatten van de zes hoofdstukken waaruit dit proefschrift bestaat, zullen we eerst in het kort de werking van deze drie contextprocessen beschrijven.

Automatisch spreidende activatie in het mentale lexicon ontstaat wanneer een woord, bijvoorbeeld het contextwoord, contact maakt met zijn representatie in dit lexicon. De activatie die als gevolg daarvan in deze representatie ontstaat, spreidt zich uit naar 'naburige' woordrepresentaties. Als de organisatie van het mentale lexicon associatieve woordverwantschap weerspiegelt, zodat de representaties van associatief gerelateerde woorden dicht bij elkaar liggen, dan zal de geheugenlocatie die in eerste instantie wordt geactiveerd zijn activatie doorgeven aan de representaties van woorden die associatief gerelateerd zijn aan het contextwoord. Wanneer vervolgens als doelstimulus een woord wordt aangeboden dat correspondeert met een van deze 'voorbewerkte' geheugenrepresentaties, dan zal het relatief snel worden herkend. Als echter een doelwoord wordt aangeboden dat in het mentale lexicon niet door een van deze voorbewerkte geheugenlocaties wordt vertegenwoordigd, dan zal zijn herkenning geen invloed ondervinden, noch positief, noch negatief, van de aanbieding van het voorafgaande contextwoord en de daarop volgende activatiegolf in het mentale lexicon. Andere kenmerken van automatisch spreidende activatie zijn dat deze zich, zoals haar naam reeds aangeeft, automatisch voltrekt, d.w.z. dat zij geen aandacht vereist, en dat zij snel tot stand komt. Bovendien impliceert het automatische karakter van dit proces dat het *altijd* optreedt en niet kan worden voorkomen.

Het tweede proces door middel waarvan een contextwoord de woordherkenning van een latere doelstimulus kan beïnvloeden is context-geïnduceerde aandachtsturing. Dit proces houdt in dat de proefpersonen het contextwoord gebruiken om hun aandacht te richten op de geheugenrepresentaties van een of meer woorden (m.a.w. om te *denken* aan een of meer woorden) *voordat* de doelstimulus verschijnt. Als een van deze 'verwachte' woorden vervolgens als doelstimulus wordt aangeboden zal zijn herkenning gefaciliteerd worden. Maar als de doelstimulus een onverwacht woord is, zal zijn herkenning belemmerd worden. Dit is een gevolg van het feit dat de capaciteit van de aandacht beperkt is. In dit opzicht verschilt context-geïnduceerde aandachtsturing van automatisch spreidende activatie, die slechts de herkenning van bepaalde woorden kan faciliteren zonder de herkenning van andere te inhiberen. Verdere verschillen tussen deze twee processen zijn dat het eerstgenoemde zich in tegenstelling tot het tweede traag ontwikkelt en aandacht vereist. Bovendien is context-geïnduceerde aandachtsturing, anders dan automatisch spreidende activatie, een voorwaardelijk proces waarvan het optreden onder meer afhankelijk is van bepaalde kenmerken van het stimulusmateriaal.

Onder het derde contextproces, de post-lexicale koppeling van woordbetekenissen, verstaan we de neiging van de proefpersonen om te zoeken naar een verband tussen de betekenissen van contextwoord en doelwoord *nadat* beide zijn herkend. De duur van het stadium van responsie-selectie bij lexicale decisie kan beïnvloed worden door de uitkomst van dit contextproces: als de contextstimulus en de doelstimulus woorden zijn met een verwante betekenis, en als deze verwantschap bovendien wordt ontdekt *voordat* de woordherkenning van de doelstimulus is omgezet in een *ja*-decisie, dan verkort het vinden van deze betekenisverwantschap het stadium van responsie-selectie. Als daarentegen de contextstimulus en de doelstimulus ongerelateerde woorden zijn en als deze ongerelateerdheid wordt ontdekt *voordat* de *ja*-decisie is geselecteerd, dan zal het ontdekken van ongerelateerdheid het stadium van responsie-selectie verlengen.

