1985

Semantic priming effects the roles of generation processes and association

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SEMANTIC PRIMING EFFECTS: THE ROLES OF GENERATION PROCESSES AND ASSOCIATION

by

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Honours B.A., Carleton University, 1979

THESIS

submitted to the Department of Psychology
in partial fulfillment of the requirements
for the Master of Arts degree
Wilfrid Laurier University
1985

Acknowledgements

First, I would like to express my appreciation to Svein Vik for writing the extensive computer programmes which allowed us to convert 94,000 records of data into easily edited files. His assistance made the data analysis one of the most enjoyable aspects of this endeavour.

Ellie Muir provided invaluable assistance in the word processing of the final document. She kept trying to convince me that it was a "learning" experience for her. Thanks Ellie, for your help and your support.

Thanks to Dr. Keith Horton, my advisor, for his direction and insight; and to my committee members Drs. Davelaar and Gebotys for their many helpful suggestions.

Finally, I would like to thank all the friends who helped me survive this undertaking. To everyone in Montreal, Toronto (especially Ludmilla), Ottawa and Waterloo: Thanks for caring and, still being there after all this time!

Дорогие Мама, Папа, и Бабушка:

Сердечное спасибо за Вашу любовь и чуткое внимание, в особенности за эти три года. Вы были всегда со мной, когда мне было так трудно. С вашей помощью и вниманием, я могла окончить эту работу.

Целую крепко,

Алёна

Abstract

Four groups of participants were tested in order to assess Blaxton and Neely's (1983) suggestion that the nature of the processing (reading or generating) carried out on the primes and targets determines the degree of priming (facilitation or inhibition). Reading and generating were directly manipulated by the inclusion of a semantic adequacy check (Donaldson & Bass, 1980) designed to augment the "automatic" process of reading, and a speeded generation task designed to limit this check, thus equating generating to reading. Associate items were included to assess Lupker's (1984) suggestion that the association between primes and targets (not their semantic relatedness) determines the facilitatory effects in "pre-access" processes such as reading, while semantic relatedness is instrumental in the priming effects of "post-access" processes such as generating.

While Blaxton and Neely's (1983) finding of inhibition from four semantic primes was replicated in the generate-generate group, the facilitatory effect of one semantic prime was not reliable. The read-recheck-generate group which was conceptually equivalent demonstrated neither facilitatory nor inhibitory effects of semantic primes, supporting Brown's (1981) conclusion that self-generation of related exemplars is necessary for inhibition to occur. There was however, no evidence of a facilitatory effect of reading semantic primes. The read-read and speeded-generate-read groups had no significant facilitation effects. The results of the recognition test, which served as a manipulation check, revealed that the two generate groups had superior retention to the two read groups, as predicted.

Contrary to predictions, associate items produced inhibition in the generate-generate group, and no facilitating effects in the read-read group. These results were interpreted in terms of procedural and item selection factors.

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The rapid expansion and popularization of computer technology in the 1950s created new approaches to the understanding of human cognitive processing. The computer became a model for human information processing. Quillian (1968) described a theory in which human semantic memory structure and cognitive processes were explained in such terms.

Quillian's model assumed that semantic memory was organized as a network. This network consisted of a large set of nodes which represented concepts. A concept was defined as the information an individual maintained about certain things. Properties of the concept were represented as labelled relational links from a specific node to other concept nodes. From each of the nodes linked to a given node, there were links to other concept nodes, and from each of these in turn to still others. These links had to be complex enough to represent any relation between two concepts: relations which specified class membership or property relations which defined the properties of the concept (Collins & Loftus, 1975).

Quillian suggested that a memory search between concepts involved a parallel tracing along the links from the node of each concept specified by the input words. The words could be a sentence fragment or stimuli (words) in an experimental task. The spread of activation expanded progressively, from the first linked nodes to all those nodes linked to each of the first nodes. At each node reached in this process, an activation tag was left that specified the starting node and its immediate predecessor. An intersection was created when two activation tags from different starting nodes converged. By following the tags back to both starting nodes, the path that led to the intersection could be reconstructed.

An important postulate of the spreading activation theory involved the effects of semantic priming. Priming is the process by which concepts and their meaning in semantic memory are activated. A significant decrease in reaction time (RT) to the second stimulus constitutes the typical evidence for priming.

According to Quillian, priming involved the same tracing process as memory search. When a concept is primed, activation tags are spread by tracing an expanding set of links in the network out to some unspecified depth. When another concept is subsequently presented, it makes contact with one of the tags left earlier. As such, priming a node such as "red" will prime the links involving the relation "colour" throughout the network (Loftus & Loftus, 1974).

Collins and Loftus (1975) extended Quillian's theory by adding further processing and structural assumptions. It is assumed that activation spreads out along the paths of the network with decreasing strength when processing a concept. Only one concept can be actively processed at a time, implying that activation can start out at one node at a time. However, it continues in parallel from other nodes that are encountered as it spreads out from the node of origin. Both time and intervening activity decrease activation (see Collins & Loftus, 1975).

Quillian also proposed that the semantic network is organized along lines of semantic similarity and that the strength of the relation between concepts is dependent on the number of common properties. The greater the number of links between the nodes, the more closely the related concepts are thought to be. As such, semantic relatedness is based on an aggregate of the interconnections between two concepts.

Theoretical predictions of the spreading activation model have received empirical support. Freedman and Loftus (1971) designed a study to provide more information about the retrieval mechanism, with emphasis on spreading activation. They required subjects to name a category instance that began with a given letter or was characterized by a given adjective. For example, subjects might have been asked to name a fruit that began with the letter A or a fruit that was red. Presentation of the category label varied across different trials such that it was either shown before or after the letter or adjective cue. Hence, this was a priming experiment in that one concept was activated before the other. Reaction time was measured from the onset of the second stimulus. Results demonstrated that subjects were faster when the category label was given first than when it followed the letter or the adjective cue.

This finding can be explained by the spreading activation theory. When the category name is presented first, activation spreads to nodes which are closely interlinked with each other, a relatively small number. However, when an adjective or a letter is presented first, the activation spreads to a much wider set of concepts which may not be particularly associated with one another, resulting in relatively little priming. Because priming the category name leads to greater activation of the category instances, these are closer to their threshold of firing. Consequently, it takes less activation and less time to trigger an intersection when the letter or adjective is presented.

More support for the spreading activation model comes from Loftus (1973a) using a different paradigm. Loftus manipulated the frequency (degree of association) of both category exemplars and instance exemplars using four types of category instance pairs: both category and instance were high frequency items (e.g., tree-oak); high frequency category with low frequency instance items (e.g., seafood-shrimp); low frequency category with high frequency instance items (e.g., insect-butterfly); low frequency category and instance items (e.g., cloth-orlon). Instance exemplars were classified as high frequency if at least 70% of the subjects gave the instance in response to the category, and low frequency if fewer than 26% gave the instance in response to the category. Category exemplars (category name given in response to an instance) were classified with the same criterion as instance exemplars. Both category frequency and instance frequency were varied independently to determine the extent to which each variable predicted the speed with which subjects could decide whether a word belonged to a familiar category. Subjects were presented with items consisting of categories and words, and were told to respond "yes" if the word belonged to the category and "no" if it did not. They were required to respond as quickly as possible.

Results indicated that reaction times (RTs) were sensitive to the order of presentation of the instance and the category. When the category preceded the word, high frequency instances were responded to more quickly than low frequency instances. Conversely, when the instance preceded the category, high frequency categories were responded to more quickly than low freequency categories.

The spreading activation theory assumes that production frequency is a measure of the strength of the association from one concept to another. When the first concept (either category or instance exemplar), which is a highly frequent one, invokes the second concept, activation spreads to the second. Thus, when the second concept is presented, it takes less time to reach threshold for an intersection. As such, the amount the first concept primes the second concept determines reaction time (RT).

Meyer and Schvaneveldt (1971) also demonstrated that the presentation of related information prior to retrieval reduces reaction time. They employed a paradigm which required subjects to identify letter strings as pairs of words, nonwords, or a combination of both. In one task, subjects were required to respond "yes" if both strings were words, and otherwise to respond "no". A second task substituted "same" and "different" for responses to the letter strings.

The results of the two experiments revealed a substantial effect of association between pairs of words. The pairs of associated words were judged to be words an average of 85 msec faster than pairs of unassociated words. Similar effects were obtained in the same-different experiment. While these results lent further support to the spreading activation model, Meyer and Schvaneveldt offered an alternate explanation in terms of a location shifting hypothesis. This hypothesis assumed that stored information could be read out of only one memory location at a given instant, that time was required to "shift" readout from one location to another, and that shifting time increased with the distance between locations. Thus, the association effect occurred because shifting to nearby locations was faster than shifting to more distant locations.

However, the location shifting model was not supported by their subsequent findings. Schvaneveldt and Meyer (1973) presented three horizontal strings of letters simultaneously in a vertical array. Stimuli consisted of either three words, or a combination of words and nonwords. The subjects were to respond "yes" if all letter strings were words and "no" otherwise. Reaction time was measured as a function of both the degree of association between words in the stimulus and the position of the words and nonwords in the stimulus display. Schvaneveldt and Meyer (1973) emphasized that both models would assume that the strings of letters were processed serially.

With this assumption, the location shifting model would suggest that degree of association should affect reaction time and that this effect would depend upon the position of the associated words in the display. If the associated words follow each other, they will facilitate retrieval, hence decreasing reaction times. However, there would be no effect of association when the unassociated word was in the middle position. Conversely, the spreading activation model would predict that associated words should facilitate retrieval regardless of the position of the associated word. For negative responses, both models would predict that association should facilitate retrieval and shorten reaction time if a nonword follows two associated words. If the nonword were in either the middle or top position, no effect of association would be seen. As predicted by both models, reaction times were faster when two associated words were displayed above a nonword, but when the nonword appeared in the middle position, there was no effect of association.

Results of the positive responses provided substantial evidence against the location shifting model. While the mean RTs for the positive responses revealed a significant effect of association, the magnitude of the association did not depend upon the position of the unassociated word in the stimulus display. This lent support to the spreading activation model.

Similarly, Loftus (1973b) supplied further evidence for rejection of a location shifting model to explain semantic processing. She postulated that the first presentation of a category increases the accessibility of one or more memory locations, thus facilitating information retrieval upon second presentation of that category. However, this effect is temporary and decays gradually. As such, the facilitatory effect of repeating a category would decrease as the number of intervening items between the two presentations was increased. However, a location shifting model would predict no differences in reaction times with increasing numbers of items between category presentations. This model assumes that a subject reaches a memory location of a second category from the memory location of whichever other category was most recently named. The distances to the categories between memory locations would remain on average, the same.

Subjects were presented with a category label and a letter (e.g., fruit-A) and were required to produce a member of the category that began with the given letter (e.g., apricot). After 0, 1, or 2 intervening trials, subjects were presented with the same category paired with a different letter (fruit-P) and once again were to produce an instance. While facilitation occurred, as seen by shorter reaction times for the second instance of a category than the first instance, the amount of facilitation declined as the number of intervening items between the two categories increased. The aforementioned results all offer firm support for the spreading activation model, while the use of such different paradigms demonstrates its generalizability.

However, Posner and Snyder (1975) argue that spreading activation and location shifting operate in conjunction with each other in information processing. They postulate that an automatic spreading activation process and a limited capacity attentional mechanism (analogous to location shifting) are involved in the retrieval of information from long term memory. Posner and Snyder's theory is quite explicit in specifying the properties of each of the two processes, and how they operate individually and in conjunction with one another (Neely, 1977).

Posner and Snyder (1975) agree with Morton (1970) that verbal long term memory contains logogens, which are memory structures containing information about familiar events. The logogens for semantically related words are assumed to be located closer to one another than semantically unrelated logogens. In the spreading activation process, a stimulus automatically activates its logogen and this activation automatically spreads to adjacent, semantically related logogens only. This automatic spreading activation process is fast acting, unconscious, and does not affect the retrieval of information stored in semantically unrelated logogens to which it has not spread.

Thus, a semantically related priming word will facilitate processing of a target word if the latter is presented before there is a decay of logogen activation produced by the priming word. This facilitation occurs due to a higher activation level in the logogen of the target word.

Similarly, the limited capacity attention mechanism can also facilitate processing with facilitation occurring when attention is accorded to specific logogens. This mechanism is slow acting, requires conscious awareness, and inhibits retrieval of information stored in unattended semantically unrelated logogens. In regards to this retrieval inhibition, the conscious attention mechanism does not inhibit the buildup of activation in unattended logogens, but rather inhibits the readout of information from unattended logogens. As such, the conscious attention mechanism will process a target word faster when it follows a semantically related priming word because the distance that attention must be shifted is shorter between semantically related logogens. Moreover, conscious processing also causes some activation to spread to related logogens. Specifically, if a to-be-remembered stimulus activates an unattended logogen, attention must shift to that logogen to analyze its information. This "location shifting" process is faster when the unattended logogen is highly related to the consciously attended logogen.

Neely (1977) attempted to test the basic assumptions underlying the Posner-Snyder theory to clarify the roles of limited capacity attention and automatic spreading activation in a lexical decision task, a task in which a subject must decide as quickly as possible whether a visually presented letter string is a word or a nonword. Both semantically related and unrelated primes were included to measure the effects of automatic spreading activation. Several variables were manipulated. The first variable involved a Shift-Nonshift manipulation. In the Shift condition, subjects were instructed to shift their attention to exemplars of a category different from that of the prime. In the Nonshift condition, subjects were told to expect exemplars of the category represented by the prime. Prior to presentation of each target letter string which required a lexical decision, the subject saw a neutral stimulus XXX, or the priming words BIRD, BODY, or BUILDING. The neutral stimulus condition served as a baseline for performance in the priming conditions (BIRD, BODY, BUILDING).

To illustrate, subjects were informed that when BIRD was the priming word, they should expect the name of a type of bird as the target (Nonshift condition). However, when the priming words were either BODY or BUILDING, they were expected to shift their attention to expect a target from the other of the two categories (Shift condition). Namely, when the priming word was BODY, they were to expect a target from the category BUILDING and vice versa. With the neutral stimulus XXX, the target would be chosen equally often from the aforementioned semantic categories.

The second variable was whether the target following the prime was an exemplar of the category a subject expected on the basis of the word prime (BIRD-robin) or was an exemplar of an unexpected category (BIRD-arm). The third variable concerned the semantic relatedness (BODY-heart) or unrelatedness (BUILDING-leg) of primes and targets. In addition, the times between prime and target presentations varied between long and short SOAs (stimulus onset asynchrony) to control for the operation of the limited capacity attentional mechanism. If prime and target were separated by a long SOA, the subject would be given enough time to engage the limited capacity attention mechanism. Conversely, a short SOA would not give enough time for a subject to commit attention. The SOAs were 250 (short), 400, 700, and 2000 (long) msec. The critical dependent measure was the lexical decision time on the target words.

Neely's predictions for both automatic spreading activation and limited capacity attention were based upon the following assumptions. Automatic spreading activation would have an effect only when the prime and target were semantically related, and this facilitation would decay unless consciously maintained through rehearsal. Thus, the facilitatory effect of automatic spreading activation would decrease as SOA increased. Neely assumed that the long SOA (2000 msec) was sufficiently long to ensure a complete decay of automatic spreading activation.

Limited capacity attention would produce a facilitatory effect when the target was from an expected category, and an inhibitory effect when the target was from an unexpected category. These effects of limited capacity attention would only occur, however, with increasing SOA, since short SOAs would ensure that the limited capacity attention mechanism would not be functioning. Again, Neely assumed the short SOA (250 msec) to be sufficiently short that the limited capacity attention mechanism would not be functioning.

The various combinations of the variables yielded five conditions. For the two Nonshift prime conditions, the subjects were informed that the target would come from the category specified by the prime (the category was always BIRD). As such, for condition Nonshift-Expected-Related, the prime and the target would be BIRD-robin. For condition Nonshift-Unexpected-Unrelated, the prime-target combination would be BIRD-arm, since the subject was told to expect an exemplar of the category BIRD, but was presented with a target from an unexpected category. In the Shift conditions, subjects were required to shift attention to a category different from that of the prime. In condition Shift-Expected-Unrelated, the target was an exemplar of the expected category, but the prime and target were semantically unrelated (e.g., BODY-door). For the Shift-Unexpected-Unrelated condition, the subject shifted attention based on the prime. However, the target actually presented was from an unexpected category, and was not semantically related to the prime (e.g., BODY-sparrow). As subjects had been informed that the prime BODY would be followed by exemplars from the category parts of a BUILDING, the target "sparrow" would be unexpected. In the final condition, Shift-Unexpected-Related, the target was again an exemplar of a category the subject did not expect based on the prime, but was semantically related to the prime (e.g., BODY-heart). The SOAs between the prime and target letter string varied between 250 and 2,000 msec, with the dependent measure being the time to classify the target string as a word or a nonword.

Predictions for the five experimental conditions were as follows. Facilitation was predicted at all SOAs in condition Nonshift-Expected-Related (BIRD-robin) because the facilitatory effects of limited capacity attention increase as the facilitatory effects of automatic spreading activation dissipate. By contrast, the facilitatory effect in condition Shift-Expected-Unrelated (BODY-door) would start at zero and would increase with increasing SOA until it converged with the facilitatory effect obtained in the former (BIRD-robin) condition. Once both the bird and body logogens were activated, Neely proposed that subjects used the attentional mechanism to maintain activation so that it would not decay during the 2000 msec SOA.

The facilitation obtained in the Nonshift-Expected-Related condition (BIRD-robin) is based on an overlearned automatic association. Namely, robin is a high associate, easily brought to mind when BIRD is the prime. Thus, this overlearned association produces the facilitation for the BIRD-robin trials due to automatic spreading activation at short SOAs. However, no inhibition develops at the short SOA in condition (Nonshift-Unexpected-Unrelated), since there is no involvement of limited capacity attention. The inhibitory effects in conditions Nonshift-Unexpected-Unrelated (BODY-robin) and Shift-Unexpected-Unrelated

(BODY-sparrow) would be equivalent, starting at zero at the short SOA and growing in magnitude with increasing SOAs. Both of these conditions involve the commitment of limited capacity attention, and it is this mechanism which exerts an inhibitory effect.

However, primes in the Shift condition would produce facilitation for Shift-Expected-Unrelated (BODY-door) only if there was an accompanying inhibitory effect for the Shift-Unexpected-Unrelated condition (BODY-sparrow). Facilitation in the Shift-Expected-Unrelated trials (BODY-door) results from subjects' expectancies that a BODY prime will be followed by a "part of a building" target, requiring a shift to the "BUILDING" logogen in memory. Hence, such facilitation must involve the commitment of limited capacity attention. The inhibitory effect for the BODY-sparrow trials occurs because subjects' expectancies which are raised by the prime are not met with the presentation of the target. The target is an unexpected one. As such, the limited capacity attention mechanism once again produces inhibition.

A net facilitation effect would occur at the short SOA in the Shift-Unexpected-Related (BODY-heart) condition due to the automatic spread of activation from the body logogen to the semantically related heart logogen. At the short SOA, there would be insufficient time for limited capacity attention to exert inhibitory effects. However, with increasing SOAs, there would be decay in automatic spreading activation, at which time the limited capacity mechanism would begin to produce inhibition, resulting in a net effect of inhibition at the long SOA.

In sum, facilitation due to automatic spreading activation would occur only at short SOAs, when primes and targets were semantically related. Facilitation for semantically related primes and targets at longer SOAs would occur from the influence of the limited capacity attention mechanism. The effects of limited capacity attention would be evident with increasing SOAs and subject's expectancies of the target words would determine whether the effects would be facilitatory or inhibitory. Thus, when the target was from the expected category, facilitation would result whereas, when the target was from an unexpected category, inhibition would result at the longer SOAs.

Neely's (1977) results confirmed his predictions. For condition Nonshift-Expected-Related, facilitation was obtained at all SOAs. Facilitation in the Shift-Expected-Unrelated condition was not evident at short SOAs but did develop with increasing SOAs, until it converged with the facilitation effect for the Nonshift-Expected-Related condition (700 msec). The Shift-Unexpected-Unrelated and Nonshift-Unexpected-Unrelated conditions produced the same amount of inhibition, with both originating at zero at the 250 msec SOA, and growing with increasing SOAs. At the 400 msec SOA, the Shift-Unexpected-Unrelated condition produced a significant inhibitory effect while Shift-Expected-Unrelated produced a nonsignificant effect of facilitation. Neely interpreted this finding as evidence that conscious attention inhibition built up faster than conscious attention facilitation. Theoretically, conscious attention facilitation builds more slowly since it is being produced by activation spreading from the attended logogen, but only after attention has been fully shifted to that logogen. Conversely, conscious attention inhibition is being produced during the time that attention is being shifted to a logogen that was not automatically activated by the word prime.

A facilitatory effect was seen in the Shift-Unexpected-Related condition at 250 msec SOA. An inhibition effect was observed at the 700 msec SOA.

The implications of Neely's research are fairly extensive. While his results offer further support for the existence of automatic spreading activation within the semantic network, the evidence for inhibitory effects produced by semantically related primes in some circumstances requires a different interpretation.

The models of both Quillian (1968) and Collins and Loftus cannot account for the inhibitory effects of semantic priming as they only allow for facilitation with semantically related items. However, numerous investigators have demonstrated that retrieval of target information both from episodic and semantic memory can be hindered by the presentation of semantically related information (e.g., Brown, 1979; 1981; Rundus, 1973; Slamecka, 1968; 1972). Clearly, a theoretical approach which can encompass both inhibitory and facilitatory effects of spreading activation is required. Before such a model can be discussed, it is necessary to discuss some of the literature dealing with retrieval inhibition.