In *Hoofdstuk I* wordt het effect van de associatieve sterkte tussen contextwoord en doelwoord onderzocht. Lexicale decisies op middelmatig verwante doelwoorden (d.w.z. woorden die in een vrije-woordassociatie-test door ongeveer 40% van de proefpersonen als woordassociatie op het contextwoord worden gegeven) werden gefaciliteerd ten opzichte van doelwoorden die werden aangeboden na een neutrale contextstimulus. Bovendien werden doelwoorden die ongerelateerd waren aan het voorafgaande contextwoord geïnhibeerd. Erg zwakke woordassociaties van het contextwoord (met een associatieve sterkte van minder dan 3%) werden noch gefaciliteerd noch geïnhibeerd. Deze resultaten kunnen op verschillende manieren worden verklaard. De zuinigste interpretatie is echter dat zij worden veroorzaakt door slechts een van de drie contextprocessen die boven werden genoemd, namelijk post-lexicale koppeling van woordbetekenissen. De proefpersonen in de experimenten van Hoofdstuk I gebruikten waarschijnlijk de strategie van context-geïnduceerde aandachtsturing niet omdat deze niet bevorderd werd door de samenstelling van het stimulusmateriaal. Automatisch spreidende activatie in het mentale lexicon zal, omdat deze nooit kan worden voorkomen, daarentegen wel opgetreden zijn als gevolg van de aanbieding van het contextwoord. Het uitblijven van een effect van laatstgenoemd proces wijst er daarom op dat dit proces niet effectief was in de betreffende experimenten. Op zijn beurt wijst deze ineffectiviteit erop dat de representaties van de middelmatig en zwak gerelateerde doelwoorden die in die experimenten werden aangeboden niet werden bereikt door de zich spreidende activatie, en dat de structuur van het mentale lexicon wel eens minder hecht zou kunnen zijn dan vaak wordt aangenomen. Behalve met het bestuderen van het effect van de associatieve sterkte tussen contextwoord en doelwoord, houden we ons in Hoofdstuk I ook bezig met het evalueren van een aantal neutrale contextstimuli. De uitkomst hiervan is dat het niet-talige karakter van een neutrale contextstimulus die uit een reeks *Xen* bestaat, de responsies op de daarna aangeboden doelstimuli lijkt te vertragen.

In *Hoofdstuk II* houden we ons voornamelijk bezig met automatisch spreidende activatie in het mentale lexicon. De associatieve sterkte binnen de gerelateerde woordparen die werden aangeboden in (een aantal van) de experimenten in dit hoofdstuk was aanzienlijk groter dan die binnen de gerelateerde woordparen in de experimenten van Hoofdstuk I. We mogen daarom aannemen dat een contextstimulus, als hij al ooit de verwerking van een later doelwoord beïnvloedt door middel van automatisch spreidende activatie, dit dan in elk geval zal doen binnen deze sterk gerelateerde paren. In het bijzonder wordt in Hoofdstuk II het optreden van 'voortgezette' spreidende activatie onderzocht, d.w.z. dat de activatiegolf zich niet slechts beweegt tot aan de representaties van directe woordassociaties van het contextwoord, maar zich ook nog voortzet naar woordrepresentaties die een stap verder weg liggen in het geheugennetwerk (bv. van de locatie van *stier* via die van *koe* naar die van *melk*). De resultaten wijzen erop dat activatiespreiding stopt wanneer zij de geheugenlocaties bereikt heeft die onmiddellijk grenzen aan de representatie van het contextwoord. Deze uitkomst verschaft ons een nieuwe visie op de structuur van het mentale lexicon, waarbij wordt uitgegaan van meervoudige opslag van woorden in twee typen geheugenrepresentaties die kwalitatief verschillend zijn.

Om een eenduidig antwoord te krijgen op de vraag naar het optreden van voortgezette activatiespreiding, werden de contextwoorden in drie van de experimenten in Hoofdstuk II zodanig 'gemaskeerd' dat zij niet bewust konden worden waargenomen door de proefpersonen. Op die manier werd het optreden voorkomen van context-geïnduceerde aandachtsturing en post-lexicale koppeling van woordbetekenissen, die beide slechts werkzaam kunnen zijn als de contextstimulus minstens zo lang wordt aangeboden als nodig is om hem te kunnen identificeren. De invloed van de contextstimulus op de herkenning van het doelwoord kon daarom worden toegeschreven aan automatisch spreidende activatie in het mentale lexicon.

De effectiviteit van zowel automatisch spreidende activatie als van context-geïnduceerde aandachtsturing, en dientengevolge de grootte van de contexteffecten, zijn in hoge mate afhankelijk van de tijdsduur tussen de aanbiedingsmomenten van contextstimulus en doelstimulus. Het derde contextproces, post-lexicale koppeling van woordbetekenissen, is veel minder afhankelijk van deze tijdsduur, die we 'SOA' zullen noemen (het acroniem voor de engelse term voor deze tijdsduur: stimulus-onset asynchrony). Bij elke SOA kan dit laatste proces plaatsvinden wanneer zowel contextwoord als doelwoord lang genoeg worden aangeboden om geïdentificeerd te kunnen worden. In *Hoofdstuk III* wordt verslag gedaan van een studie waarin de ontwikkeling werd onderzocht van contexteffecten bij elf SOAs, variërend tussen 100 en 1240 msec. Het faciliterende effect van een gerelateerd contextwoord werd groter naarmate de SOA toenam, terwijl het inhiberende effect van een ongerelateerd contextwoord nagenoeg constant bleef. Alleen in de conditie met de langste SOA weken de resultaten af van dit algemene beeld.

Onder gunstige omstandigheden leveren alle drie de contextprocessen een bijdrage aan de facilitatie van gerelateerde doelwoorden. Bovendien veroorzaken twee van deze processen, met name context-geïnduceerde aandachtsturing en post-lexicale koppeling van woordbetekenissen, inhibitie van ongerelateerde doelwoorden. Het is daarom over het algemeen moeilijk vast te stellen hoeveel elk van de drie contextprocessen afzonderlijk bijdraagt aan de totale hoeveelheden facilitatie en inhibitie die wordt gevonden in een bepaalde conditie. In Hoofdstuk III is een analyse van de responsies op de doelstimuli die geen woorden vormen (bv. *plink*) opgenomen om toch conclusies te kunnen trekken over de relatieve bijdragen van de verschillende contextprocessen.

In *Hoofdstuk IV* wordt een experiment gerapporteerd waarin zowel de SOA van contextstimulus en doelstimulus (drie niveaus) als de proportie gerelateerde paren in het experimentele materiaal (vier niveaus) systematisch werden gevarieerd. De gelijktijdige manipulatie van deze twee variabelen verschaft ons met name veel informatie over de bijdrage van context-geïnduceerde aandachtsturing aan contexteffecten. Terwijl de factor proportie vermoedelijk bepaalt of de proefpersonen deze strategie al dan niet gebruiken, bepaalt de SOA van contextstimulus en doelstimulus in welke mate zij effectief is. Beide variabelen bleken de grootte van de contexteffecten te beïnvloeden. Bovendien wezen de gegevens erop dat deze twee variabelen hun invloed niet onafhankelijk van elkaar uitoefenen: de grootte van het contexteffect was alleen afhankelijk van de SOA wanneer er relatief veel gerelateerde woordparen in de materiaalset voorkwamen. Er werd daarentegen een effect van proportie waargenomen in alle SOA-condities, ofschoon dit effect groter was bij de langste SOA dan bij de twee kortere SOAs. In Hoofdstuk IV wordt aangenomen dat dit resultaat erop wijst dat context-geïnduceerde aandachtsturing bij erg korte SOAs al effect sorteert. Deze interpretatie wordt in Hoofdstuk V echter in twijfel getrokken. In dat hoofdstuk wordt het idee geopperd dat niet alleen context-geïnduceerde aandachtsturing, maar ook post-lexicale koppeling van woordbetekenissen gevoelig is voor het manipuleren van de factor proportie, en dat laatstgenoemd proces verantwoordelijk is voor het effect van proportie in de kortste SOA-conditie.

In *Hoofdstuk V* wordt het effect vergeleken van een gerelateerde contextstimulus op het verwerken van de doelstimulus bij lexicale decisie enerzijds en hardop lezen anderzijds. Anders dan in de overige experimenten in dit proefschrift werden in het materiaal van dit experiment geen ongerelateerde woordparen opgenomen. Er wordt in dit hoofdstuk beargumenteerd dat de uitkomst van post-lexicale koppeling van woordbetekenissen wel van invloed kan zijn op de responsietijden bij lexicale decisie, maar niet bij hardop lezen. Automatisch spreidende activatie in het mentale lexicon en context-geïnduceerde aandachtsturing kunnen daarentegen de responsietijden beïnvloeden in beide taken. We mogen dan ook verwachten dat contexteffecten bij lexicale decisie groter zijn dan bij hardop lezen. Dit bleek inderdaad het geval. Ook werd in het experiment van Hoofdstuk V de SOA van contextstimulus en doelstimulus systematisch gevarieerd. Deze manipulatie was enkel van invloed op de grootte van het facilitatie-effect bij hardop lezen. In de lexicale-decisie-taak werd al relatief veel facilitatie waargenomen bij de kortste SOA en werd het effect niet groter naarmate de SOA toenam. Bij hardop lezen nam de facilitatie lineair toe met langer wordende SOAs. In de conditie met de langste SOA was het facilitatie-effect ongeveer even groot in beide taken. Aangenomen werd dat de groei van het facilitatie-effect met toenemende

SOAs bij hardop lezen werd veroorzaakt door verhoogde effectiviteit van context-geïnduceerde aandachtsturing, en dat deze groei bij lexicale decisie verborgen blijft onder het relatief grote effect van post-lexicale koppeling van woordbetekenissen dat al bij korte SOAs optreedt.