Inhibitory Effects of Semantically Related Primes

Slamecka (1968) introduced the part-list cuing paradigm which has generated extensive research into the inhibitory effects of semantically related primes. Typically, subjects are required to study a list of words and later are presented with some items from the the list with instructions to use these items as cues (Context) to recall the remainder of the list. Recall of the target words (those list items not used as cues) is compared to recall of the same words by free recall subjects (Control). Generally, these part-list cues impair recall.

Slamecka (1968) utilized part-list cuing to determine if traces of stored items were organized in relation to each other or if they were stored independently. A series of six experiments was conducted to address this issue. Manipulations included the provision of a varying number of context cues (ranging from 5 to 29 of a total of 30 list items) in addition to the use of both randomly constituted and categorized lists. His results consistently demonstrated that the provision of context cues hampered recall performance, supporting the notion of independently stored traces. Such a conclusion defies the assumptions of semantic network models which postulate that semantically related information should benefit recall, since presentation of some list members should activate other related list members.

Further investigations have been designed to determine the conditions under which retrieval cues hinder recall. Slamecka (1972) designed another experiment to test the role of associative links between items in recall tasks. Associative links between items develop because words within a category become more strongly interassociated as a result of their appearance in the same list. Contrary to network models, Slamecka offered a "cognitive view" hypothesis to explain recall inhibition with part-list cues. This cognitive view argued that when a subject is presented with a categorized list, the succession of words gives rise to some perception of that list's structure. The subject represents each perceived category to himself with a name, and stores these names. At recall, these names serve as the structural elements of a retrieval plan, thereby allowing the information to be recalled in an organized output sequence. This cognitive view portrays recall as a generative process controlled by the higher-order cognitive units (category names) into which the collection of words has been coded. Network models would predict that recall proceeds by the spreading of activation between interword associative connections. Slamecka (1972) predicted that the effect of list cues would operate through facilitating access to additional categories, but would not increase the recall of items within a category. As well, part-list cues would be effective only when some categories could not be recalled unaided.

Two experiments tested these predictions. Five words were presented from each of 4, 8, or 12 categories. Either 0, 1, or 4 list item cues per category were given at recall. After presentation of the study list, subjects were required to recall as many words from the list as possible. For cue conditions 1 and 4, subjects were informed that some words were already on the sheet and that they should write down the rest.

The results indicated that no cuing benefits occurred when four categories were represented on the study list. However, when 8 or 12 categories were represented, there was a significant increase in category recall in the 1 cue condition, compared to the 0 cue condition, indicating a positive cuing effect. Cuing did not increase or decrease the proportion of items recalled per category. Rather, as predicted, cuing only facilitated access to additional categories (categories that could not have been recalled unaided).

Slamecka (1972) interpreted his results as verification of his predictions that any gains in the proportion of items recalled under cued conditions would be entirely attributable to increased recall of categories, not to increased recall within categories. However, according to the early association models, if there are direct associations among items in memory, then presentation of some of the items as cues should aid recall of the remaining items within a category through the activation of the associative links. Clearly, the early associative models cannot account ~~for~~ Slamecka's findings.

Rundus (1973) proposed a hierarchical memory model to explain the part-list cuing effect. Rundus assumed that higher order memory units would be represented ~~best~~ as hierarchies where associations would only be formed between higher order control elements and the underlying individual elements (word nodes), not among the individual elements themselves. For example, associations would be formed between fruit (higher order control element) and apple (individual element), not between—pear and apple (both individual elements).

The main assumptions of the model are: only a limited number of items can be sampled in any attempt to retrieve items from a category or a higher order unit; there are varying degrees of strength in the relationship between items and category names (control elements); the act of recalling an item increases its relational strength to the category name thereby decreasing the relative strengths of other items (since the probability of choosing a particular cue is assumed to be the ratio of the strength of association of that cue with the list cue to the sum of the strengths of association of all retrieval cues to the list cue); this last factor ensures that any future attempts to retrieve items from a particular category tend to result in the repeated retrieval of items previously recalled, to the exclusion of additional items; recall stops after repeated retrievals fail to yield a new item (Rundus, 1973). As such, the presentation of part-list retrieval cues should impair recall since the given items (i.e., the cues) should have a tendency to be re-retrieved, effectively blocking access to other words from the list.

Rundus (1973) designed an experiment to test his model's assumptions. Each subject received a single study-test trial on each of eight 40-item lists of nouns. Each list was composed of four 10-item categories with different categories used for each list. The eight items presented on each recall test were selected such that each of the categories of a list contributed either 0, 1, 2, 3, or 4 items to the set of eight given items. For example, four items were selected from one category, three items were chosen from another category, one item from another category, and no (0) items were selected the fourth category, totaling eight items. Across recall test lists, various combinations of the number of items selected from each category were used. Thus, subjects were required to recall the remaining 32 items.

The results supported the model's predictions. The mean number of target items recalled decreased as the number of items listed from a category increased. Recall from categories in which no items were presented on the recall test was extremely low. Further analysis revealed that category recall was lower for the 0 cue condition than for the conditions in which either 1, 2, 3, or 4 primes were provided. Rundus (1973) interpreted this finding as support for the notion that providing the subject with at least one member of a category at recall increased the likelihood that he would access that category.

A given item (retrieval cue) produced two effects: It both increased the probability of accessing the category of which it was a member and decreased the recall probability of other items associated with it. Essentially, retrieval inhibition occurs because recall of some of the list items reduces the probability of recall of the remaining items on the list.

In sum, Rundus' (1973) model postulates that inhibiting effects of part-list cues arise from the special properties of the retrieval process in memory. Roediger (1973) provides support for Rundus' model while presenting further evidence which conflicts with interitem association theories.

Roediger (1973) presented subjects with long categorized lists with instances blocked by category and with each category preceded by its category name. After presentation of the lists, subjects received sheets listing category names and, in some conditions, varying numbers of category instances from the lists. Subjects were to recall as many remaining items as possible from each category.

Once again, as more category instances were presented as retrieval cues, recall of the remaining list items decreased. Roediger interpreted his findings within the framework of Rundus' model. According to the model, the presentation of part-list retrieval cues in the form of category instances should increase the associative strength of each instance to the category name (control element), thereby decreasing the relative strengths of other items and effectively blocking the retrieval of the latter items.

In addition, Roediger observed a declne in recall over successively recalled categories. He termed this output interference between categories. This interfering effect was greater with the presentation of both category names and item retrieval cues than with the presentation of category names only.

Roediger (1973) proposed that certain words (core words) within categories have stronger associations to the category name than other words (extracore words). Presentation of the category name produces access to the core words which then interfere with the recall of the other (extracore) words, thereby decreasing the accessibility of the remaining words. He further explained this output interference by differentiating between core and extracore organizational processes. Core organizational processes involved the integration of list items into coherent higher order units. Core items were highly available as a result of the organization a subject was able to accomplish at storage (e.g., BIRD-robin, canary). Extracore processes were concerned with the much looser linkage of items with a higher order control element. Extracore items would be less strongly linked to the control element (e.g., BIRD-egret, stork, wren). Roediger postulated that output interference between categories resulted from the decreasing availability of extracore information. The recall of control elements and initially presented items strengthened these elements, causing competition with recall of extracore information later in the output sequence.

While Roediger offers support for Rundus' (1973) hierarchical model, his findings, in combination with those of Rundus, suggest that the facilitative effects of cues are negated by certain inhibiting processes activated by part-list cues. Subsequent research has offered consistent support for this position.

Roediger, Stellon, and Tulving (1977) investigated the effects of recall rate on such inhibition. They proposed that recall inhibition may result from a slower output process which occurs because part-list cued subjects take time to check retrieved items against the cues, which slows their recall rate. To assess how part-list cues affect the rate at which items are recalled requires the cumulative record of recall over time.

Their first experiment assessed the effects of part-list cues on both the level of final recall and recall rate. Subjects were presented with two lists of 48 unrelated words and were provided at recall with 0, 16, or 32 list items as cues. A ten minute recall period was provided and recall rate was measured to determine cumulative recall functions. At the end of the recall period, those subjects receiving 16 or 32 item cues recalled significantly fewer items than free recall subjects. As well, the rate of recall of subjects receiving 32 cues was significantly lower than that of subjects in the free recall and 16 cue conditions. Roediger et al. compared subjects' recall performance by scoring all subjects on a set of critical items, the target set for subjects who received 32 list cues. Subjects receiving 16 cues had their cues selected from the 32 cues used for 32-cue subjects, so they could be scored on the same set of 16 critical items. Free recall subjects were randomly paired with subjects receiving 32 cues for purposes of scoring on identical sets of critical items. Cumulative free recall for free recall subjects was better than for subjects receiving 16 or 32 list cues. Roediger et al. concluded that these data offered further insight into the inhibiting effects of part-list cues, as well as supporting the assumption that part-list cues produce competition with the recall of the critical items at retrieval.

Roediger (1978) has further investigated the recall interference between categories which decreases the availability of extracore information. Specifically, he presented evidence that recall not only facilitates and guides later recall, but also limits the amount of additional information that can be recalled. Subjects heard blocked categorized lists, each containing eight categories. Appropriate category names preceded the category instances. Four different recall conditions were created. One group of subjects was given free recall instructions while the second group was given similar instructions, but was provided with all eight category names as cues. In the other two conditions, subjects were given four category names from the list. The third group received four category labels at recall with instructions to ignore those categories and recall words of the remaining categories. The last group also received four category labels but was instructed to recall as many words as possible from all categories on the list. The cuing conditions were arranged so that subjects in all four conditions could be scored on equivalent sets of 32 critical items.

Critical items were those that did not appear on the recall sheets of the last two groups. They were the only items that the fourth group recalled, and were the items for which the third group did not receive category names. For the second group (provided with all eight category names as cues), the four critical category names were written after those for the other four categories on the top of the recall sheets, and thus critical categories tended to be recalled after other categories. For free recall subjects, the critical items were simply a random half of the words. Results indicated that recall of critical items was significantly poorer for the third group relative to the other 3 groups.

Roediger concluded that the main difficulty subjects in this condition had in recalling critical items was in gaining access to the categories rather than recalling items within categories. Thus, cuing with only some of the category names from a list enhanced recall of the cued categories relative to free recall, but reduced recall of noncued categories.

A second experiment, a replication and extension of the first experiment, manipulated the number of category names given at recall; zero, two, four, or seven. Subjects were to recall as many items as possible from the list, from both the cued and noncued categories. Cuing subjects with a large number of category names (7) resulted in the poorest recall of the noncued categories. Thus, these results confirmed the findings of the first experiment that presentation of category names impairs the recall of items from noncued categories. Recall interference was specific to recall of categories (through difficulty in gaining access to the categories) and did not affect recall of words within those categories. These results were interpreted with Rundus' (1973) model. Provision of category names allowed access to those categories and hence superior recall. However, the associations between the general list control element (category name) and the cued category representation was strengthened so that these cued control elements would be repeatedly retrieved, at the expense of the noncued categories. The model would also assume that the detrimental effect of category cuing should be in the recall of categories, and not just in the recall of words from the categories.

It is evident that Rundus' memory model is sufficient to account for the inhibitory effects of part-list cuing as its predictions are supported with various manipulations. This model postulates hierarchical (vertical) associations in contrast to the interitem (horizontal) associations of network models. However, it is possible to conceptualize memory as a large network of both horizontal and vertical associations, and still be able to interpret part-list cuing effects.

Raaijmakers and Shiffrin (1980) have proposed such a model: Search of Associative Memory (SAM). This search theory of retrieval consists of a retrieval structure based on an associative network (Raaijmakers & Shiffrin, 1981). Their explanation for the inhibitory effects of part-list cuing incorporates interitem associations. SAM assumes that memory is partitioned into images (memory structures) which vary in complexity and may overlap considerably with one another. The basis for retrieval is assumed to be the strength of associative relationships between probe cues and memory images. Information is recalled through the use of a retrieval plan. On the basis of the retrieval plan, subjects construct probe cues to be used in retrieval. These probe cues may be either general context cues, or in the case of cued recall, experimentally presented cues. To begin, in free recall, the subject utilizes only context cues. As items are recalled, probe cues are modified to include the recalled items in addition to context cues. A probe cue is used until it fails to produce any new items and reaches the stopping criterion, the L-max parameter. After cues have been exhausted, an additional rechecking process begins, where additional targets are searched for by varying combinations of probe cues and context cues. Eventually, when a critical number (K) of failures to retrieve a new item have occurred, a stopping rule is invoked and recall ceases. Moreover, the model assumes that words are interassociated in triads (the number of words selected for interassociation was apprently somewhat arbitrary), with all other interword associations being negligible. When an image from a triad is sampled, the other two members are immediately recalled (Raaijmakers & Shiffrin, 1981).

SAM predicts part-list cuing inhibition. The model assumes that both free and cued recall conditions involve extensive cuing of words. However, while free recall subjects begin memory search with self-generated context cues, those in the cue condition must utilize experimentally provided cues. Since the cued group's sampled triads will contain cue words, the number of critical words will be relatively small. The control group's triads contain no cue words and hence have a higher number of critical words. This confers an advantage to the control group resulting in their superior recall of critical items.

While SAM offers an innovative approach to the study of retrieval processes, and a novel solution to the part-list cuing problem, it is extremely complex and may be difficult to test adequately (Roediger & Neely, 1982). Moreover, SAM's ten parameters and numerous processes cannot explain why extralist cues have an equally damaging effect on recall (Mueller & Watkins, 1977; Watkins, 1975).

While the inhibitory effects of part-list cuing are known to be category specific and to increase with the number of provided cues (Roediger, 1973; Rundus, 1973), the generality of the phenomenon is demonstrated by Watkins (1975). Watkins attempted to determine if the inhibition effect was dependent on cue words being members of the to-be-remembered list or would remain when cues were not list members. He utilized categorized lists and manipulated the number of presented cues.

In the first experiment, subjects studied lists of six exemplars of each of six categories. When tested, subjects received all six category names, while five of the six testing conditions also received category exemplars as retrieval cues. The cue words that usually appeared were either two or four intralist or extralist category exemplars. To ensure that subjects attended to the cues, prior to recall, they were to mark each item they recognized from the list.

The probability of recall decreased as the number of intralist cues increased. With zero, two, or four intralist cues, the probability of recall of the critical items was .56, .50, and .47, respectively. This trend was significant. As well, recall was inhibited by extralist cues with proportions for the respective conditions equalling .56, .48, and .46. This decline in recall was also significant.

These results support the conclusion that extralist cues from the target category have the same inhibiting effects as intralist cues.

Watkins (1975) postulated that both intralist and extralist cues are stored as additional list members. As such, they impair recall similarly to long lists. Increasing the length of a list decreases the probability of recalling a random item from that list (Murdock, 1962). The inhibitory effects of intralist and extralist cuing incorporated the cue overload principle (Mueller & Watkins, 1977). This principle contends that recall is mediated by retrieval cues. Overloading the retrieval cues (e.g., TREES) with an increasing number of items (e.g., birch, spruce, maple, oak) hinders the recall of any of those specific items. Cuing results in inhibition since each encounter with an item is unique in retrieval, and cues provide a greater number of encounters with cued items, which invariably become overloaded.

Mueller and Watkins (1977) tested the generality of the effect in a series of experiments. In the first experiment, subjects received a series of categorized lists for cued recall, each of which included four critical categories. Two of these were cued with the category name alone, and two with the category name together with three items. For half the lists, the list items were from the tested category while the remaining lists utilized items from an untested category. It was predicted that list items would inhibit recall only if they were members of the tested category. Since presumably the cue "tree" is effective only for list items from the tree category, then according to the cue overload principle its efficiency with respect to trees should not be impaired by the simultaneous presentation of other categories.

Results confirmed the predictions. The probability of recall in the related test list condition (.48) was significantly lower than the control condition (.58).

However, recall in the unrelated test condition (.55) was not significantly different from the control condition. As such, the inhibitory effect of extralist cues is category specific. Subsequent experiments utilized different modes of categorization to further assess the inhibitory effects of extralist cues. Part set cuing inhibited recall with rhyme sets (Experiment 2), and with subjectively organized word sets (Experiment 3). While Watkins' cue overload approach can account for both intralist and extralist cuing inhibition, this interpretation does not provide a molecular account of the mechanisms which might be producing these effects (Roediger & Neely, 1982). Moreover, neither Rundus' hierarchical model nor Raaijmakers and Shiffrin's SAM can explain the equivalent inhibitory effects of extralist cues without extensions or modifications.

Retrieval Inhibition in Semantic Memory

The aforementioned studies deal with the inhibitory effects of part-list cuing in retrieval from episodic memory. Retrieval inhibition resulting from related information in semantic memory creates further problems for spreading activation models.

Brown (1979) wished to test the generality of the priming facilitation effect with a paradigm where semantic information in the form of definitions was used as the stimulus for word retrieval. Subjects were informed that they would see a word followed by a definition and that they were to decide whether the two matched. If they did, they were to respond "yes". If not, they were required to generate the correct word. Subjects were informed about the nature of the four different prime types.

The priming word was one of the following types: correct word (C prime) that matched the definition; semantically related word (S prime) that was related to the correct word in meaning; orthographically related word (O prime) that was related to the correct word in number of syllables, syllabic stress, and initial and terminal sounds; unrelated word (U prime) that had no relation whatever to the correct word. An example of the type of word set constructed was "gobble" (C prime), "cram" (S prime), "goggle" (O prime), and "feud" (U prime). The dependent measure was the probability of retrieving the correct word when primed with incorrect primes.

An inhibitory effect of semantically related primes was demonstrated in the first experiment. Using those stimulus sets in which 90% or more of the subjects correctly identified the C prime as the correct match to the definition, the percentage of trials in which the correct word was given was 5.0 for the S prime, 15.6 for the O prime, and 13.1 for the U prime. The subsequent studies confirmed the reliability of this finding.

The second study also revealed significant differences in retrieval latencies. Correct words were retrieved slowest after S primes, and fastest after O primes. Experiment 4 increased the number of primes to increase the magnitude of the inhibitory effect. Either the definition was preceded by a single C, S, or U prime, or it was preceded by a triple prime. These triple primes consisted of the correct word accompanied by two semantically related words (CSS), three words semantically related to the correct word (SSS), or three words all unrelated to the correct word (UUU). However, the three unrelated primes themselves were from one category. If three primes exaggerate the inhibitory effect, it is predicted that longer retrieval latencies would occur after SSS than after single S primes. Response latencies were significantly longer under SSS (6.89 sec) than under S (5.16 sec), U (5.47 sec), or UUU (5.20 sec) primes, indicating an inhibitory effect with increased number of semantically related primes. There were however no differences among the S, U, and UUU primes. This result indicated that the inhibitory effect of the S prime became evident as the number of primes increased. Furthermore, this effect was not simply due to the increase in number of primes since the U and UUU primes did not differ. However, it should be noted that there was little difference between the S and U primes, with the U primes actually causing slightly longer latencies than the S primes.

To address this issue, Brown added a fifth study which included a no prime (N) condition to further clarify the effects of S and U primes on performance. In this condition, a subject saw a set of 3 asterisks in the place of a prime word. Both S (3.60 sec) and U (3.49 sec) primes significantly increased response latencies compared to the N prime (2.98 sec) condition. Response latencies for both S and U primes were significantly longer than for the N primes, however there were no significant differences between them. As such, both unrelated and semantically related primes proved detrimental to retrieval processes.

Brown interpreted his results as evidence for automatic spreading inhibition in the semantic memory network. To explain the presence of retrieval inhibition which is contrary to the basic finding of facilitation, Brown noted the discrepancies between previous studies and his own.

Brown argued that Loftus (1973b) used only conceptually categorized items. Other studies have employed a lexical decision paradigm in which a letter string is paired with or immediately preceded by a semantically related word (Meyer & Schvaneveldt, 1971). The response required in these paradigms is distinctly different from that required in Brown's studies. The nature of the retrieval process would also seem to be different in Brown's paradigm. Here subjects are more active in initiating and maintaining a search through their semantic structure to locate the correct word. The presentation of an item would cause excitation to spread from that word to related words through the interconnections between these words. This should result in an increase in the availability of the related word, with an accompanying decrease in the use of the interconnections between these words. Brown suggested this latter process was similar to the refractory period with neurons; for a short period after a path's activation it is more difficult to reactivate that same path.

A lexical decision does not require a search along the path from the prime to the correct word, since the correct word is presented. Therefore, only facilitation will occur. However, Brown's paradigm requires the aforementioned search process, thus providing the possibility for inhibition.

However, more recent evidence challenges this interpretation. Roediger, Neely, and Blaxton (1983) argued that Brown's inhibitory effects (seen in longer retrieval latencies for semantically related primes) were simply an artifact of his procedure.

The inclusion of correct primes necessitated that subjects check each prime to determine if it was the correct answer. A correct match elicited a yes response, different from the other responses. With an incorrect match, subjects would attempt to retrieve the right word. However, since semantic relatedness increases the time to reject false information (e.g., Anderson & Reder, 1974), subjects may have been slower to reject semantically related primes as incorrect relative to rejection of unrelated primes. Thus, there would be a delay in initiating a retrieval attempt following related primes, hence resulting in longer response latencies.

Thus, Roediger et al. (1983) asserted that the inhibitory effect of semantically related primes may have resulted from the slower rejection of the related prime which produced a delay in initiating retrieval. To test this prediction, Roediger et al. omitted correct prime trials for one group of subjects.

For another group of subjects, correct primes were included on some of the trials. When trials involving correct primes are omitted, there is no need for subjects to determine if the prime is the correct answer, and thus subjects may begin to retrieve the correct target as soon as they hear the definition. If inhibition remains on these trials, then Brown's hypothesis of automatic spreading inhibition would be supported. However, if no inhibition occurs, this would be explained by Roediger et al.'s hypothesis of slowed rejection of related primes. They also required subjects to produce the correct word on all trials. This would equate the responses in all priming conditions, whereas a "yes" response following a correct prime differed from the responses required by the other conditions. In addition, they included a neutral priming condition which would assess any priming effects of related primes. Four primes were chosen by the experimenters for each question. For example, the correct prime for the question "What yellowish metal is used in making trumpets?" was "brass"; the related prime was "tin"; the unrelated prime was "sheriff"; and the neutral prime was "ready" (used in all trials).

Their experimental results also demonstrated inhibition from semantically related primes when the correct item was included. Correct responses after a correct prime averaged 1.18 sec, while responses following a semantically related prime required an average of 1.7 sec. Neutral and unrelated primes had equivalent latencies of 1.49 sec and 1.51 sec, respectively. The exclusion of correct primes yielded a different pattern of results. Here related primes conferred a small amount of facilitation with response times of 1.38 sec. These response times were reliably faster than those in the unrelated priming condition (1.51 sec). However, the facilitation following the related primes was reliable only in comparison to the unrelated priming condition, not to the neutral priming condition (1.42 sec).

Typically, it is this latter condition which is utilized to assess facilitation. Moreover, these response times were much shorter than Brown's (e.g., S=7.37 sec, and U=5.56 sec in Experiment 2) which would suggest that they are a function of the time needed to reject false alternatives. Conceivably, when subjects know that the correct word is not included, they can begin generating immediately.

Their findings supported their assumptions of subjects' use of "different strategies" to process primes, specifically slower retrieval initiation following related primes. However, the presence of inhibitory effects in semantic memory resulting from semantically related primes has been obtained with other paradigms.

Brown (1981) determined that successive retrievals from the same semantic category were inhibitory, resulting in increasing retrieval latencies and the decrease in the probability of retrieval. Subjects were required to generate five successive instances from each of nine categories. Categories were blocked, and the stimulus display consisted of a category instance paired with an initial letter (fish-B).

~~Mean~~ response latencies increased across items within a category. Brown (1981) concluded that repeated retrievals from a single semantic category resulted in a progressive increase in inhibition since it also occurred with pictorial stimuli (Experiment 2), whether each category instance was preceded by a category name (Experiments 2 and 3), or the category instances were intermixed in presentation (Experiment 4).

Brown explained his inhibitory effects within the framework of Raaijmakers and Shiffrin's (1980) SAM model. Subjects' initial probe cues consisted of the specific category paired with the initial letter (or picture). The first retrieval would increment that word's associative strength to the category cue.

This information would be added to the probe cue, and this process would continue across the successive items. The first few retrievals elaborate the probe cue. However, inhibition builds up since the subject implicitly retrieves extra items before selecting the one which fits the requirements of the cue. These implicit retrievals reduce the tendency of retrieving other items from memory, thereby causing an increase in inhibitory effects. If a subject was presented with the category FISH, he would begin to retrieve different instances of FISH from his memory (e.g., trout, salmon, pike, carp, herring). When he is subsequently presented with the category as the target item (e.g., FISH-B), the instances already retrieved will interfere with the retrieval of the instance stipulated by the target.

Blaxton and Neely (1983) have confirmed the inhibitory effects of prior retrieval of semantically related primes and have shown that the greatest inhibition occurs when subjects must actively retrieve both primes and targets. Specifically, they tested Brown's (1981) hypothesis of retrieval inhibition resulting from the prior implicit retrieval of several category instances. Speculating that both facilitatory and inhibitory priming effects could be obtained with a variable number of category exemplars, they attempted to minimize covert retrievals before and between probe trials in two ways. They eliminated Brown's 5 sec warning presentation of the category name between category instances. The number of consecutive retrievals from a particular category was either one or four.

Moreover, they manipulated the specificity of the inhibition by testing an unrelated priming condition. This would determine whether inhibitory effects resulted from successive retrievals of a specific category (Brown, 1981) or were simply the result of nonspecific inhibition. To test Brown's (1981) hypothesis of inhibitory effects resulting from active retrieval of generated primes, Blaxton and

Neely (1983) included a read-generate group. Subjects simply read primes aloud (no active retrieval) and only generated category exemplars on target trials. The reading of primes, which they speculated does not require active retrieval, was not expected to produce inhibition. As such, Blaxton and Neely proposed that if inhibition occurred because of active retrieval of related primes, RTs in the unrelated priming condition would exceed those of the related priming condition in the read-generate group, regardless of the number of primes, since there would be no inhibition from successive retrievals of related primes. Facilitation would occur in the related four prime condition since no active retrieval inhibition would accumulate in these trials to offset the facilitatory effects of spreading activation. The results confirmed their predictions. The read-generate group demonstrated facilitatory effects of semantic relatedness in both the one and four prime conditions. For the read-generate group, the 108 msec facilitation effect in the related priming condition, relative to the unrelated priming condition, was significant.

Different predictions were offered for the generate-generate group. First a facilitatory effect would be obtained in the related one prime condition compared to the unrelated one prime condition. This would result from activation without inhibition buildup due to successive retrievals from a category. Inhibitory effects would be evidenced in slower RTs for the related four prime condition, in comparison to the related one prime condition due to the consecutive active retrieval of category instances. Once again, the predictions were sustained with the results. Reaction times in the related four prime condition were considerably faster than those in the unrelated priming condition. The 139 msec facilitation effect in the related one prime condition compared to the unrelated one prime condition was significant. Reaction times in the related four prime condition were

considerably slower than those in the related one prime condition, seen in the 101 msec inhibition effect. While reaction times in the related priming conditions increased as the number of primes increased, the RTs in the unrelated priming condition decreased nonsignificantly. Neither the 57 msec decrease in RTs in the unrelated four prime conditions relative to the unrelated one prime condition, nor the 19 msec inhibition effect in the related four prime condition relative to the unrelated four prime condition was significant. Blaxton and Neely interpreted these results as evidence for an inhibitory effect that was category specific.

However, it must be noted that Blaxton and Neely interpreted their inhibitory effects atypically. Normally, an inhibitory effect is seen when there is a significant difference between the related and unrelated prime conditions. However, in the generate-generate condition of Blaxton and Neely's paradigm, there was a nonsignificant difference between these two RTs in the 4 prime condition (approximately 19 msec). As such, the inhibitory effects they describe are simply the result of the increase in RTs from one to four primes.

A second experiment was conducted to further explore the issue of whether category specific inhibition depends on the active retrieval of both primes and targets or if it is simply a function of subjects performing an identical task on primes and targets. Two different conditions were created to address these questions: a generate-read group and a read-read group. Thus, the only methodological variation in the second experiment was that subjects always read the targets. The results of the generate-read group would indicate if the active retrieval of targets is necessary to obtain category specific inhibition, while the read-read group would illustrate whether inhibitory effects simply resulted from subjects performing the same task on semantically related primes and targets or were dependent upon the active retrieval (generation) of both primes and targets.

Here the read-read group revealed facilitation in the related priming condition relative to the unrelated priming condition. However, no such facilitation occurred in the generate-read group. The increase in reaction times in the related four prime condition relative to the related one prime condition was not greater than that observed in the corresponding unrelated priming conditions. As well, reaction times in the generate-read group were much slower than those in the read-read group.

The combined results of these experiments demonstrated that semantically related primes may either facilitate or inhibit the retrieval of target information. Evidence of inhibition in the form of slower RTs following four related primes was obtained only when subjects generated both primes and targets. The absence of inhibition in the read-read group indicated that it was the active retrieval of both primes and targets that produced category specific inhibition in the generate-generate group.

Furthermore, they concluded that facilitation from one related prime will not occur if the amount of active retrieval of primes exceeds that of targets. Facilitation will be obtained only if the amount of active retrieval on priming trials is less than (e.g., read-generate group) or equal to (e.g., read-read group) that required on target trials.

Blaxton and Neely (1983) speculated upon the operation of an inhibitory mechanism which is invoked when related primes are generated (actively retrieved). This inhibitory mechanism competes with the operation of a facilitatory mechanism and cancels out the facilitative effect that occurs with the reading of related primes (spreading activation). More importantly, they concluded that it is the types of operations performed on primes and targets that determine if facilitation or inhibition will occur within semantic priming paradigms.

While Blaxton and Neely have offered evidence for the determinants of inhibitory effects, some questions remain unanswered. They have speculated that generation involves active retrieval, while reading does not, but have not actually tested this processing difference directly. One purpose of the present investigation is to directly assess one hypothesis about the processing differences which yield either facilitatory or inhibitory effects. While Blaxton and Neely's paradigm will be essentially replicated, certain additional manipulations will be introduced. These modifications are included to further assess the effects of generation.

For their experimental purposes, Blaxton and Neely (1983) defined generation as active retrieval. However, generation as a processing phenomenon has a much greater scope, and though it has received a great deal of empirical attention, it has yet to be definitively explained. Before any specific predictions of the current investigation can be advanced, a review of the pertinent literature on generation is warranted.

The Generation Effect

Since its introduction as an experimental phenomenon (Slamecka & Graf, 1978), generation effects have undergone extensive scrutiny. Slamecka and Graf's (1978) research was directed by the factual observation that active involvement in the learning process is more beneficial to recall than passively acquiring the same information. Through a series of five experiments, they demonstrated the robustness of the generation effect across a variety of testing procedures.

Subjects were restricted in generating to avoid confounding. It was deemed necessary to eliminate any idiosyncratic item-selection habits which a subject might employ in generating, thus conferring unfair advantage to this condition. They were given a stimulus word with the initial letter of the semantically related response (e.g., rapid-f), and were expected to produce a word that began with the given letter. The first experiment assessed generation effects with recognition. A read group was included as a control and five different encoding rules for the words were established: associate (lamp-light), category (ruby-diamond), opposite (long-short), synonym (sea-ocean), and rhyme (save-cave).

Results of the experiment revealed a substantial advantage for the generation condition over the read condition. Further, the magnitude of the generation effect did not vary as a function of the particular rule involved. Subsequent experimental manipulations showed the effect to be relatively robust. A within subjects design which omitted intentional learning instructions for half the subjects did not alter the findings (Experiment 2).

The performance of subjects in the generate conditions was consistently superior to that of subjects in the read condition. This held for measures of cued and uncued recognition, as well as free and cued recall.

Slamecka and Graf considered various interpretations of the generation effect, the most salient being one which states that the generation task forces a distinctive encoding of the relation between stimulus and response. In contrast, the reading task does not effectively demand any registration of that relation. Though both groups were informed of the encoding rules, it is possible that the subjects in the read condition did not utilize the information, since it was not necessary for the task. As such, their encodings would lack relational specificity. Conceivably, the generation effect could be explained within such terms, since such distinctiveness is an important factor in memory. Similarly, Kane and Anderson (1978) used the concept of relational specificity, which they termed differentiation, to account for the superior performance of subjects in a sentence completion task (generation) relative to those who simply read the sentence.

Subsequent investigators have offered different interpretations. Graf (1980) extended the previous findings (Slamecka & Graf, 1978) by applying an organizational perspective to generation. He postulated that generating a sentence, as opposed to reading one, results in an increase in the interword organization (integration) of the sentence. He suggested that this increased interword organization of generated sentences could account for the generation effect.

Graf tested this hypothesis by examining the retention benefits of generating both meaningful and anomalous sentences. An anomalous sentence should not permit interword organization. As such, generating a meaningful sentence would result in superior retention relative to the generation of anomalous sentences and this retention benefit would be evident with cued recall, a retention measure sensitive to the interword organization of memory traces.

Graf's first experiment consisted of a Read and Generate condition with both meaningful and anomalous sentences as input. The anomalous sentences consisted of a random rearrangement of the content words of the meaningful sentences. The grammar for the meaningful sentences was: Article (the), Adjective, Noun, Verb (-ed), Article (the), Noun. A subject in the Generate-Anomalous condition would be given a set of words (e.g., Piano, Leaflet, Baked, Blond) and required to generate a sentence within the specified grammatical sequence. Subjects in the Read condition simply read the displayed sentence aloud.

A cued recall test was used to assess retention, with verbs of the input sentences serving as recall cues. Results demonstrated the expected generation effect for meaningful sentences but not for anomalous sentences. Recognition of word pairs was also utilized to further investigate the presence of interword organization. Subjects received a list of word pairs with instructions to indicate which pairs they had seen before. Subjects were shown pairs of words that had been included in input sentences. Some words were taken from the same sentence (intact pair) while others were from two different sentences (broken pair). It was expected that a subject's ability to recognize an intact pair and to reject a broken pair would depend on whether or not the words of the sentences had undergone interword organization during input. Once again a generation effect was seen with meaningful sentences, but not with anomalous sentences. The consistency of these results provides support for the notion that the increased interword organization resulting from generation is semantically based.

Finally, Graf attempted to determine whether generating also produced increased intraword organization, which refers to the sensory and perceptual organization of a word. Meaningful and anomalous conditions should not differ with respect to the meaningfulness of the individual words. Generating a meaningful sentence may cause subjects to expend more processing capacity, since individual words are examined more closely than in reading. Similarly, generating an anomalous sentence as opposed to reading one would also require greater attention to the individual words. Therefore, the greater attention to individual words in the generation condition may result in an increase in intraword organization. Consequently, recognition of all generated material should be superior to that of read material. The same words were used in the Meaningful and Anomalous conditions, although they were combined into sentences according to different rules. The input consisted of all critical sentences, which had been used in previous experiments, half of which were shown in the Meaningful format, with the remainder in the Anomalous format. A YES-NO recognition test of all the nouns of the input sentences was administered. Results of this experiment demonstrated a generation effect for both types of input material, indicating that generation involves intraword organization in addition to interword organization.

McElroy and Slamecka (1982) attempted to determine whether a generation effect would emerge with nonwords. Superior retention of generated nonwords would demonstrate that the generation process itself increases retention, irrespective of the material. However, equivalent retention of read and generated nonwords would be consistent with the view that processing to a deeper, semantic level must be involved for generation to yield superior retention.

They devised a list of paired associates, consisting of word pairs and nonword pairs. The members of a nonword pair were related by a letter-transposition rule which required the first three letters of the stimulus to be put in backward order after a consonant that was provided as the first letter (e.g., preet-terp). Word pairs were opposites (hot-cold). For the generated items, subjects were instructed to produce an opposite to each word stimulus and to use the transposition rule for each word stimulus.

Recognition performance revealed the typical generation effect for words, but no difference for generated and read nonwords. There was also no indication of a generation effect for nonwords related through a letter transposition rule when measured by free recall. The addition of a rhyme rule to the letter transposition rule for nonwords did not yield a generation effect. McElroy and Slamecka concluded that the generation effect, which is not obtained with nonwords, is independent of task demands, and requires processing to the semantic level.

Donaldson and Bass (1980) introduced the concept of arousal to explain the generation effect. They postulated that generating a word induces arousal which subsequently leads to deeper processing. This arousal and hence deeper processing of generated items would occur in either of two ways: differential energy expenditure due to the generate situation as a function of uncertainty or due to an adequacy check which required rechecking the completed word's relatedness to the experimentally provided cue.

Experiment 2 tested the first hypothesis of generation involving increased effort. They eliminated the uncertainty engendered by the generation task by constructing pairs of words in such a way that the missing letter was always an E. Subjects in the generate condition were informed that the missing letter would always be an E and were required to write it down. For the read condition, the E was always underlined, and subjects were required to copy it.

Cued recall was superior for the generate condition indicating a generation effect. Eliminating the uncertainty did not eliminate the effect. As such, the generation effect goes beyond the reduction of uncertainty about the missing letter and the increased effort required to produce the missing letter.

Experiment 3 tested the second hypothesis of an adequacy check. According to the hypothesis, when a subject generates a response, he will check back to the cue word to ascertain that the response word possesses the required semantic relationship with the cue word. Donaldson and Bass (1980) suggested that this adequacy check may require controlled processing, both conceptually driven and data driven operations (cf. Norman & Bobrow, 1975). Conceptually driven processing requires the use of semantic knowledge, while data driven processing is largely perceptual in nature. If generating a response involves a semantic adequacy check between the item and the cue word, the recall advantage of the generation condition should disappear if such a check is performed on all pairs of items.

An adequacy check for semantic relatedness as well as an analogous orthographic task were created. The adequacy check tasks were designed to mimic the hypothetical "looking back" process which Donaldson and Bass suggested might be activated as part of generation. Subjects were again instructed to either write down the missing letter (generate condition) or the underlined letter (read condition). In addition, subjects in the semantic adequacy check condition were required to assess, on a 3 point scale, the semantic relatedness of both read and generated words to the cue words. In the orthographic adequacy check condition, subjects recorded the number of times that the letter (either missing or underlined) just written occurred in the first word of the pair. This also became a 3 point scale, either 0, 1, or 2 times.

The results showed that the addition of a semantic adequacy check eliminated the recall differences between generated and read word pairs. However, differences remained with the orthographic task. Here subjects who had written down missing letters recalled significantly more words than those subjects who had simply written down the underlined letter.

The Donaldson and Bass findings are relevant in that they have provided a specific mechanism to account for this effect, a looking back process (semantic adequacy check). Another factor which must be considered is Donaldson and Bass' attention to reading. Typically, the reading condition is used as a control condition since it is assumed not to require active retrieval of information (Blaxton & Neely, 1983). However, reading is a complex cognitive process, and Donaldson and Bass have demonstrated that augmenting reading with a semantically oriented task which necessitates controlled processing eliminates the recall differences between reading and generating. If it is a semantic adequacy check which is the basis for the generation effect, then it should also be possible to eliminate the generation effect by establishing the experimental parameters such that there is little opportunity for subjects in the generate condition to activate this check. Conceivably, if a subject is required to generate a word within a very short time, he will have less opportunity to recheck the generated word's semantic relatedness to the cue word. As such, the generation effect will be reduced or eliminated.

This synopsis of the generation effect illustrates that the task of generating induces fairly extensive processing (and not simply active retrieval, as defined by Blaxton and Neely), as well as demonstrating that there exists no single explanation for this effect. Assessing the effect of generating through its direct manipulation with a semantic adequacy check or speed may provide a further test of Donaldson and Bass' (1980) explanation of the effect.

The present investigation will attempt such a manipulation. As mentioned previously, Blaxton and Neely's (1983) paradigm will be extended to include these manipulations. As in their experiment, the number of primes will be either 1 or 4 and RTs will be used to assess the presence of facilitatory and inhibitory effects. As well, recognition tests will be included to assess memory for primes and targets. While RTs typically determine the presence of facilitatory and inhibitory effects, RT is not a sufficient indication of the presence of a semantic adequacy check. As this semantic adequacy check may be the critical factor in the generation effect, it is necessary to control for its occurrence. Moreover, such manipulations may also help clarify the important processing factors that yield facilitation and inhibition.

As such, four experimental conditions will be created. A read-read condition in which both primes and targets are read; a generate-generate condition in which both primes and targets are generated; a condition in which primes are generated with speed and targets are read; a condition in which primes will be read and rechecked and targets generated. It is these latter two conditions which directly manipulate both generating and reading through the inclusion of speed and an adequacy check. Assuming that these manipulations have the expected effects on the generation and reading processes, the primes in each of the four conditions will undergo processing which is equal to that of the targets. Blaxton and Neely (1983) argued that this was one factor which determines facilitation or inhibition. The use of deeper (controlled) processing for both primes and targets should yield inhibitory effects in (multiple prime conditions, while higher level (more automatic) processing should yield facilitation. A semantic adequacy check and generating, are hypothesized to be equivalent cognitive functions that involve controlled processing. An experimental condition which utilizes either of these tasks should result in inhibition. Similarly, reading and speeded generation (which should preclude a looking back process) should invoke less controlled processing, and therefore should yield only facilitation.

The read-read condition and generate-generate conditions are essentially a replication of Blaxton and Neely (1983). These two conditions are included in the present experiment to replicate Blaxton and Neely's findings that the repeated active retrieval (as in four primes) (generation) of both primes and targets produces inhibition in semantic memory, while equivalent processing that does not involve active retrieval (e.g., reading) of primes and targets yields facilitation. As well, these two conditions should serve as baselines for the remaining two conditions.

Based upon previous findings, the following predictions can be made. It is hypothesized that the read-read condition should yield facilitation in the semantically related priming condition, relative to the unrelated condition, for both one and four primes. As previously mentioned, this condition is a replication of Blaxton and Neely (1983). Blaxton and Neely stress that facilitation is dependent upon the relative amount of processing of primes and targets. Facilitation is obtained only if the amount of processing of primes is less than or equal to that of targets. The active retrieval of both primes and targets (e.g., generating both) is necessary for inhibition.

The generate-generate condition should produce inhibition in the related four prime condition. There should also be facilitation in this condition with one related versus one unrelated prime. Again, this condition replicates Blaxton and Neely (1983) in which reaction times in the related priming condition increased as the number of primes increased from one to four. As such, it is predicted that the related four prime condition will yield longer reaction times (inhibition) than the related one prime condition. Identical cognitive operations which involve equally active retrieval are being performed on both primes and targets, a necessary factor for the occurrence of inhibitory effects (Blaxton & Neely, 1983).