Hoofdstuk VI is een bespreking van alle experimenten in de voorafgaande hoofdstukken. Hierin wordt geconcludeerd dat de contexteffecten die in deze experimenten werden waargenomen op doeltreffende wijze kunnen worden verklaard door middel van automatisch spreidende activatie, context-geinduceerde aandachtsturing en post-lexicale koppeling van woordbetekenissen.

CURRICULUM VITAE

Antoinette Maria Birgitta de Groot werd geboren op 24 december 1951 te Uden. Daar bezocht zij twee jaar MULO en vervolgens het gymnasium. In 1972 behaalde zij het diploma gymnasium-ß, waarna zij Nederlandse Taal- en Letterkunde studeerde aan de Katholieke Universiteit Nijmegen. Na het kandidaatsexamen in 1975 koos zij Algemene Taalwetenschap als doctoraalstudie met als hoofdrichting psycholinguïstiek en als bijvakken onderwijskunde en Nederlands. In december 1977 legde zij het doctoraalexamen af. Van maart 1978 tot januari 1979 verrichtte zij, gesubsidieerd door de Nederlandse Organisatie voor Zuiver Wetenschappelijk Onderzoek (Z.W.O.), onderzoek naar spraakperceptie aan de Applied Psychology Unit te Cambridge, Engeland. Van februari 1979 tot januari 1983 was zij als wetenschappelijk medewerkster verbonden aan de Vakgroep Psychologische Funktieleer van de Katholieke Universiteit Nijmegen ten behoeve van het door Z.W.O. gesubsidieerde onderzoeksprojekt: 'Contextfactoren bij visuele woordherkenning: het effect van priming.' Vanaf januari 1983 is zij tijdelijk en op part-time basis als stafmedewerkster verbonden aan het bureau van de Nederlandse Stichting voor Psychonomie te 's-Gravenhage.

STELLINGEN

1. Het gebruik van de lexicale-decisie-taak voor het meten van het effect van een woordcontext op de woordherkenning heeft als nadeel dat lexicale-decisie-tijden op doelwoorden voorafgegaan door een context mede worden beïnvloed door een proces dat pas op gang komt nadat de doelstimulus als woord is herkend.

   Dit proefschrift.

2. Goede lezers kunnen beter dan minder goede lezers woorden verderop in een tekst voorspellen. Dit wordt vaak gezien als een bevestiging van de onjuiste opvatting dat zij voor woordherkenning meer gebruik maken van de context en juist daardoor goede lezers zijn

   Stanovich, K E , West, R F , & Feeman, D J A longitudinal study of sentence context effects in second-grade children: Tests of an interactive-compensatory model. *Journal of Experimental Child Psychology*, 1981, *32*, 185-199.

3 De verschuiving van overwegend syntagmatische naar overwegend paradigmatische woordassociaties bij kinderen van zes a zeven jaar heeft vermoedelijk als oorzaak dat het taalonderwijs hun linguistisch bewustzijn ontwikkelt en dat zij daardoor woorden leren beschouwen als metatalige objecten in plaats van ze uitsluitend als communicatiemiddel te gebruiken.

   De Groot, A.M.B., *Mondelinge woordassociatie normen: 100 woordassociaties op 460 Nederlandse zelfstandige naamwoorden* Lisse· Swets & Zeitlinger, 1980

4 Het verschijnsel genoemd in de vorige stelling en de daarvoor geopperde verklaring geeft aanleiding tot de algemene vraag in hoeverre de ontwikkeling van het linguïstisch bewustzijn afhankelijk is van op taalreflectie gericht onderwijs.

5 De belangrijkste aspecten van leerbaarheid en bruikbaarheid van een spelling zijn minder een aangelegenheid voor de taalkunde dan voor de psychologie

6. Het nut van het op grote schaal invoeren van pictogrammen als aanwijzingen voor gedragingen wordt beperkt door het feit dat er afspraken over hun betekenis gemaakt moeten worden.

7. De vakwetenschappelijke opleiding van de leraar Nederlands zou aanmerkelijk aan effectiviteit kunnen winnen wanneer docenten Nederlands aan lerarenopleidingen meer zouden stilstaan bij wat zij zelf als leerling niet van grammatica begrepen hebben

8 De selectie van kandidaten voor wetenschappelijke functies moet minder worden afgestemd op inhoudelijke aspecten van functieprofielen dan op algemene kwalificaties van de kandidaten die kunnen worden afgeleid uit hun specifieke antecedenten

9 Informatie over doodsoorzaken in publieke overlijdensberichten maakt inbreuk op de intimiteit van het levenseinde

10 Een financiele sanctie op de eerste dag van ziekteverzuim is een bedreiging voor de volksgezondheid

Deze stellingen horen bij het proefschrift
A M B de Groot, *Lexical-context effects in visual word recognition*.
Katholieke Universiteit Nijmegen, 28 april 1983, 16 00 uur