The third condition of speeded generation of primes and reading of targets is conceptually similar to the read-read condition. With restricted time to generate, subjects may have less opportunity to invoke the adequacy check normally performed on generated items, thereby reducing this generation effect. As such, there should be no cognitive process (such as an adequacy check) to produce inhibition. Thus, the related trials should yield facilitation in both the one and four prime conditions. Essentially, performance in this condition is expected to mimic that of the read-read condition.

Finally, the fourth condition is analogous to the second. The reading and rechecking of primes and the generation of targets is equivalent to generating both primes and targets. Thus, the predictions will be similar.

Recognition should also be differentially affected by the various manipulations in the four conditions. If generated items undergo a semantic adequacy check, they should be more readily available at retrieval than items that are simply read. As such, recognition performance should be optimal when primes and targets undergo a semantic adequacy check. The second condition of generation of both primes and targets, and the final condition of reading and rechecking of primes and generation of targets should yield superior recognition to that of the first condition in which primes and targets are both read, and the third condition where speeded generation of primes should preclude any looking back process.

It is possible that the facilitatory and inhibitory priming effects obtained by Blaxton and Neely (1983) may be specifically associated with the various components of generation which have been suggested by Donaldson and Bass (1980). If so, the direct manipulation of generation through speed and a semantic adequacy check may help isolate the source of some of these facilitatory and inhibitory effects. Specifically, it is conceivable that facilitatory effects may be isolated in the activation stages of generation, while inhibitory effects may result from processing occurring in the rechecking stages.

As mentioned previously, a recognition test will be included in all conditions. This test should serve as a manipulation check for speeded generation and the semantic adequacy check. Thus, it is expected that speeded generation will result in the reduction or elimination of generation effects, whereas the semantic adequacy check will result in enhanced memory for the read items (cf. Donaldson & Bass, 1980, Experiment 3).

Associatively Related versus Semantically Related Primes

One further manipulation will be incorporated within the study. Prior to describing this manipulation, the relevant literature will be reviewed briefly. The phenomenon of facilitation which occurs after the presentation of a related prime has been thoroughly investigated. However, there is little evidence to suggest that priming is actually semantically rather than associatively based. Semantically related words are those related through their membership in the same semantic category, while associatively related words share a certain degree of association.

The latter do not have to be in the same semantic category to be associatively related (e.g., camel-hump or harpoon-whale) but they can be (e.g., lion-tiger). Typically, priming effects are explained within the framework of a semantic network model (e.g., Collins & Loftus, 1975) where semantically related concepts are believed to be closely linked. However, there has been no control over the type of relation between primes and targets. Namely, these studies have included words which are associatively related.

Fischler (1977) has suggested that, in consideration of such stimuli, an alternative explanation for the facilitatory effects of priming is possible. He argues that words which become frequent associates may attain that status not on the basis of common semantic properties, but from accidents of contiguity. As such, the viability of the semantic network conceptualization of priming could be tested with stimulus pairs in which the two words were not normatively associated, but had a certain degree of semantic similarity. Specifically, the encoding of "nurse" should make analysis of "wife" proceed more quickly, since they share a certain number of similar semantic features, despite the absence of any tendency for "nurse" to directly elicit "wife" as an associate. Thus, finding a significant facilitation for pairs like "nurse-wife" would support such an interpretation.

Fischler utilized a double lexical decision task to test his hypothesis. Subjects were shown pairs of letter strings and had to decide as quickly as possible whether both strings were words. The word pairs included associates (e.g., cat-dog), semantically similar but not normatively associated words (e.g., nurse-wife) and unrelated control pairs (e.g., bread-stem).

Both associates and semantically related pairs were responded to more quickly than the control pairs. However, facilitation was obtained for pairs of words which shared no direct associative relationship, but which had been judged as semantically similar (e.g., nurse-wife). Fischler concluded that the encoding of a word can be facilitated by the prior processing of a semantically related word.

While Fischler has demonstrated the important role of semantically related primes in a lexical decision task, subsequent investigators have not been able to extend his finding to other paradigms, specifically the naming task. Massaro, Jones, Lipscomb, and Scholz (1978) attempted to determine whether a category member prime influences naming of that category's instances. In their first experiment, subjects were asked to name an instance as rapidly as possible under the prime and no prime conditions. If priming facilitates naming of category instances, naming RTs should be shorter for the instances when they are preceded by the category prime, relative to no prime trials.

Results indicated a nonsignificant 7 msec facilitation effect. Similar results were obtained in a second experiment. Such a nonsignificant facilitation effect would seem to imply that a semantic relationship between the prime and target may have a minimal effect in a naming task.

However, these findings are not conclusive since no attempt was made to control for associatively related prime-target pairs. Conceivably, the nonsignificant facilitatory effects of priming may be attributed to residual association strength between word pairs (Lupker, 1984). Attempts to eliminate association effects in a naming task and utilize prime-target pairs that were only semantically related also appeared to support the argument that semantic relatedness has very little effect in a naming task (Irwin & Lupker, 1983).

While these studies would seem to suggest that semantic relatedness has a minimal effect in priming, there are some common features inherent in all (Lupker, 1984). All shared a very long prime-target onset asynchrony (SOA). The

SOA used by Massaro et al. was 1500 msec, while the SOA used by Irwin and Lupker was the response time to the prime, as well as a one second interstimulus interval, creating a total SOA which would undoubtedly exceed 1500 msec. As Posner and Snyder (1975) have suggested, automatic spreading activation which can carry information from the prime's concept to related concepts accrues extremely quickly, but decays rapidly unless maintained by active attention (Neely, 1977). With SOA's in excess of 1500 msec, any priming that was available would have been substantially diminished unless subjects were highly motivated to continue attending to the automatically activated concepts (Lupker, 1984).

As such, Lupker's (1984) six experiments were an attempt to generalize the previous findings of the role of semantic relatedness in priming. Experiment 1 evaluated the role of a semantic relationship between prime and target in a naming task. Two concepts were defined as being semantically related if they were members of the same semantic category. Associatively related stimulus pairs were not permitted (e.g., ANIMALS: cat, dog). It was determined that there was little if any facilitation when targets were preceded by semantically similar primes (VEHICLES: canoe, tractor). The two subsequent experiments which included slight modifications yielded similar results.

Lupker suggested that while priming with semantically related stimuli may not produce facilitation in the absence of an associative relationship, it may augment the priming available from associative relationships when both are present. Conversely, priming in a naming task may be solely a function of associative relations, with semantic similarity alone having no effect. Experiment 4 explored this issue. Results indicated that the existence of a semantic relationship (e.g., leg-hand) between prime and target did nothing to augment priming derived from an associative relationship (e.g., camel-hump) in a naming task. The size of the priming effects with (e.g., lion-tiger) and without (e.g., harpoon-whale) a category relationship were essentially identical.

Experiment 5 was a replication of Fischler's (1977) procedure. It was an attempt to demonstrate semantic priming without association in a sequential lexical decision task. Since semantically related stimuli produce little if any priming in a naming task (Experiments, 1, 2, and 3), any priming in a lexical decision task would suggest that the effects of semantic relationship are task dependent. The stimuli used were items which were semantically related, but had no degree of association. Results of the sequential lexical decision task determined that a semantic relationship alone could produce priming. A significant 26 msec relatedness effect was obtained.

Lupker claimed that this result both supported Fischler's findings, and reinforced the conclusion that the effects of semantic relatedness are task dependent. Moreover, all of the experimental results support the idea that the input priming observed in naming tasks may be influenced solely by associative relatedness, while semantic factors determine the amount of priming available at the post-input level accessed by the lexical decision task.

His sixth experiment was designed to further assess this idea. The task was once again lexical decision, and half the stimuli were strong associates, while the remainder were composed of two members of the same semantic category, which were not associates. If input priming is a function of associative strength, associatively related stimuli would benefit from the facilitation. Moreover, if post-input priming is a function of semantic relatedness, only the pairs sharing semantic features should benefit from this process. Thus, the semantically related pairs should produce a larger priming effect than pairs which are just associatively related.

Results once again indicated that priming was predominantly influenced by associatively related stimuli. Semantically similar pairs did not augment this facilitation.

Lupker concluded that within the semantic network, the majority of the activation which spreads to neighbouring nodes appears to spread along direct associative links. Any activation spreading along semantic links between infrequently associated concepts would have a restricted range. While purely semantic relationships can produce priming in a lexical decision task, they do nothing to augment the priming provided by associative relatedness. However, the amount of priming provided by a semantically related stimulus pair is task dependent. The amount of priming observed in the LDT (Experiments 5 and 6) was substantially larger than that observed in naming tasks using the same stimuli (Experiments 1-4).

Lupker suggested a model to account for these results, one which proposed two primeable processes. The first would be a pre-access process that can be facilitated by activation spreading along the links of a network of direct associations. Semantic links between infrequently associated concepts would have no part in this stage of processing. The second would be a post-access process which can be influenced by semantic relationships.

Lupker's findings raise some important questions. He has argued that the semantic network accounts of priming are incomplete, and suggests that a full understanding of the nature of priming will involve a more thorough analysis of what the subject does with the word after accessing the lexicon. There have been no reports of priming studies utilizing semantic memory which have attempted to control for associative relationships between primes and targets.

The studies of Brown (1979; 1981) and Blaxton and Neely (1983) do not control for association. The stimuli for these studies were selected on the criterion of semantic relatedness. All of these studies report inhibitory effects with semantic primes, seemingly contradictory to the postulates in the semantic network models. However, these researchers do not offer any explanation for this effect, other than the presence of inhibitory mechanisms within the semantic network.

It is possible that the effects described by Brown and by Blaxton and Neely are entirely associative. Thus, the inhibiting effect of semantic priming may result from the associative relationships between primes and targets and not from their semantic relatedness. To answer this question, it is necessary to study both semantically and associatively related primes and targets. As such, a second purpose of the present investigation involves the control of association between primes and targets. Half the primes and targets will be associatively related, while the remainder will be semantically related. Such a manipulation may provide a better understanding of the inhibitory effects which accrue with the active retrieval of a number of category instances.

Generation involves active retrieval (Blaxton & Neely, 1983) and is hypothesized to involve a semantic adequacy check which is depicted as a looking back process (Donaldson & Bass, 1980). Presumably, the semantic adequacy check is a post-access process. Lupker (1984) has suggested that post-access processing is influenced by semantic context.

However, the repeated retrieval (generation) of primes and targets results in inhibition. This inhibition may be dependent upon the semantic or associative relatedness of primes and targets. If post-access processing is influenced by semantic context, then generation may be differentially affected by semantically related and associatively related primes and targets, since the semantic adequacy check classifies as a post-access process.

Blaxton and Neely (1983) maintain that the repeated generation of primes inhibition in generating the target when semantically related primes and targets are utilized. However, it is possible that associatively related primes and targets may induce less inhibition, since they are more important in the pre-access processes. As such, inhibition will not accrue to the same degree in the generation of associatively related primes and targets.

However, associative relatedness should affect processes which involve a pre-access level, such as reading and speeded generation (which should preclude a looking back process) in a different fashion. Presumably, association should play a larger role in determining facilitation than semantic relatedness. Lupker has suggested that the pre-access process is facilitated by activation spreading along the links of a network of direct associations. In such a case, there should be more facilitation when reading and generating (with speed) associatively related primes and targets, as compared to any facilitation obtained with semantically related primes and targets. Moreover, such results should help clarify the nature of facilitatory effects reported in previous priming studies.

Finally, it should be noted that a parallel exists between the aforementioned concepts and the work of Posner and Snyder (1975). With associative relatedness, it is predicted that only pre-access or perceptual processing is affected and yields only facilitation. This is similar to Posner and Snyder's concept of automatic spreading activation which results in facilitation with no inhibition. As well, Lupker (1984) suggests that semantic relatedness may affect post-access or conceptual processing, and can yield either facilitation or inhibition. This latter concept is analogous to Posner and Snyder's conscious attention mechanism.

Method

Participants

One hundred and forty eight male and female students from Wilfrid Laurier University participated. The majority (76) of participants were selected from an undergraduate student subject pool. The remainder were graduate (10) and undergraduate (62) students personally recruited by the experimenter. All participants were native English speakers, and none had previously participated in a priming study. Thirty seven participants were randomly assigned to each of the four conditions.

Design

The design was a 4 (groups: generate-generate, read-read, speeded-generate-read, read-recheck-generate) X 2 (number of primes: one or four) X 3 (type of item: associate primes and targets, semantic primes and targets, and unrelated primes and targets) X 2 (trial type: prime or target) mixed factor design. The within subject variables were prime number (1 or 4) and type of item (associate, semantic, or unrelated). The between subjects variable was the task performed on the primes and targets. Group 1 generated both primes and targets. Group 2 read both primes and targets. Group 3 generated primes with a time restriction, and read the targets. Group 4 read and then checked the semantic adequacy of the primes, and generated the targets. The dependent measure was reaction time to either read or generate the target item.

Materials

The semantic and unrelated primes and targets were selected from the Horton (1983), Hunt and Hodge (1971), and Shapiro and Palermo (1968) category norms. Postman and Keppel's (1970) word association norms were utilized for the associate primes and targets. In total, 100 categories were selected for the construction of the word lists. Each list consisted of 20 semantic primes and targets, 20 unrelated primes and targets, and 20 associate primes and targets.

Five dominant exemplars of each category were used. The target item for all trials was the most dominant exemplar of that category. A semantic trial consisted of four primes from one category (e.g., A TYPE OF FISH: bass, cod, perch, salmon) and a target from the same category (e.g., trout).

For the associate items, the first five associates to the encoding cue were used unless these contained one or more words from one of the previously selected semantic categories, in which case it was replaced with another associate of the encoding cue. The target item for associates was also the most dominant associate to the test word. An associate trial for "ASSOCIATED WITH BED" would have sheet, pillow, blanket, and rest as primes and sleep as the target.

The stimulus lists for the semantic and unrelated items were constructed using a procedure similar to that reported by Blaxton and Neely (1983). Two base lists containing the primes (Prime 1 and Prime 2) were developed. Forty categories were randomly assigned to each list, with each category represented by four primes. Two base lists containing the targets (Target 1 and Target 2) were also constructed using the same 40 categories used in the corresponding prime base lists. Each of the four base lists was divided into two blocks of 20 categories each. The 20 related trials were derived by pairing primes and targets from the same base lists, while the 20 unrelated trials were derived by crossing the primes of one list with the targets of the other. Half of the semantic and unrelated trials were one prime trials, and half were four prime trials. Each prime and target category was used equally often with semantic and unrelated items and in the one and four prime conditions.

A separate list was constructed for the associates. The prime list consisted of 4 associate primes for each of the 20 associate cues. The target list consisted of one item for each of the 20 associate cues.

These list structures resulted in eight stimulus lists. Each subject saw only one stimulus list. Each stimulus list was randomized independently for each subject by an Apple IIe microcomputer prior to presentation.

There were 10 replications of each of the 6 priming conditions (semantic one prime, semantic four prime, associate one prime, associate four prime, unrelated one prime, unrelated four prime). These 10 replications were presented in 6 blocks with each block containing 1 replication of each of the 6 within list conditions. This resulted in a total of 210 stimuli per experimental session, with a total of 60 targets, 30 one-primes and 120 four-primes. In addition, buffer trials were included at the start of each experimental session to acquaint the participant with the tasks required in the different conditions. These buffer trials consisted of a single trial for each of the 6 priming conditions for a total of 21 stimuli.

Primes and targets that were read were presented as complete words in the context of the encoding cue. When generation was required, participants were presented with the encoding cue plus an incomplete letter string consisting of the first two letters of a word (e.g., A FARM ANIMAL: HO). In the fourth condition, where participants were required to read and recheck the semantic adequacy of primes and generate targets, the semantic adequacy check mimicked that of Donaldson and Bass (1980). After reading the primes, subjects were asked to indicate on a 7 point scale how closely related the primes were to the presented encoding cue. Participants were provided with 5 pages which had each prime instance numbered, as well as a 7 point Likert type scale on which they were to record their answers. This scale was numbered from 0-6, with "0" specifying 'no relation' and "6" being 'very closely related'.

The orienting questions, primes, and targets were presented to the participants on a remote video monitor (Apple Monitor III) which was connected to an Apple IIe microcomputer. The computer recorded the response times for primes and targets by a voice activated relay device (Gerbrands G1341). Participants responded by speaking into a microphone which was attached to the voice activated relay system. Response times were determined from the onset of the primes and targets until a participant voiced a response.

Upon task completion, subjects were presented with a recognition test which served as a manipulation check. The recognition test was presented in a 6 page booklet. Ninety "old" words and ninety "new" words were presented, with fifteen of each per test page. Of the 90 old words, 36 were target items, while the remaining 54 consisted of some of the primes that had appeared with these 36 targets in the stimulus lists. One sixth (6) of the targets tested represented each of the six priming conditions. When a target in a one-prime condition was tested, the prime that accompanied it in the stimulus list was also tested. When a target in a four-prime was tested, two of the four primes were utilized. Six possible 2 item combinations of the primes were selected. Therefore, 36 targets, 18 one-primes, and 36 four-primes from the stimulus list were tested. Within the restriction that 15 "old" words appear on each page of the test booklet, the order of presentation of old and new words was completely randomized.

For every "old" word tested, a new word was chosen from the norms to serve as a distractor item. These distractors were selected from the same categories as the old test words.

Procedure

Participants were tested in individual sessions. While they were seated in front of the screen, they were read instructions pertaining to the appropriate conditions. They were told that an encoding cue would be presented, which they were to read aloud. Next a prime would be presented (either a full word, or an incomplete letter string). The participant would then be required to respond to the target as demanded by the specific condition. Participants were not informed about the differences between one and four primes, or between primes and targets, only about the various tasks required of them. The instructions included two sample questions. These sample questions were analogous to a single prime and target trial, and were specific to the orienting task condition assigned to the participant. These sample trials consisted of words from unrelated categories and were designed to familiarize the participant with the specifics of the tasks he would be performing. Unlike the experimental trials, the presentation of these trials was experimenter-controlled.

Six buffer trials were included at the start of the timed sequence of experimental trials to further acquaint the participant with the tasks associated with the different conditions. Participants were not informed that these were practice trials. These six trials were not analyzed.

In all trials in which participants read the items, the items appeared for 5 sec. In all trials in which the items were generated, the two letter cue appeared for 5 sec, with the exception of Group 3 (speeded-generate-read) in which the two letter cue appeared for 1200 msec. The encoding cue was displayed for 2.6 sec followed by the presentation of the item (or two letter cue) in less than 1 sec. There was a 1.5 sec interval between the offset of the item (or two letter cue) and the onset of the next encoding cue.

For the three groups who generated primes or targets or both (generate-generate, speeded-generate-read, read-recheck-generate) feedback was provided whenever the participant did not produce an appropriate response. The experimenter verbalized the correct response at the end of the response period. This ensured that all participants received correct primes and targets on all trials.

The recognition test was presented to participants following the completion of the experimental trials. Participants were instructed to circle 15 words they recognized on each of the 6 pages of the booklet for a total of 90 words. This requirement was designed to minimize problems of response biases across participants. The duration of the testing session ranged from 35 minutes for the speeded-generate-read group to 50 minutes for the remaining groups.

Results

In the multiple prime paradigm (Blaxton & Neely, 1983), the facilitatory and inhibitory effects of semantic primes are typically assessed with the unrelated primes as a baseline. Such comparisons are possible since the items chosen as semantic and unrelated primes are the same items used equally often in the two conditions.

Similarly, in the present study, the unrelated items were used as a baseline to measure any facilitatory and inhibitory effects of semantic items. The present study included items selected on the basis of associative properties. However, since the targets used in the associate condition were not the same as those used in the unrelated condition, it is not possible to directly compare performance in these two conditions, since other factors may covary with the associate/unrelated variable (e.g., familiarity, concreteness, imagery, etc.). Accordingly, there will be no comparisons of associate and unrelated items. The associate items will be discussed individually, with respect to the two priming conditions.

Errors

Those trials for which participants either failed to emit a response during the response period, or gave an unexpected response were excluded from the analyses, as were any trials with response times of less than 150 msec. Response times of less than 150 msec typically resulted from participants prematurely triggering the voice activated relay. Response omissions (and any other 0 responses) totaled 19.78% of the responses, while response commissions totaled 4.74% of total responses (when generation was required), and 5.3% of the responses had times of less than 150 msec.

The total number of response errors for semantic and unrelated primes and targets was computed for each subject. These errors were converted to percentages and submitted to a four-way analysis of variance. This 4 (Group) X 2 (Number of Primes) X 2 (Type of Item) X 2 (Trial Type) ANOVA yielded a significant Group X Trial Type interaction, $F(3,144)=13.66$, $MSe=196.29$, and a significant Group X Number of Primes interaction, $F(3,144)=4.67$, $MSe=63.59$. The respective Fisher LSD's were determined to be 6.38 and 3.63. The cell means for this analysis are displayed in Table 1, while the ANOVA summary table can be found in Appendix C.

In the generate-generate group, there were significantly more errors on prime trials than on target trials (16.5 vs. 10.3), and a marginally significant difference between the errors in the one prime condition and the four prime condition (11.24 vs. 14.58).

The significantly lower error rate seen on target trials relative to prime trials was most likely caused by the use of highly dominant category exemplars for targets. These highly dominant targets should be less prone to errors in generation than primes which consisted of less familiar category instances.

The results of the speeded-generate-read group are analogous to those of the generate-generate group. This group (Group 3) had significantly more errors on priming trials than on target trials, since the latter were always read (38.8 vs. 2.3). There were however, no reliable differences between the one-prime and four-prime conditions (19.8 vs. 21.9, respectively).

Any errors in the read-read group resulted from overt responses not being picked up by the voice activated relay or prematurely triggering a reaction time of less than 150 msec. The error rate (approximately 2.6%) in this group may be used as a comparison for the error rates of the other groups.

There were no differences in the percentage of errors for primes and targets (2.45 vs. 2.75), or in the one-prime and four-prime conditions (3.1 vs. 2.05, respectively).

Finally, the read-recheck-generate group demonstrated a significantly lower percentage of errors on all prime trials than on target trials, since the latter were always generated (5.9 vs. 11.9), but no reliable differences in the one-prime and four-prime conditions (8.99 vs. 8.81).

It should be noted that the average percentage of errors on the prime trials in this group is higher than that of the errors of the read group (5.9 vs. 2.4). The additional requirement of the semantic adequacy check on the prime trials of this group could have contributed to this difference. There was rustling paper which could have triggered the voice-activated relay. Similarly, the microphone could have missed some of the overt responses if participants were intent on rating the words and responded out of the microphone's range. A means of reducing such response errors would be the use of a vocal rating of the words rather than a written rating.

Overall, this analysis indicated that more errors were produced for generated than for read items, and that the targgets were less prone to errors than primes when generation was required.

The separate analysis of the associate items also yielded a reliable Group X Number of Primes interaction, $\underline{F}(3,144)=3.12$, $\underline{MSe}=53.09$, LSD=3.32, and Group X Trial Type interaction $\underline{F}(3,144)=155.89$, $\underline{MSe}=154.43$, LSD=5.69. The ANOVA summary table is displayed in Appendix D.

In the generate-generate group, there was a significantly higher percentage of errors on the prime trials than on the target trials (24.2 vs. 9.71). There were no differences between the one-prime and four-prime conditions (17.0 vs. 17.4). Similarly, the speeded-generate-read group also demonstrated a significantly higher percentage of errors to primes than to targets (53.67 vs. 3.28).

The read-read group yielded no reliable differences between primes and targets (2.45 vs. 2.33) or in the one-prime and four-prime conditions (3.3 vs. 1.5). However, the read-recheck-generate group did reveal significantly more errors on the targets than the primes (12.97 vs. 6.09), since the targets were always generated.

The results of this separate associate item analysis parallel those of the semantic and unrelated item analysis. More errors were made when associate items were generated than when they were read.

Median Target Reaction Time Analysis

The three types of items (semantic, unrelated, and associate) selected for targets in the present study were analyzed separately, both with subjects as a random factor and with items as a random factor. There were no reliable effects for associate items analyzed with subjects as a random factor, and with items as a random factor. Similarly, unrelated items revealed no significant effects when analyzed both with subjects as a random factor, and with items as a random factor. There were also no reliable effects when semantic items were analyzed with items as a random factor. However, semantic items, when analyzed with subjects as a random factor, yielded a reliable difference due to number of primes, indicating that the targets were generated reliably slower in the four-prime condition relative to the one-prime condition. With the exception of this latter finding, the results of the item analyses yielded comparable outcomes to those of the primary analyses reported below.

Median target reaction times (RTs) were the critical dependent measure. Median RTs for each participant in each priming condition were used since mean RT distributions tend to be positively skewed. The analysis included all trials for which the response to the target was correct, regardless of any errors that might have been made on the prime trials.

A 4 (Group) X 2 (Type of Item) X 2 (Number of Primes) analysis of variance (ANOVA) was performed on the semantic and unrelated target RTs. The significance level was set at .05. The ANOVA summary table appears in Appendix E. Where appropriate, reliable effects were evaluated using the Fisher's Least Significant Difference (LSD) test. The error term for the LSD was based on the mean squared error term (MSe) for the significant component.

Contrary to the predictions, and in contrast to the findings of Blaxton and Neely (1983), the Group X Type of Item X Number of Primes interaction did not approach significance, $F(3,144)=1.14$, $MSe=21763.48$. There was however, a significant main effect of group, $F(3,144)=57.15$, $MSe=147243.64$, LSD=175, indicating that the reaction times of the two "read" groups (read-read and speeded-generate-read) were considerably faster than those of the two "generate" groups (generate-generate and read-recheck-generate). There was also a reliable main effect of type of item, $F(1,144)=4.87$, $MSe=25725.35$. Reaction times to the targets preceded by related primes were faster than those to the targets preceded by unrelated primes.

Blaxton and Neely (1983) had demonstrated both facilitation and inhibition in their experiment. Specifically, in their generate-generate group, they reported a significant 139 msec facilitation effect in the semantic one-prime condition relative to the unrelated one-prime condition, and a a significant 101 msec inhibition effect with four semantic primes compared to one semantic prime. The lack of a significant Group X Number of Primes X Type of Item interaction in the present study indicates that the facilitation found for semantic items occurred equally often for one and four primes. These results are similar to those of Imhoff

(1985), who also included a generate-generate group with unrelated and semantically related items. She did not replicate Blaxton and Neely's (1983) findings of target facilitation with one related prime nor inhibition from four related primes.

The separate analysis of the associate items yielded only a significant main effect of group, $\underline{F}(3,144)=63.08$, $\underline{MSe}=112172.93$, indicating that the two "generate" groups also had longer reaction times than the two "read" groups. The Group X Number of Primes interaction was unreliable. The ANOVA summary table is displayed in Appendix F.

In sum, the target analysis did not yield findings comparable to those of Blaxton and Neely (1983). The facilitation effect of semantic items occurred equally often in the one-prime and four-prime conditions. The inhibition effect of four semantic primes reported by Blaxton and Neely was not replicated.

Separate Four Prime Analysis

The results of the median target analysis revealed a relatedness effect across the four groups. A second analysis was performed to determine what trends in RTs occurred over the priming trials. A separate ANOVA was performed on the four primes and the targets of the four prime condition. This was also a 3-way analysis of variance, a 4 (Group) X 2 (Type of Item) X 5 (Trial Type: 4 primes and 1 target) ANOVA. The dependent measure was reaction time.

A significant main effect of group was obtained, $\underline{F}(3,144)=92.15$, $\underline{MSe}=303926.36$, along with a main effect of trial type, $\underline{F}(4,576)=5.30$, $\underline{MSe}=38714.79$. The Group X Trial Type interaction was reliable, $\underline{F}(12,576)=19.90$, $\underline{MSe}=38714.79$, as was the Group X Type of Item X Trial Type interaction, $\underline{F}(12,576)=1.78$, $\underline{MSe}=32847.05$, LSD=82.59. The ANOVA summary table is displayed in Appendix G.

The primary group of interest for posthoc comparisons was the generate-generate group (see Figure 5). As can be seen, inhibition accrued steadily across the primes of both semantic and unrelated primes. For semantic primes, RTs of the fourth prime differed from the Rts of the three preceding primes. For the unrelated primes, reaction times for the fourth prime differed from the first and third primes, but not the second prime. For both semantic and unrelated items, reaction times to the targets were faster than to each of the four successive primes (1200 vs. 1387, 1320, 1477, 1599 msec, and 1232 vs. 1321, 1532, 1458, 1574, respectively).

Imhoff's separate four prime analysis also revealed a buildup of inhibition across the four primes. In her related condition, the reaction times of the fourth prime differed from those of the second prime, but not from those of the first prime.

Imhoff's results in conjunction with those of the present study illustrate that inhibition begins to develop as successive primes are generated. This inhibition effect peaks at the fourth such prime.

The read-recheck-generate group (Group 4) was conceptually similar to the generate-generate group. Contrary to the predictions, the results of the read-recheck-generate group were not identical to those of the generate-generate group. The results are displayed in Figure 6. There was no evidence of inhibition developing across the primes. Moreover, there was the suggestion of a facilitatory effect of relatedness, seen in the nonsignificant 54 msec facilitation effect at the semantic target compared with the unrelated target. There was however, a significant increase in the RTs to the target relative to the primes, since the targets were generated (231 msec for semantic items; 267 msec for unrelated items).

The results of this group, specifically the lack of inhibition across the successive semantic primes, suggests that inhibition requires the specific process of generating both primes and targets (active retrieval of exemplars, cf. Blaxton & Neely, 1983). Augmenting the process of reading with the semantic adequacy check may equate recall to that of generating (Donaldson & Bass, 1980). In fact, as the recognition hits analysis will show, there were no differences in the proportion of recognition of the read-recheck-generate and generate-generate groups. However, reading and rechecking may not promote the self-generation of related exemplars when successive instances of a category are presented. Generating repeated exemplars of a category affords the opportunity for the self-generation of appropriate exemplars. This self-generation may produce the demonstrated inhibition effect. The results for this group suggest that, if it were methodologically possible to prevent the self-generation of exemplars of the test category, inhibition would not develop in a multiple prime condition.

The two read groups also produced somewhat unexpected results. It had been predicted that type of item would have an effect on RTs, namely that semantic items would have significantly shorter RTs than unrelated items, but that inhibition would not develop (cf. Blaxton & Neely, 1983). However, while clearly no inhibition developed across the successive primes, the read-read group also showed no evidence of facilitation with semantic primes relative to unrelated primes, with a nonsignificant 16 msec difference in the respective targets. The results are displayed in Figure 7.

In a separate analysis of the read-read group, Blaxton and Neely (1983) found a significant 25-msec facilitation effect for semantic items compared to unrelated items. A similar analysis on the present data revealed no reliable effects. The ANOVA summary table for this analysis can be seen in Appendix H.

It is not immediately apparent why these data differ from those of Blaxton and Neely (1983). One possibility is that the items used in the present study were somewhat different. The items utilized in the present study, though obtained from the same norms as Blaxton and Neely (1983) (with the exception of Horton, 1983), differed substantially from the 80 categories selected by Blaxton and Neely: Only 6.25% of their semantic categories were used here.

Other factors may also be critical. Blaxton and Neely (1983) presented each prime and target for 8 sec, while the present study used a display time of 5 sec. Moreover, the inclusion of associate items in the present study was unique, and may have resulted in some unspecified carryover effects on the semantic and unrelated items. Finally, the present criterion of excluding any RTs of 150 msec or less also differed from Blaxton and Neely's procedure. They did not eliminate any responses in their read-read group. This criterion led to the elimination of 2% of the data in the present read-read group.

Similar results (to those of the read-read group) were obtained for the speeded-generate-read group. There was no evidence of a facilitatory effect of semantic relatedness, with a nonsignificant 27 msec facilitation effect at the semantic target compared with the unrelated target. However, target RTs were reliably faster than those to the fourth prime, since the targets were read (105 msec for semantic items; 96 msec for unrelated items). Figure 8 illustrates these results.

The separate four-prime analysis of the associate items yielded a main effect of group, $F(3,144)=110.58$, $MSe=213680.49$, and a significant Group X Trial Type interaction, $F(12,576)=6.71$, $MSe=64798.25$, LSD=116.

Associate items, in the generate-generate group produced unexpected results. It had been predicted that RTs to the associate items in the generate-generate group would not differ across successive primes. Association was expected to have a minimal role in the generation process, since generation is a post-access process (Lupker, 1984). Lupker had proposed that association would have greater influence in the pre-access processes such as reading.

However, contrary to these predictions, inhibition began to develop across successive associate primes. There was a significant 165 msec inhibition effect at the third prime relative to the second prime, and a reliable 242 msec inhibition effect at the fourth prime, relative to the second prime. Targets were generated 339 msec faster than the fourth prime.

Similar to the four prime analysis of the semantic and unrelated items, the read-read and speeded-generate-read groups had consistent RTs across the successive primes. The read-recheck generate group also revealed a significant difference in the RTs of primes and targets. The target was generated 300 msec slower than the fourth prime which was read.

The results of this associate four prime analysis also suggest that the significant Group X Trial Type interaction can be ascribed mainly to the effects of the generate-generate group. Inhibition was demonstrated across the successive primes. These effects disappeared in the remaining groups. Similar to the previous analysis, the read-recheck-generate group did reveal a reliable increase in RTs to the target (which was generated) relative to the primes (which were read).

The results of this separate four prime analysis suggest that the significant Group X Type of Item X Trial Type interaction can be largely attributed to the effects of the generate-generate group. Inhibition accrued across successive primes, peaking at the fourth prime. As well, there was a significant drop in target RTs compared with the fourth prime. This effect was not seen in the read-read group. However, the read-recheck-generate group did reveal a reliable increase in Rts to the targets (which were generated) compared with the primes (which were read), while the speeded-generate-read group indicated a reliable decrease in RTs to the targets (which were read) compared with the primes (which were generated).

Recognition Hits Analysis

The recognition test was administered as a manipulation check to determine if the semantic adequacy check and speeded generation tasks yielded the predicted effects. The data for the recognition analysis were subject to the same criterion as used in the reaction time analysis. Only those items which were used in the reaction time analyses were included in the recognition data analysis. The proportion of correct hits to the semantic and unrelated items which met the criterion was the dependent measure submitted to a 4 (Group) X 2 (Type of Item) X 2 (Number of Primes) X 2 (Trial Type; prime or target) ANOVA. The cell means for this analysis can be found in Table 2, and the ANOVA summary table is displayed in Appendix J.

A significant main effect of group was obtained, $F(3,136)=20.76$, $MSe=.071$, indicating that participants in the two "generate" groups (generate-generate and read-recheck-generate) recognized significantly more items than those in the two "read" groups (read-read and speeded-generate-read) (.93 vs. .80, respectively; LSD=.06). Moreover there were no differences in recognition between the two "generate" groups (.94 vs. .92) or between the two "read" groups (.79 vs. .81). These results concur with the predictions of the four groups and lend support to Donaldson and Bass' (1980) finding that a semantic adequacy check performed on read items renders them as memorable as generated items. In addition, these data show that the speeded generation task reduces memory for the generated items to that of reading.

A significant main effect was obtained for type of item, $F(1,136)=14.00$, MSe=.026. This result reflects better memory for semantic items compared with unrelated items (.88 vs. .85). A significant Group X Trial Type interaction, F(3,136)=13.92, MSe=.015, and a significant Number of Primes X Trial Type interaction, F(1,136)=8.2, MSe=.017, were found. Fisher's LSD was determined to be .06 for both these interactions. The Group X Trial Type interaction can be attributed to the significantly higher proportion of recognition in the two "generate" groups compared with the two "read" groups, as any differences in the recognition of primes relative to targets within each group were unreliable. These results indicate that (as measured by recognition) the processing of primes was equal to that of targets in all groups. One of the aims of this study was to equate the processing of primes and targets in view of Blaxton and Neely's suggestion that this factor is vital for the occurrence of facilitatory and inhibitory effects. The results indicate that the inclusion of a semantic adequacy check augmented the reading process to that of generating, while the speeded-generation task reduced the retention of generated items to that of read items.

With respect to the Number of Primes X Trial Type interaction, there were no reliable differences in the recognition of primes and targets in either the one-prime or four-prime conditions. There were also no reliable differences in the recognition of primes and targets in the four-prime condition relative to the one-prime condition.

The proportion of correct hits for the associate items was submitted to a 4 (Group) X 2 (Trial Type) X 2 (Number of Primes) ANOVA. This ANOVA summary table is displayed in Appendix K.

Main effects were obtained for group, F(3,136)=13.16, MSe=.055, and number of primes, F(1,136)=26.93, MSe=.026, indicating that participants in the two generate groups also recognized significantly more associate items than those in the two "read" groups (.90 vs. .77, LSD=.11), and that there was better recognition of items in the four-prime condition than in the one-prime condition (.87 vs. .80).

A significant Group X Trial Type interaction was obtained as well, $F(3,136)=6.44$, $MSe=.023$, $LSD=.07$. While there were no differences in the recognition of primes and targets in the generate-generate, read-read, and read-recheck-generate groups, the speeded-generate-read group had a significantly higher proportion of recognition for primes than for targets (.83 vs. .73) This result can be largely attributed to the high proportion of recognition of associate primes in the associate four-prime condition (.88).

As such, the recognition hits analysis revealed that associate items in the four prime condition had a higher proportion of recognition than those in the one-prime condition. There were no differences in the recognition of primes and targets (with the single exception of better memory for primes than for targets in the speeded-generate-read group).

In sum, the two "generate" groups had significantly higher recognition compared with the two "read" groups. Most importantly, there were no differences in the recognition of primes and targets, suggesting that primes were remembered as well as targets.

False Alarms

The restriction of circling exactly 15 words per page was designed to reduce subjective bias. However, it was realized that the random assignment of distractors on each page could still allow for response bias to affect performance in the recognition test. As such, analysis of the false alarms was deemed necessary.

In the analysis of false alarms, group was the between subject factor and number of primes, type of item, and trial type (prime/target) were within-subjects factors. The latter variable is actually a dummy variable since distractors were randomly assigned to primes and targets. The proportion of distractor items chosen to the total of those distractor items corresponding to the items which met the criterion in the recognition hits analysis was the dependent measure submitted to analysis.

The 4 (Group) X 2 (Type of Item) X 2 (Number of Primes) X 2 (Trial Type) ANOVA revealed significant main effects of group, $F(3,136)=18.04$, $MSe=.06$, number of primes, $F(1,136)=88.96$, $MSe=.02$, and type of item, $F(1,136)=9.43$, $MSe=.02$. The cell means can be found in Table 3, while the ANOVA summary table for this analysis is displayed in Appendix L. The proportion of false alarms in the two "read" groups (read-read and speeded-generate-read) was greater compared to those in the two "generate" groups (generate-generate and read-recheck-generate) (.18 vs. .07; LSD=.11). A greater proportion of false alarms occurred in the four-prime condition than in the one-prime condition (.17 vs. .10), and for unrelated items compared with semantic items (.14 vs. .11).

The analysis also revealed reliable interactions of Number of Primes X Trial Type, $F(1,136)=7.49$, $MSe=.017$, LSD=.06, Type of Item X Trial Type, $F(1,136)=8.29$, $MSe=.016$, LSD=.06, and Group X Trial Type, $F(3,136)=4.72$, $MSe=.015$, LSD=.06. These results reflect a higher proportion of false alarms to the primes and targets in the four prime conditions than in the one prime conditions (.18 and .15 vs .09 and .07). With respect to the Type of Item X Trial Type interaction, none of the individual comparisons of semantic and unrelated primes and targets was reliable. Similarly, with respect to the Group X Trial Type interaction, there were no reliable differences in any of the primes and targets within each group.

The 4 (Group) X 2 (Number of Primes) X 2 (Trial Type) ANOVA of the false alarms to the associate items revealed a significant main effect of group, $F(3,136)=18.71$, $MSe=.03$, LSD=.08. The ANOVA summary table for this analysis is displayed in Appendix M. Similar to the previous analysis, the proportion of false alarms in the generate groups was lower compared to the two read groups (.05 vs. .15).

To summarize the results of the recognition data, participants correctly recognized more items in the two generate groups compared to the two read groups. There was no difference in the recognition of primes and targets within each group, indicating that the memorial retention of primes was equivalent to that of the targets. This finding offers further support for Donaldson and Bass' (1980) suggestion that the generation effect requires a specific mechanism, a semantic adequacy check. The inclusion of this check to reading bestows the same memorial advantage of generating to the read items. Conversely, a speeded-generation task may limit this check, and thereby reduce memory for such items to that of read items.

Discussion

The present study directly compared the reading and generation processes to assess their respective facilitatory and inhibitory effects in the semantic priming paradigm. Blaxton and Neely (1983) concluded that the nature of the processing carried out on the primes determines the degree of priming. Generation of multiple primes and targets (active retrieval) from a single category results in inhibition while reading of both (no active retrieval) promotes facilitation. Blaxton and Neely did not however combine these different processes into one experiment to evaluate their opposing priming effects. The two generate groups (generate-generate and read-recheck-generate) and the two read groups (read-read and speeded-generate-read) of the present study examined the dual nature of the priming effects directly. The semantic adequacy task was expected to augment the "automatic" process of reading to the level of generating (Donaldson & Bass, 1980), while the speeded generation task was designed to limit the activation of the check in generation and thereby reduce the processing of generated items to that of read items.

Contrary to the predictions, the analysis of the target data showed that Blaxton and Neely's finding of facilitation from one semantic prime and inhibition from four semantic primes was not replicated. Rather, a facilitation effect of semantic primes which occurred equally often for the one-prime and four-prime conditions was obtained.

However, inhibition developed across the successive prime trials. This inhibition that develops as successive primes are presented may result from the implicit retrieval of related exemplars (Brown, 1981). Brown's (1981) study also revealed inhibition which accrued across five successive exemplars of a category.

Brown had a 5 sec presentation of each new category name prior to the first category-letter test probe for that category. Brown hypothesized that this 5 sec interval induced participants to covertly retrieve several related category exemplars. Such a strategy would produce retrieval inhibition on subsequent tests of that category.

The inhibition that results from the successive presentation of semantic primes can be explained within the framework of Raaijmakers and Shiffrin's SAM model (Blaxton & Neely, 1983; Brown, 1981). According to SAM, when an item is retrieved from memory in response to a retrieval cue (such as a category label), the associative strength of that item to the retrieval cue increases. When that same retrieval cue is used again, there is a greater tendency for the previously retrieved item to be retrieved again, since its strength of association to the retrieval cue has been enhanced. This recurring retrieval of previously retrieved and strengthened items can block the retrieval of other category instances. As such, the increase in reaction time to retrieve additional exemplars of a category results from the retrieval of items with a higher associative strength to the retrieval cue interfering with the retrieval of other items.

The results of the present experiment (generate-generate group) can be explained within this framework as well. In the four-prime condition, an increase in RTs to generate primes was observed across the four prime trials. While the category label was not presented for 5 sec, as in Brown's study, the category label did appear for 2.6 sec prior to each two letter cue. Those 2.6 sec would allow the participant time to implicitly retrieve extra items prior to the presentation of the two letter cue. There were however, trials in which participants had not finished reading the cue before the onset of the item (as judged by the RTs of 150 msec or less). As such, the effects (implicit retrievals) would be smaller than those in

Brown's conditions. However, within the 5 second trial presentation, participants had sufficient time remaining after a response was made and before the next category label appeared to covertly retrieve additional exemplars of that category. It is possible that participants developed an implicit retrieval strategy in anticipation of the forthcoming trials. Indeed, participants consistently reported that they would generate related category exemplars in the available time during a trial.

To more directly compare Blaxton and Neely's results with those of the generate-generate group in the present study, a separate analysis was performed on the data of the generate-generate group with semantic and unrelated items only. The ANOVA summary table is displayed in Appendix N. This 2 (Number of Primes) X 2 (Type of Item) ANOVA revealed significant main effects of number of primes, $F(1,36)=7.11$, $MSe=19485.63$, and type of item, $F(1,36)=5.50$, $MSe=35897.34$. There was a significant 73 msec increase in RTs for four primes relative to one prime, and a significant 61 msec facilitation effect of semantic primes compared with unrelated primes. However, the Number of Primes X Type of Item interaction was not reliable, $F(1,36)=2.03$, $MSe=30588.49$, $p=.16$, whereas Blaxton and Neely had reported a significant two-way interaction in the analysis of their generate-generate group.

Conceivably, the large difference in the number of participants in the two studies contributed to the different findings. Blaxton and Neely tested 72 subjects per group while the present study had 37 participants in each of the four groups. The larger sample size employed by Blaxton and Neely increased their power. A calculation to estimate the sample size needed to achieve differences between the means was performed with a procedure described by Cohen (1977). Based on the mean square error term of the Number of Primes X Type of Item interaction in the separate ANOVA of the generate-generate group, it was determined that approximately 360 participants would be required to detect the interaction 80% of the time. With the current number of participants (37), the probability of detecting the interaction was only .14. A similar power calculation on Blaxton and Neely's data revealed that their probability of detecting the interaction was only .22 (with 72 participants), and that they would also require approximately 360 participants to detect the interaction 80% of the time. The results of these power calculations suggest that the "effect" which results from the generation of multiple semantic primes (inhibition) may be a very small one, requiring exceedingly large sample sizes to detect. Cohen (1977) has argued that tests of small effects have "abysmally low power" unless unusually large experiments, with large sample sizes are undertaken (p.375). However, it should be noted that these limitations which result from a small effect size may apply only to target data, when targets are the most dominant category exemplars. In the present study, inhibition was clearly demonstrated in the successive prime trials which consisted of less familiar category instances. A complete description of the power calculations can be found in Appendix O.

In a final attempt to gain more insight into the inhibition effect reported by Blaxton and Neely (1983) and Brown (1981), and suggested by the present study, a final analysis was carried out on the generate-generate group. The previous analysis had included those trials in which responses to the targets had been correct, regardless of generation errors on the priming trials. The final analysis included only those data in which all the primes, in addition to the targets had been generated correctly. Since the results of the previous analysis had only partially replicated Blaxton and Neely (1983), it is possible that there was a higher percentage of errors (14%) on the primes of the present generate-generate group than on the primes in Blaxton and Neely's generate-generate group, though this is speculative, since they do not report the percentage of errors on the primes.

Blaxton and Neely had concluded that it was the active retrieval of four successive semantic primes which results in inhibition. An analysis which included only correct prime and target trials would seem to pose a more powerful test of Blaxton and Neely's hypothesis.

As such, the separate conditional analysis included only those trials in which all the items for any given trial (primes and targets) were generated correctly. A 2 (Number of Primes) X 2 (Number of Items) ANOVA was performed on the generate-generate group using only semantic and unrelated items. This ANOVA revealed a significant Number of Primes X Type of Item interaction, $F(1,36)=6.19$, $MSe=48603.84$, LSD=104. The results are displayed in Figure 9, while the ANOVA summary table can be found in Appendix P.

The semantic four-prime condition revealed a reliable 106 msec increase in RTs compared with the semantic one-prime condition. Moreover, there was a significant 126 msec inhibition effect in the semantic four prime condition relative to the unrelated four prime condition. Blaxton and Neely reported a nonsignificant 19 msec inhibition effect in the semantic four-prime condition relative to the unrelated four-prime condition.

These results suggest that the inclusion of those trials in which all responses were correct, as opposed to those in which only the target had to be correct results in an inhibition effect both across successive semantic primes and between the semantic and unrelated items in the four prime condition. These results confirm both Blaxton and Neely's (1983) and Brown's (1981) finding of an inhibitory effect of four semantic primes, and concur with Brown's assumption that the active retrieval of several related primes is required for inhibition to occur.

However, the conditional analysis did not replicate Blaxton and Neely's facilitation effect of semantic items in the one-prime condition. There was a nonsignificant 54 msec facilitation effect for semantic items compared with unrelated items. The results of this conditional analysis suggest that the inhibitory effects of multiple semantic primes are strengthened when the active retrieval of items occurs consistently without errors on all the priming trials, whereas the facilitation effect of one semantic prime is reduced in such conditions.

It is possible that feedback may be a critical factor in these findings. Blaxton and Neely (1983) and the present study utilized feedback in prime and target presentation. If there was an incorrect response or a response omission, the appropriate response was supplied by the experimenter at the end of the trial. Such a procedure is relatively unique to the priming paradigm. Typically, participants are expected to keep trying until they supply a correct response or fail to do so entirely. However, the present study always supplied the appropriate response if it was not given. This factor may be critical to the finding of inhibition, though there appears to be no obvious explanation for such an effect.

In the present study, the results of the initial analysis did not reveal a significant inhibitory effect of four semantic primes relative to one semantic prime, an effect reported by Blaxton and Neely in a similar analysis. This initial analysis included those trials in which feedback had been supplied, since it only excluded those trials in which the target had been generated incorrectly. However, the conditional analysis of the present study included only correct trials, trials which had not required any feedback. The inhibitory effect of four semantic primes was obtained in this analysis, but not the facilitatory effect of one semantic prime.

These seemingly contrary results of the conditional analysis do not suggest a simple explanation for the role of feedback. The inhibition effect (revealed in the conditional analysis) seems to suggest that providing no feedback would produce stronger inhibitory effects (than those reported by Blaxton and Neely). However, the results of the conditional analysis also imply that feedback is necessary for the facilitatory effect of one semantic prime. Imhoff's (1985) results suggest another interpretation. Her generate-generate group received no feedback and the results showed neither reliable facilitation from one semantic prime nor inhibition from four semantic primes. Imhoff (1985) suggested that the provision of feedback could be the source of the differences between her study and Blaxton and Neely's. Participants could develop different response strategies when there is the possibility that feedback would be given if they failed to make a response.

This hypothesis could be tested quite easily. To determine the effects of providing feedback to participants, a similar design (to the generate-generate group) could be utilized. Feedback would a between-subjects variable. There would be two generate-generate groups, one with feedback, one without. Comparing these two groups may reveal whether participants respond differently to targets when feedback is provided. If feedback is the critical factor to the inhibition observed by Blaxton and Neely, then it would be expected that RTs to the targets in the condition where feedback is given would differ from a condition in which feedback is not given (Imhoff, 1985). Specifically, a significant Type of Item X Number of Primes would be obtained in the "feedback" group resulting from slower target RTs after four semantic primes than after one semantic prime. The "no feedback" group would not reveal a reliable interaction, since target RTs following four semantic primes would not differ from those following one semantic prime.

The read-recheck-generate group was included as a direct manipulation of the generation process in the priming paradigm. The semantic adequacy check was expected to equate the 'automatic' process of reading to the 'controlled' process of generating (Donaldson & Bass, 1980). This semantic adequacy check on the read items was expected to produce similar effects to that of generation, namely inhibition from four semantic primes. However, the findings of this group (separate four-prime analysis) did not support this prediction since they suggested a facilitatory effect from four semantic primes.

The addition of a semantic adequacy check to read items, which may equate the processing of these items to that of generating, does not produce an inhibition effect from multiple semantic items in the semantic priming paradigm. The result may be interpreted as consistent with Brown's (1981) assertion that inhibition results from the implicit retrieval (self-generation) of category instances in anticipation of successive tests of that category. The semantic adequacy check would appear to be an effective means of restricting these implicit retrievals of related exemplars.

Inhibition from semantic primes may be totally dependent upon the self-generation of appropriate category instances (as has been suggested previously). It may be possible to control these implicit retrievals methodologically. Visual presentation of the category label affords the opportunity for self-generation. Consistent self-reports of the participants support this notion as well. Eliminating the visual cue may reduce the possibility for implicit retrievals. An aural cue could be substituted. For example, the experimenter would provide the category label "FLOWER". Exemplars (2 letter cues) of this category would continue to appear until a new category (e.g., "VEGETABLE") was provided. Another important procedural variation would be the immediate presentation of the 2 letter cue after the encoding cue had been specified, not permitting any time for implicit retrievals. This aural cue manipulation could be directly compared to the standard visual presentation to determine whether there would be any differences in response times (e.g., would response times with the aural cue be shorter than those with a visual cue). A further measure to limit the implicit retrieval of exemplars would include the immediate removal of the letter string from the video screen upon a verbal response from the participant. Within the 5 second trial presentation of the present study, participants had sufficient time remaining after a response was made, and before the next category label appeared, to covertly retrieve additional exemplars of that category. The use of such a strategy was reported consistently by the participants. These manipulations are not expected to resolve the problem of self-generation of related category exemplars entirely. However, the presence of inhibition and the factors which determine its occurrence in semantic priming are relevant issues. As such, any attempts to gain more understanding through theoretical and methodological considerations are warranted.

Finally, the results of the two generate groups suggest that the types of operations performed on primes and targets play a key role in determining whether facilitatory or inhibitory priming effects will be obtained in semantic memory paradigms. Blaxton and Neely (1983) concluded that inhibition would occur when primes and targets were both generated (actively retrieved), while facilitation would be obtained if both primes and targets were read (no active retrieval). This latter processing would include the more automatic process of reading. The results of the generate-generate group in the present study affirm this conclusion since inhibition was produced from the generation of successive semantic primes. Moreover, these results lend further support to the assumption that covert retrieval of related category exemplars may result in this inhibition across the primes (Brown, 1981).

However, the read-recheck-generate group which also had controlled processing of both primes and targets did not show inhibition, but suggested facilitation. That the processing of primes and targets was controlled and conceptually similar to the generation of both is evident in the recognition data. There were no differences in the overall recognition of the two groups. It would appear that the processes which control the inhibitory effects in semantic priming differ from those of a semantic adequacy check which has been shown to augment the memory for read items to that of generated items (Donaldson & Bass, 1980). As such, the inclusion of a semantic adequacy check in the semantic priming paradigm does not provide a simple explanation of the inhibitory effect that results from generating multiple semantic primes.

The present study also evaluated facilitatory effects in the priming paradigm with the two read groups. It has been demonstrated repeatedly that the naming of a word is facilitated if it is preceded by a semantically related priming word rather than an unrelated prime.

Blaxton and Neely (1983) showed that when primes were read, response times were faster following semantic primes than following unrelated primes, regardless of whether there were one or four primes. This finding was not replicated by the two read groups in the present study. There was no facilitation of semantic items relative to unrelated items.

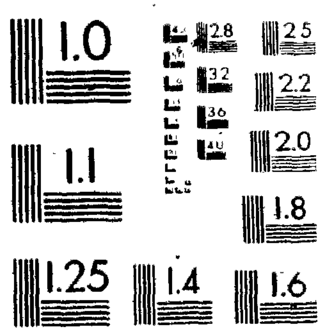
The lack of facilitation in the read-read group may also be explained in terms of the differences in item selection of the present study and Blaxton and Neely's (1983). The items in the present study were also selected from the Battig and Montague (1969), Hunt and Hodge (1971) and Shapiro and Palermo (1968) category norms as well as Horton's (1983) norms. While the sources of the words were highly similar, only 6.25% of the categories selected were identical. Moreover, Blaxton and Neely (1983) had display times of 8 sec for each trial presentation, while the present study utilized 5 sec display times. These procedural differences may seem minor, yet they may have been critical in determining the present results.

These modifications did not affect the generate-generate group in the present study to the same extent since the inhibitory effect of multiple semantic primes was replicated in the conditional analysis. Perhaps the phenomenon of inhibition in Blaxton and Neely's paradigm is more robust than that of facilitation. Generation requires deeper, more controlled processing than reading and inhibition results from the active retrieval of exemplars. As such, these processes may be less affected by subtle changes in procedure or materials. Reading, the more automatic process, may be adversely affected by such modifications.

Another factor to consider is the present criterion of excluding any reaction times of less than 150 msec. Such reaction times resulted from participants prematurely triggering the voice activated relay. Blaxton and Neely (1983) did not exclude any reaction times from the analysis of their read-read group, since they did not eliminate trials in which there were response failures or unexpected responses. This is another methodological variation which may have contributed to the different findings.

Moreover, Blaxton and Neely's read-read group had RTs of 550 msec, while the read-read group in the present study required approximately 770 msec to read an item. Thus, the longer RTs in the present study may have obscured any facilitatory effects of the semantic items.

2 OF/DE 2



To determine whether the nonsignificant facilitation effects obtained in the present study are the result of methodological differences, it is necessary to perform another experiment which would replicate Blaxton and Neely's (1983) procedure more exactly. The display time would be increased to 8 seconds, and the items would be those selected by Blaxton and Neely. Similarly, the 150 msec criterion for reaction times would not be included. These procedural modifications should yield facilitation for semantic items. If the facilitation effect remains unreliable, it suggests that the effect demonstrated by Blaxton and Neely in their variation of the priming paradigm is not a particularly robust one.

The speeded-generate-read group had virtually identical results to those of the read-read group. The predictions for this group were identical to those of the read-read group, namely, that facilitation would occur with semantic items. Similar to the read-read group, there was no facilitation. It is possible that the procedural differences outlined previously would yield facilitatory effects in this group as well.

However, the extremely high percentage of errors in this group precludes any further speculation into the causes of the unreliable facilitation effect. The speeded-generation task was expected to limit participants from activating the semantic adequacy check (Donaldson & Bass, 1980). This looking back process may result in the memorial superiority of generated items over read items. A time restriction of 1200 msec was deemed sufficiently long for generating the items, and adequately short to preclude the activation of the semantic adequacy check.

However, the time restriction proved to be too stringent. The analysis of the errors demonstrated that approximately half the primes in the four-prime condition for all types of items yielded no responses, indicating that participants were unable to generate the item within the allotted time. Judging from the mean

RTs in the four-prime conditions of the generate-generate group (1634 msec for associate, 1446 msec for semantic, 1471 msec for unrelated), a time restriction of 1500 msec may have yielded a higher percentage of correct responses for the analysis.

As such, any conclusions as to the efficacy of speeded generation in the semantic priming paradigm are premature. Replication of this group with a time restriction of 1500 msec may yield more insight into the facilitatory effects of semantic priming. However, the results of the recognition data do indicate that the task was effective in controlling any semantic adequacy check which may produce the memorial advantage in the generation effect (Donaldson & Bass, 1980). The recognition hits analysis revealed that there were no differences in the recognition scores of the read-read and speeded-generate-read groups.

It would seem that this finding lends support to Donaldson and Bass' (1980) conclusion that the generation effect has a specific mechanism, a semantic adequacy check. Moreover, it is possible to limit this semantic adequacy check by restricting the time allotted for generation. Once again, it is apparent that the processes which control the facilitation effect in semantic priming are not analogous to those processes which govern the generation effect.

As outlined previously, the speeded-generation task and the semantic adequacy check were included to directly assess the generation effect in the semantic priming paradigm. Speeded generation was expected to yield facilitation and [illegible]mantic adequacy check to promote inhibition. These two manipulations did not produce reliable priming effects of facilitation or inhibition, respectively. However, both manipulations produced the expected effects in recognition. The memory for items that underwent a semantic adequacy check was equal to generated items and superior to the memory for items which had been generated with speed or read. Generation can be viewed as a controlled process consisting of a specific mechanism, a semantic adequacy check. Similarly, the memorial results of the speeded-generation task lend further support to this position. The generation of items occurred so quickly that the semantic adequacy check could not be activated, and the typical generation effect was not produced.

Another purpose of the present study was to investigate the role of association in the priming paradigm. Words that were related through associative properties were included to gain a better understanding of both the facilitatory and inhibitory effects of primes. Lupker's (1984) model of "semantic" priming which proposed two primeable processes in the memory network was utilized to assess these effects. Lupker suggested a pre-access process that was facilitated by activation spreading along the links of a network of direct associations. The processes of reading and speeded-generation were assumed to be pre-access processes (generating within restricted time would preclude the activation of the semantic adequacy check) and as such, were expected to have little facilitation from semantic items.

The second process, a post-access process, was influenced by semantic relationships between items. Generating and the semantic adequacy check were presumed to be post-access processes. Here associative relatedness was expected to play a minimal role, with no inhibition accruing across successive primes. There would however, be inhibition from semantic primes, seen in longer target RTs after four semantic primes than after one semantic prime.

As mentioned previously, the associate condition in the present study did not utilize the same items as those in the unrelated condition, and therefore direct comparisons of the two conditions were not possible. Associate items were discussed only in terms of the one-prime and four-prime conditions.

In the read-read and speeded-generate-read groups, there were absolutely no differences in the reaction times of the semantic and unrelated items. There were also no differences in the reaction times of the associate four-prime condition relative to the associate one-prime condition.

It has been suggested that both associative and semantic priming occur as a consequence of spreading activation. The process is however, strictly limited to highly associated or semantically related words (Seidenberg, Waters, Sanders, & Langer, 1984). This stipulation of highly related words (semantic or associate) may be critical. The words selected from Postman and Keppel's (1970) association norms for the associate items in the present study were not highly associated to one another. The selection of associates was hindered firstly, by the large number (80) of semantic categories selected. None of the associates could include any of these category exemplars. Another difficulty lay in the fact that many associates are chosen as associates of discrete items, not to categories. Moreover, the most dominant associate (the target) was usually a frequent and familiar word, and occasionally an opposite of the cue (e.g., NIGHT-DAY) while the remaining four associates were often obscure words which had no clear relation or association to one another or to the target (e.g., moon, air, cool, owl).

These problems with the associate items are extremely relevant to the multiple prime paradigm. Had the present study simply utilized single associate primes and targets (e.g., bee-sting), facilitatory effects of associate primes may have resulted. Fischler (1977) has suggested that many associations develop not through category membership but through accidents of contiguity. Certainly associates such as "bee-sting" or "harpoon-whale" are of this latter type. The present study did not utilize such associates. The five associate items were all associates to a common cue. If Seidenberg et al. (1984) are correct in their assumption that activation spreads between highly associated items, the lack of facilitation of the associate items selected for the present study is not surprising.

The associate items yielded unexpected results in the generate-generate group as well. Associate items produced an inhibition effect in the associate four-prime condition compared with the one-prime condition. According to Lupker (1984), association plays a significant role in pre-access processes (e.g., reading), but has little influence in post-access processes (e.g., generating).

The increases in RTs that resulted can also be explained in terms of the items themselves, primarily the association of the items to the cue and not to one another. For example, the association between "baby" and "cane" is extremely low, though both of these words are associates to the cue "CANDY". As such, any priming of associate items would have resulted from the items being primed by the cue, and not from the items priming one another. If there was any spread of activation, it would have had to spread much farther than that required by semantic items (all words from one semantic category). This increasingly broad search of the memory network could have contributed to the significantly longer reaction times required for the generation of associate items.

It may be impossible to further address this issue of association in the multiple priming paradigm, given the limitations of the existing norms and the specific requirements of this experimental design (the inclusion of a cue). Obtaining a pool of items clearly associated with one another, and not to a specific cue, would provide valuable insight into this problem of the associate relationship between primes and targets. The use of such items in the multiple priming paradigm will also test the generalizability of Lupker's (1984) model of the two primeable processes in the memory network.

Finally, in view of the results of the present study in conjunction with those of Blaxton and Neely (1983) and Imhoff (1985), namely the discrepancies among the findings, a discussion of item effects is necessitated. As previously mentioned, the items selected for testing were analyzed separately, both with items as the random variable and with subjects as the random variable. There were no differences in these analyses with the exception of a significant interaction in the analysis of the semantic items where subjects were the random variable.

Research in cognitive processes generally assumes words to be random. Blaxton and Neely (1983), Imhoff (1985), and the present study all utilized similar sources for item selection. The use of such norms for item selection reduces sampling bias, but may not eliminate it entirely. Clark (1973) has suggested that sampling bias of words may have two effects on the experimental findings. They may spuriously increase the differences between the treatments of interest, and they may spuriously reduce the error term for the treatments effect. Either or both of these effects will lead to spuriously high estimates in the reliability of the treatment effects.

While the aforementioned studies did utilize similar sources, the words actually selected were different, thereby providing a large pool of words. However, the results of these three studies of similar design differed. Imhoff (1985) was unable to replicate Blaxton and Neely's (1983) facilitatory effect with one semantic prime and inhibitory effect with four semantic primes. The present study revealed only facilitatory effects of semantic primes in generation, and did not replicate the facilitation effect observed in Blaxton and Neely's read-read group. The items chosen in these studies may have been responsible for the different effects that were obtained. Thus, the potential item bias does introduce a cautionary note for the generalization of these effects. Generation of multiple semantic primes may result in target inhibition, while facilitation can be obtained both from the generation of single semantic primes and from the reading of such primes (Blaxton & Neely, 1983). Careful selection of items for testing, as well as additional statistical control will only strengthen any theoretical postulates of these effects.

However, given the small size of the "effect", and its low power, it remains critical to determine the origins of the inhibitory effects of semantic priming. Methodological manipulations, suggested previously, to control the implicit retrievals of related exemplars, are necessary, to assess the viability of an inhibition mechanism ~~in~~ the semantic memory network.

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TABLE 1

PERCENTAGE OF ERRORS FOR THE FOUR GROUPS AS A FUNCTION OF TRIAL TYPE, NUMBER OF PRIMES, AND TYPE OF ITEM

NUMBER OF PRIMES	TRIAL TYPE	TYPE OF ITEM: ASSOCIATE	SEMANTIC	UNRELATED
		GENERATE-GENERATE		
ONE	PRIME	25.00	14.75	12.51
	TARGET	9.05	9.24	8.45
FOUR	PRIME	23.41	17.95	16.84
	TARGET	11.37	11.43	11.97
		READ-READ		
ONE	PRIME	2.70	3.24	3.54
	TARGET	3.85	3.54	2.16
FOUR	PRIME	2.19	1.92	1.08
	TARGET	0.81	2.16	3.29
		SPEEDED-GENERATE-READ		
ONE	PRIME	51.89	35.78	38.75
	TARGET	1.89	1.91	2.97
FOUR	PRIME	55.46	39.41	42.86
	TARGET	4.67	2.43	3.27
		READ-RECHECK-GENERATE		
ONE	PRIME	6.48	6.78	6.21
	TARGET	13.24	11.70	11.37
FOUR	PRIME	5.70	5.40	5.16
	TARGET	12.70	11.14	13.54

TABLE 2

PROPORTION CORRECT RECOGNITION
FOR THE FOUR GROUPS AS A FUNCTION OF TRIAL TYPE,
NUMBER OF PRIMES, AND TYPE OF ITEM

NUMBER OF PRIMES	TRIAL TYPE	TYPE OF ITEM ASSOCIATE	SEMANTIC	UNRELATED
		GENERATE-GENERATE		
ONE	PRIME	.841	.930	.917
	TARGET	.894	.949	.949
FOUR	PRIME	.856	.918	.911
	TARGET	.935	.995	.955
		READ-READ		
ONE	PRIME	.766	.800	.797
	TARGET	.692	.797	.763
FOUR	PRIME	.775	.845	.795
	TARGET	.776	.838	.778
		SPEEDED-GENERATE-READ		
ONE	PRIME	.775	.888	.847
	TARGET	.724	.754	.724
FOUR	PRIME	.784	.880	.820
	TARGET	.786	.880	.739
		READ-RECHECK-GENERATE		
ONE	PRIME	.822	.918	.897
	TARGET	.889	.939	.908
FOUR	PRIME	.863	.896	.888
	TARGET	.882	.968	.927

TABLE 3

PROPORTION OF FALSE ALARMS FOR THE FOUR GROUPS AS A FUNCTION OF TRIALTYPE, NUMBER OF PRIMES, AND TYPE OF ITEM

NUMBER OF PRIMES	TRIAL TYPE	TYPE OF ITEM: ASSOCIATE	SEMANTIC	UNRELATED
		GENERATE-GENERATE		
ONE	PRIME	.046	.041	.014
	TARGET	.064	.027	.032
FOUR	PRIME	.079	.126	.144
	TARGET	.213	.071	.027
		READ-READ		
ONE	PRIME	.180	.156	.119
	TARGET	.200	.174	.173
FOUR	PRIME	.222	.254	.244
	TARGET	.212	.285	.216
		SPEEDED-GENERATE-READ		
ONE	PRIME	.158	.116	.119
	TARGET	.123	.151	.083
FOUR	PRIME	.205	.250	.237
	TARGET	.288	.218	.110
		READ-RECHECK-GENERATE		
ONE	PRIME	.067	.034	.041
	TARGET	.080	.050	.058
FOUR	PRIME	.137	.123	.134
	TARGET	.164	.189	.065

Figure 1. Median target reaction times of the generate-generate group as a function of number of primes and type of item.

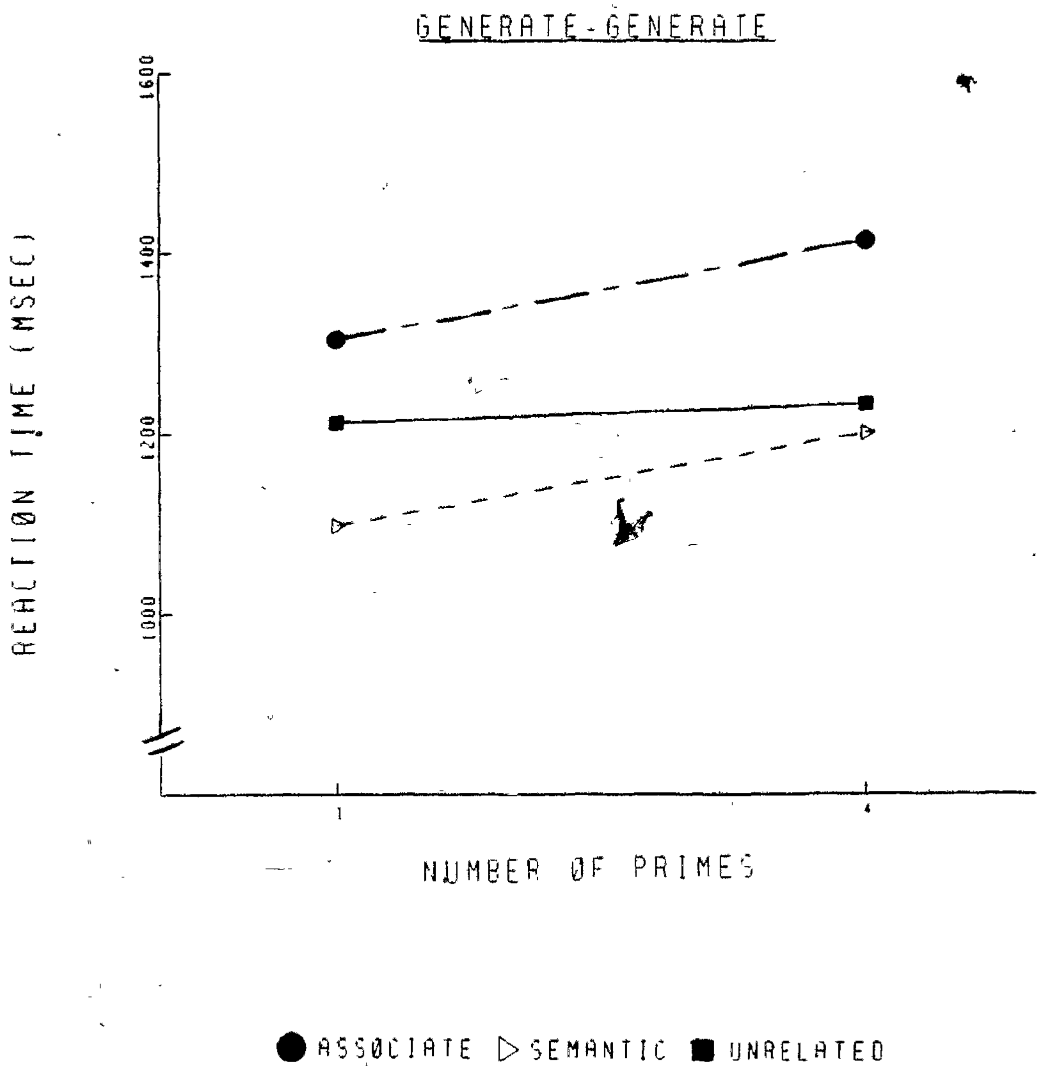

GENERATE-GENERATE
REACTION TIME (MSEC)
1600
1400
1200
1000
1
4
NUMBER OF PRIMES
ASSOCIATE
SEMANTIC
UNRELATED

Figure 2. Median target reaction times of the read-recheck-generate group as a function of number of primes and type of item.

READ-RECHECK-GENERATE

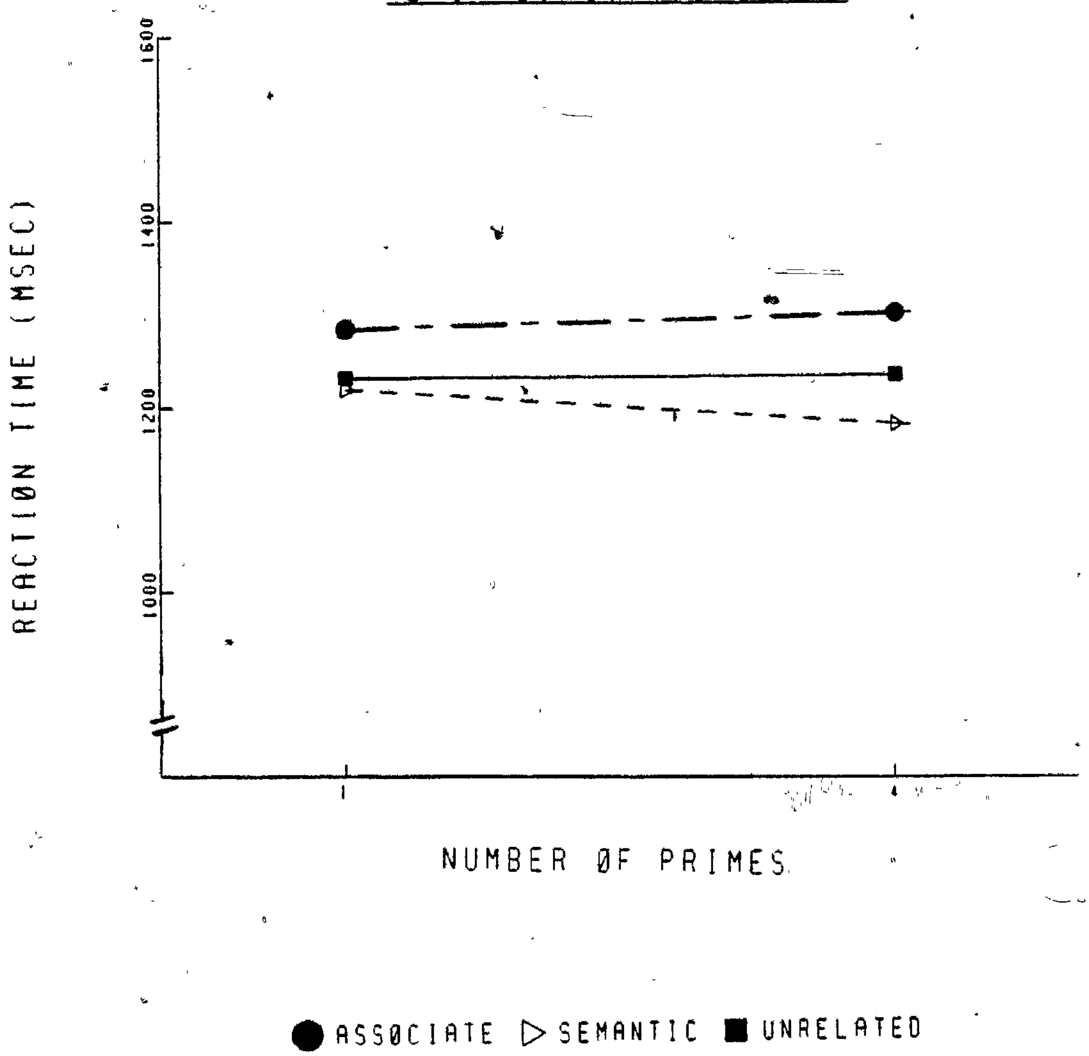


Figure 3. Median target reaction times of the read-read group as a function of number of primes and type of item.

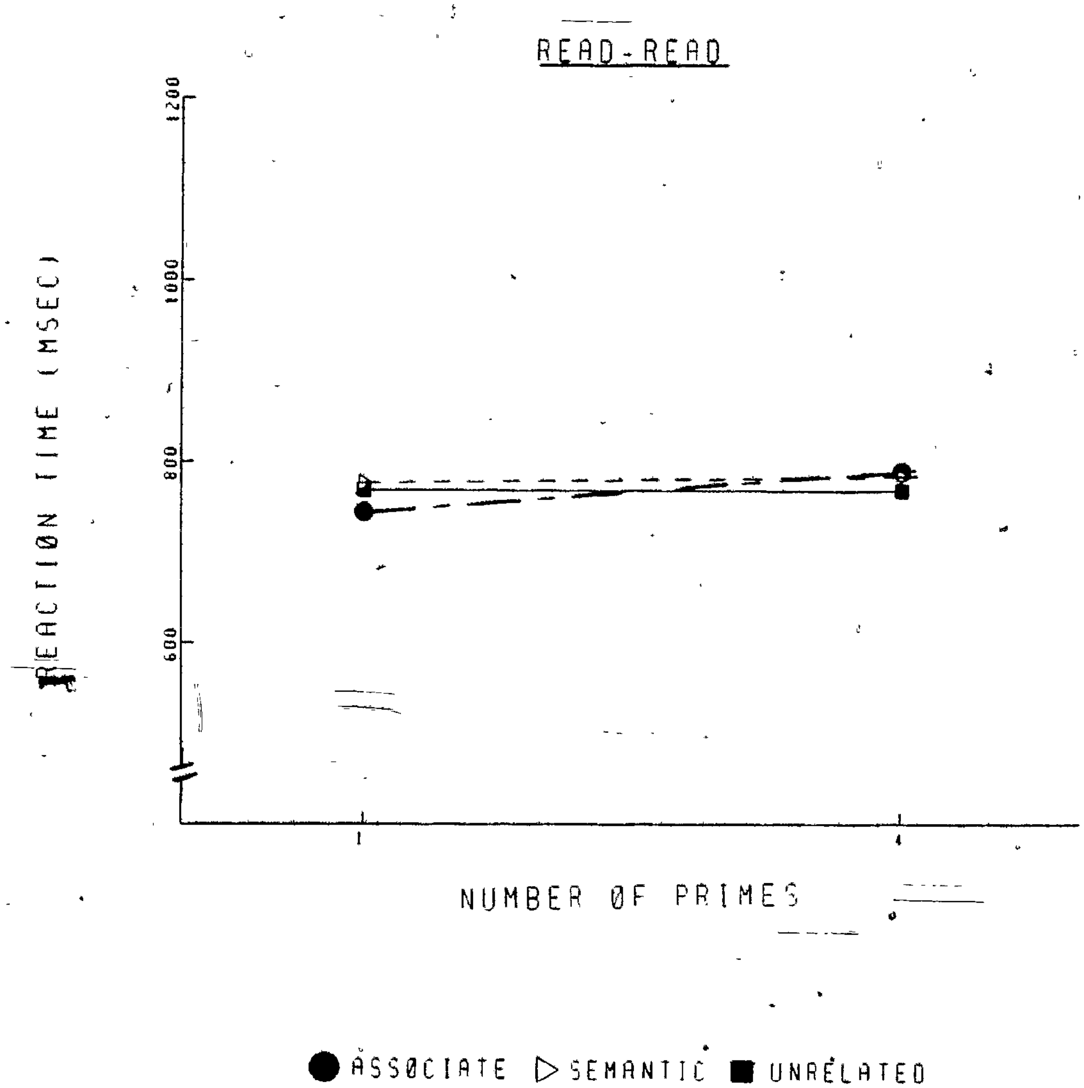

READ-READ
REACTION TIME (MSEC)
1200
1000
800
600
1
4
NUMBER OF PRIMES
ASSOCIATE
SEMANTIC
UNRELATED

Figure 4. Median target reaction times of the speeded-generate-read group as a function of number of primes and type of item.

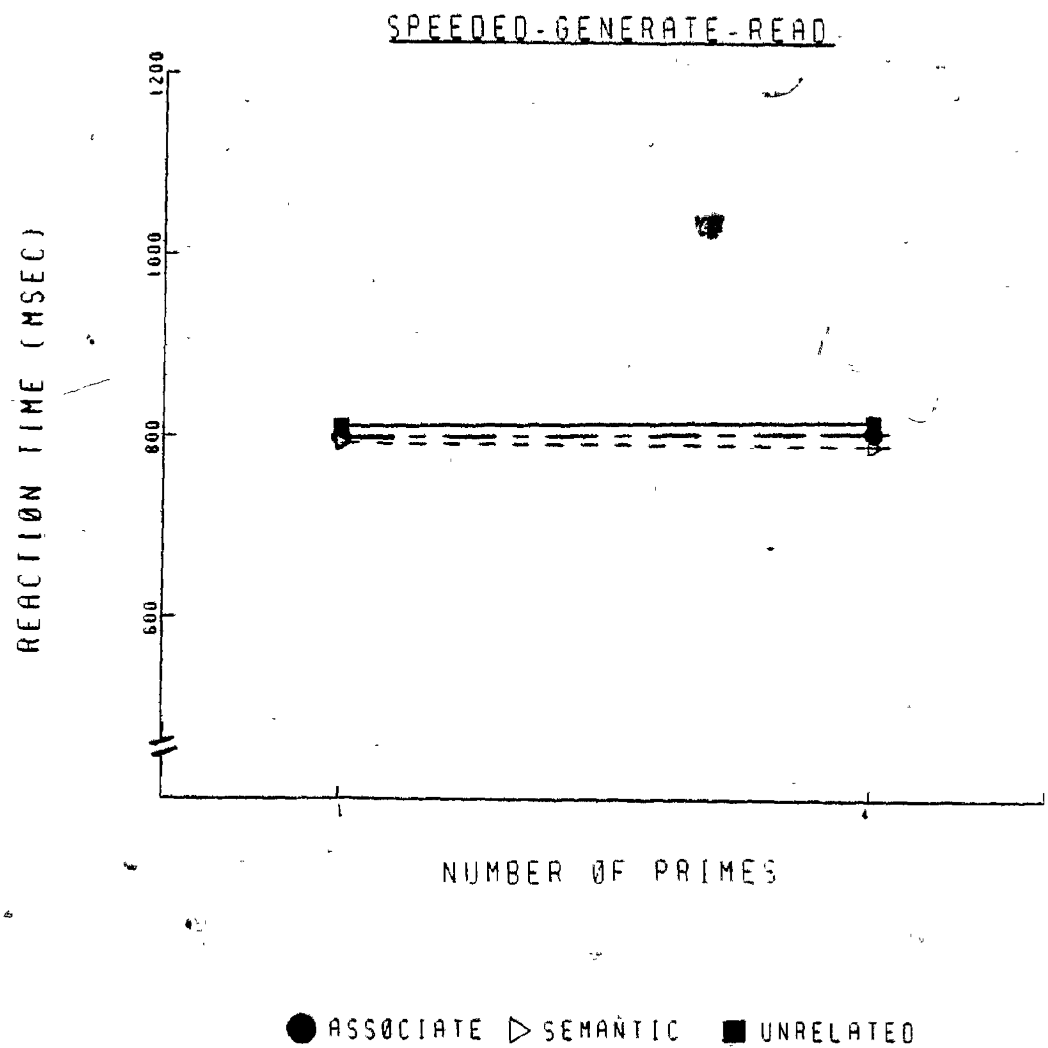

SPEEDED-GENERATE-READ
REACTIØN TIME (MSEC)
1200
1000
800
600
1
4
NUMBER ØF PRIMES
ASSØCIATE
SEMANTIC
UNRELATED

Figure 5. Median reaction times of the generate-generate group as a function of type of item and trial type.

GENERATE-GENERATE

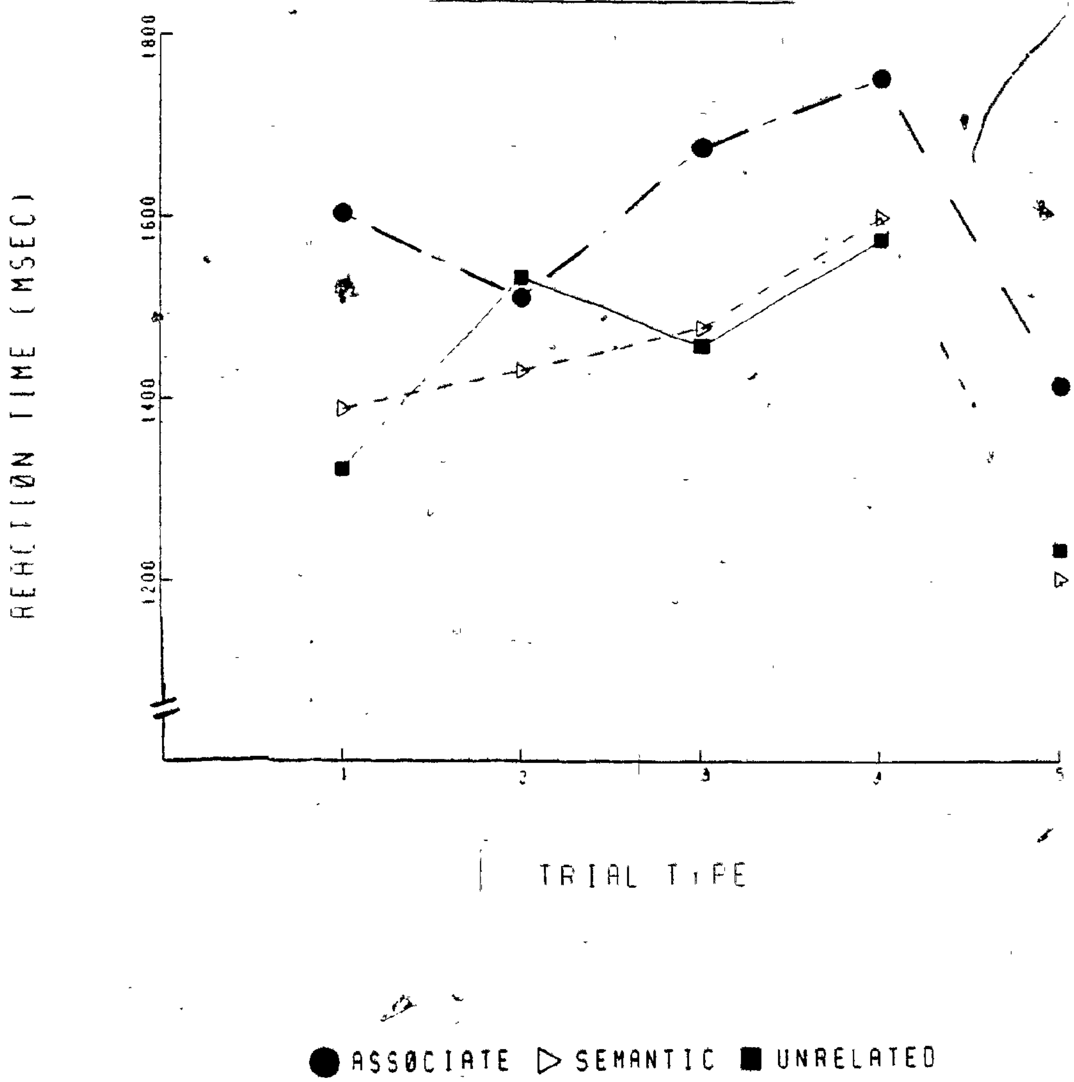
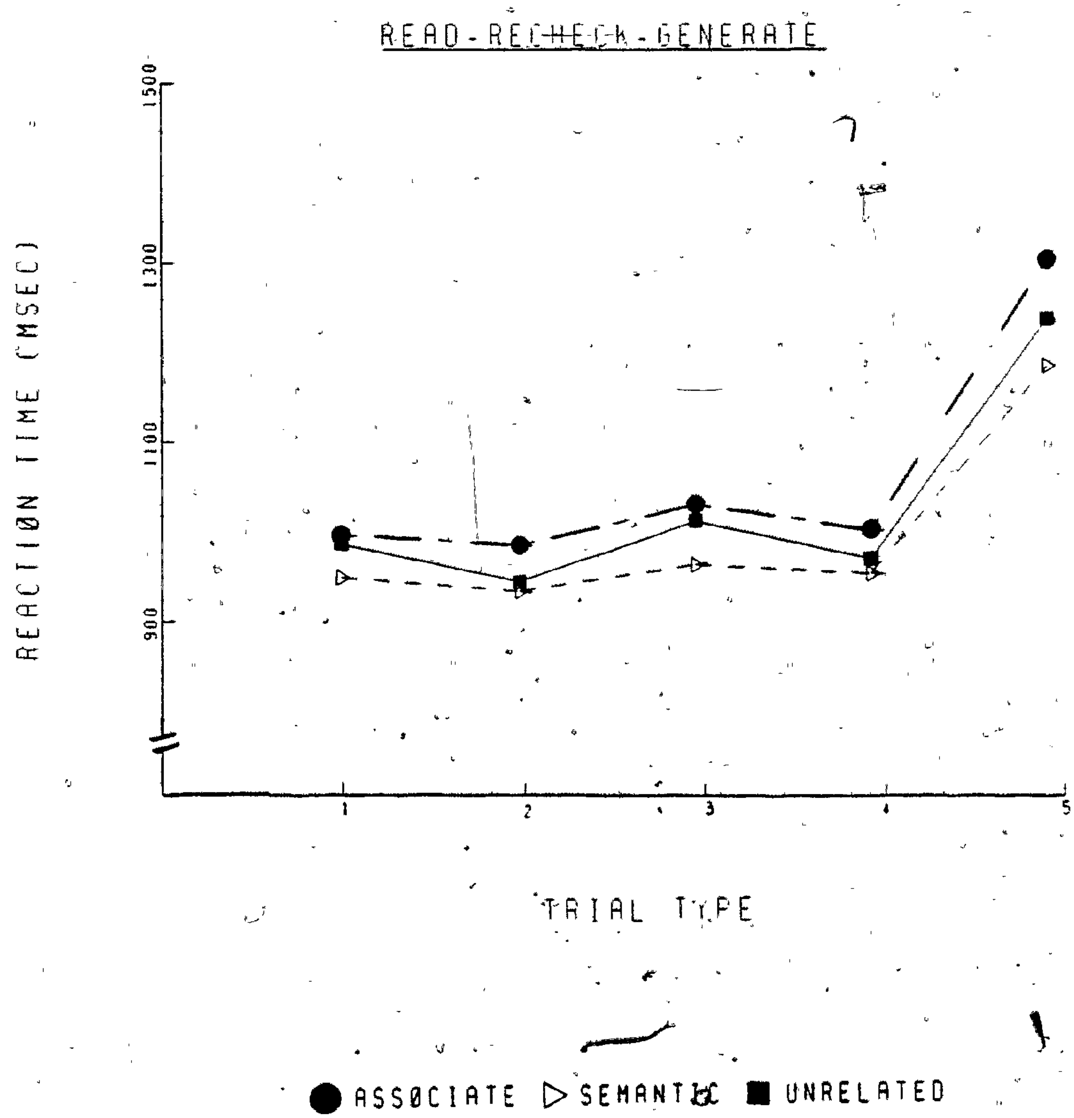


Figure 6. Median reaction times of the read-recheck-generate group as a function of type of item and trial type.


READ-RECHECK-GENERATE
REACTIØN TIME (MSEC)
1500
1300
1100
900
1
2
3
4
5
TRIAL TYPE
ASSØCIATE
SEMANTIC
UNRELATED

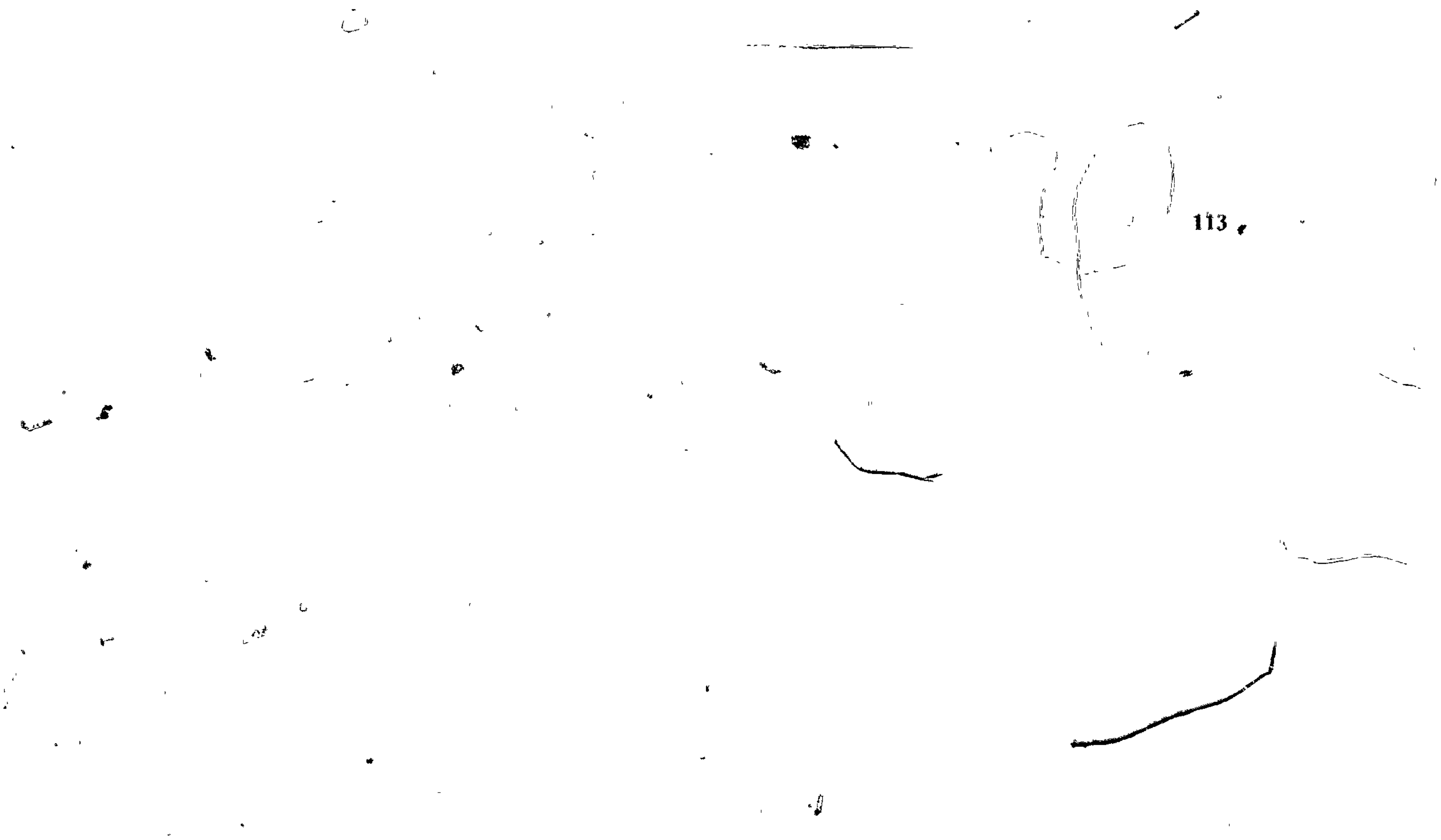
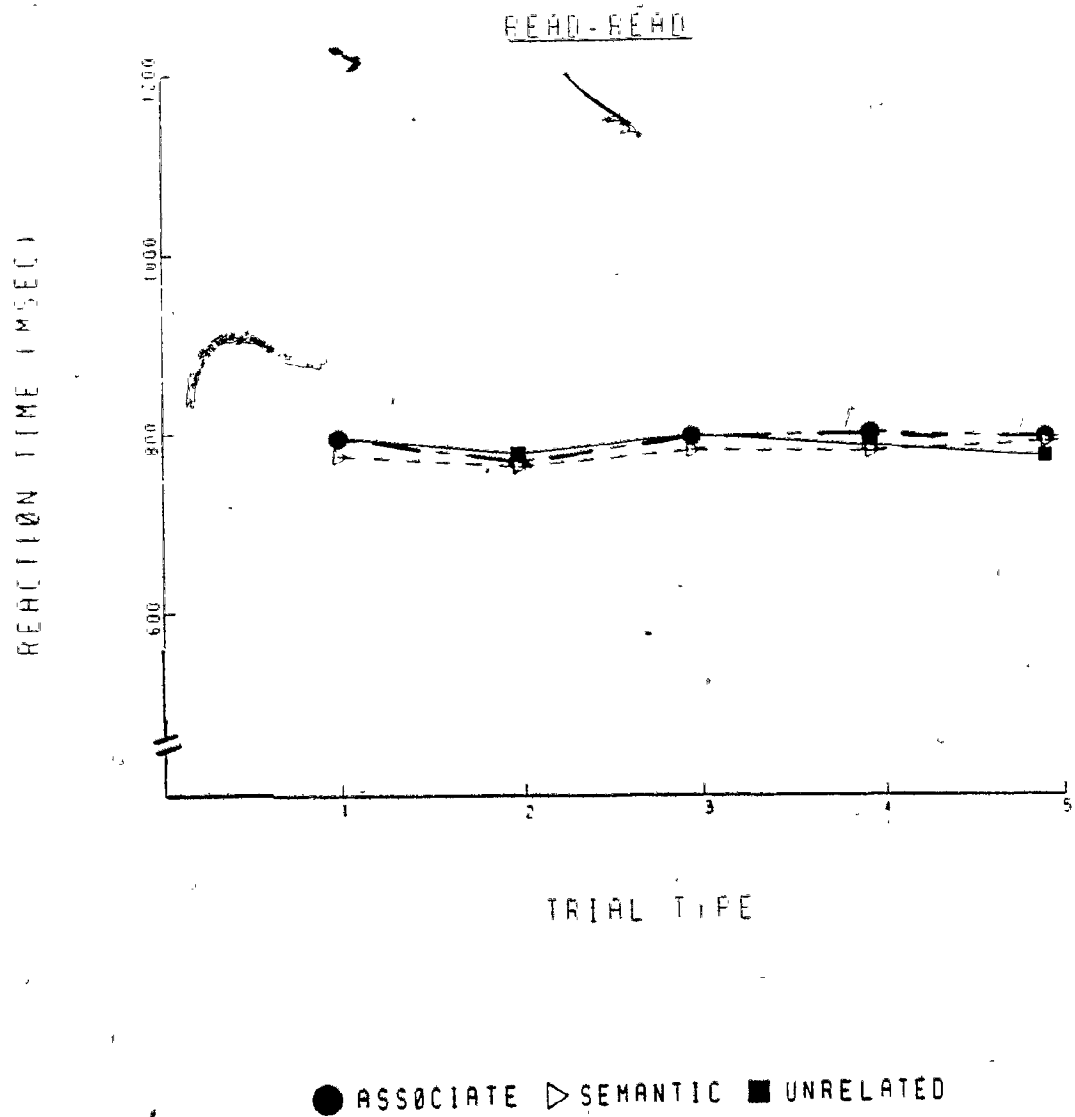


Figure 7. Median reaction times of the read-read group as a function of type of item and trial type.



READ-READ
REACTION TIME (MSEC)
1200
1000
800
600
1
2
3
4
5
TRIAL TYPE
ASSOCIATE
SEMANTIC
UNRELATED

Figure 8. Median reaction times of the speeded-generate-read group as a function of type of item and trial type.

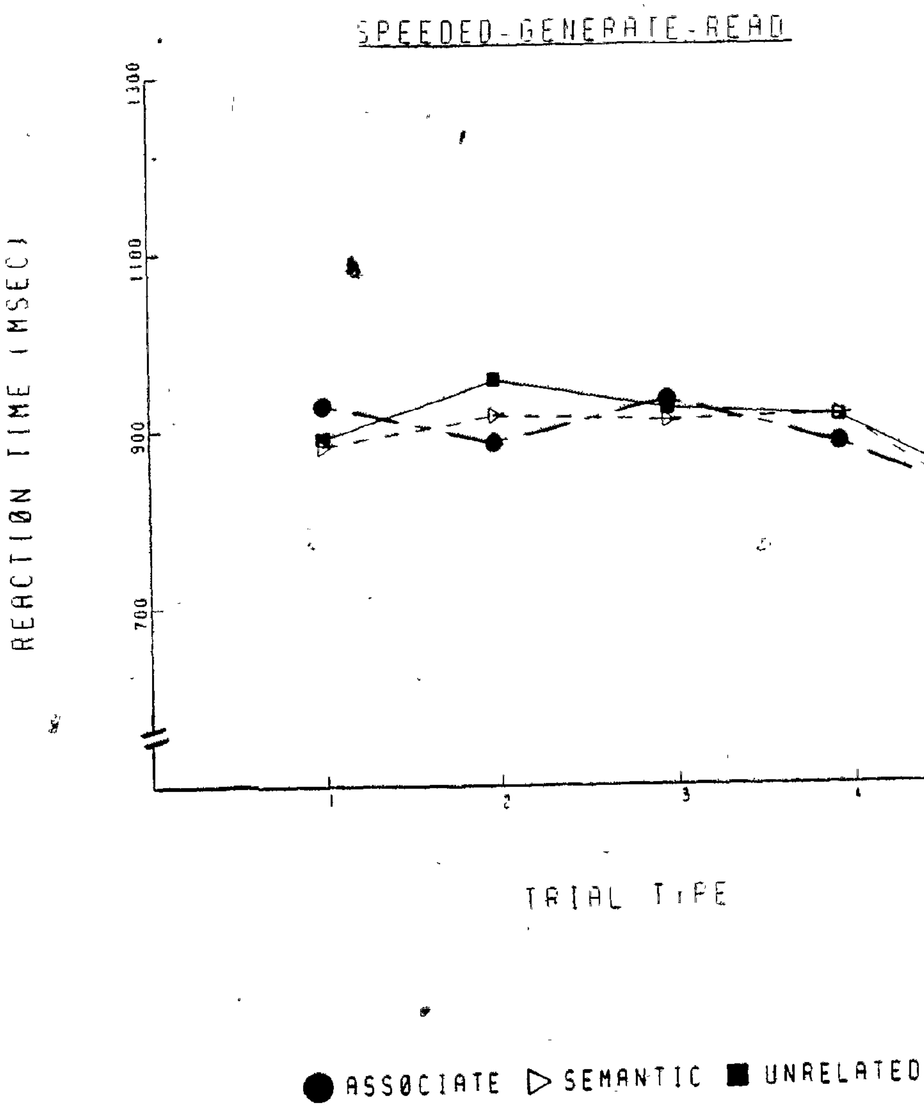
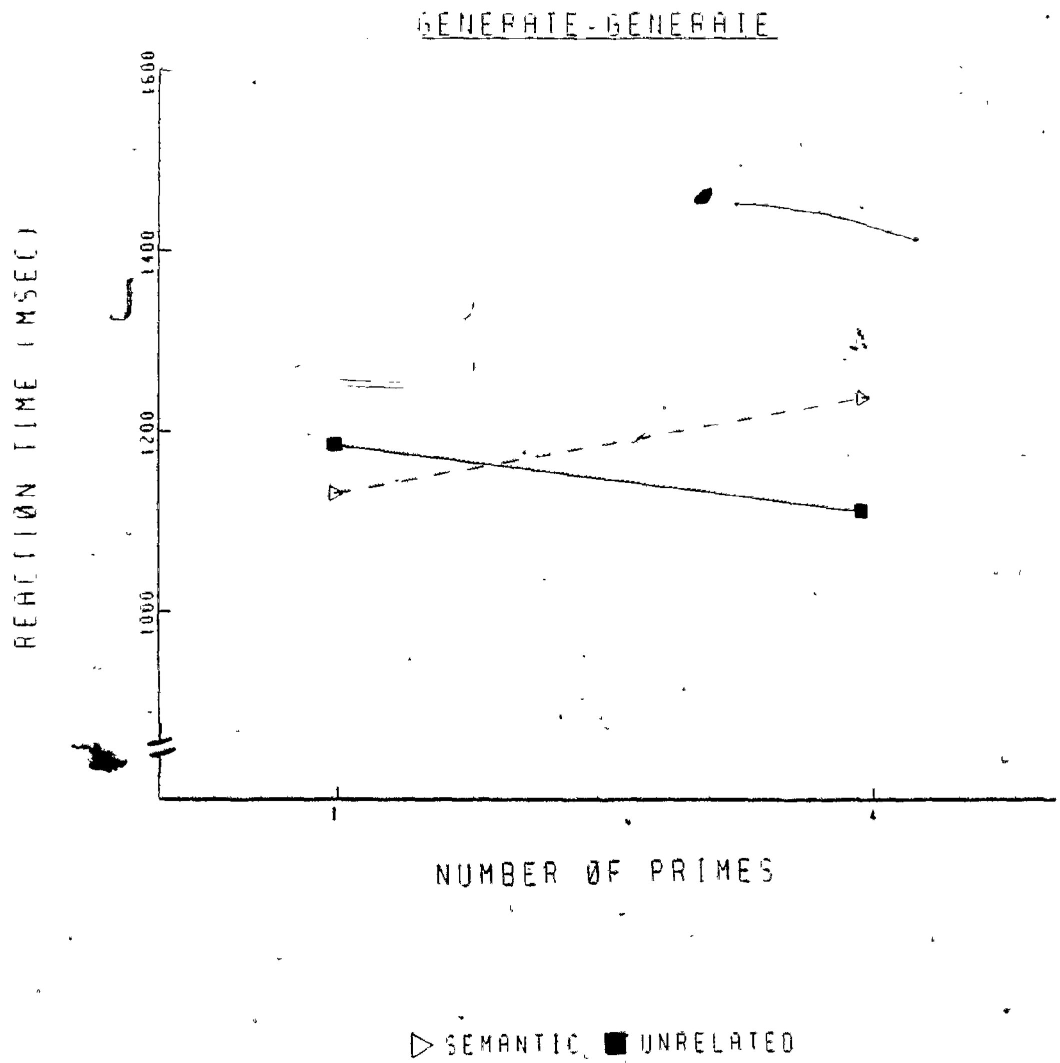

SPEEDED-GENERATE-READ
REACTION TIME (MSEC)
1300
1100
900
700
1
2
3
4
5
TRIAL TYPE
ASSOCIATE
SEMANTIC
UNRELATED

Figure 9. Median target reaction times of the generate-generate group as a function of number of primes and type of item (conditional).



GENERATE-GENERATE
REACTION TIME (MSEC)
1600
1400
1200
1000
1
4
NUMBER OF PRIMES
SEMANTIC
UNRELATED

Figure 10. Mean proportion of recognition hits of the four groups as a function of number of primes, type of item, and trial type.

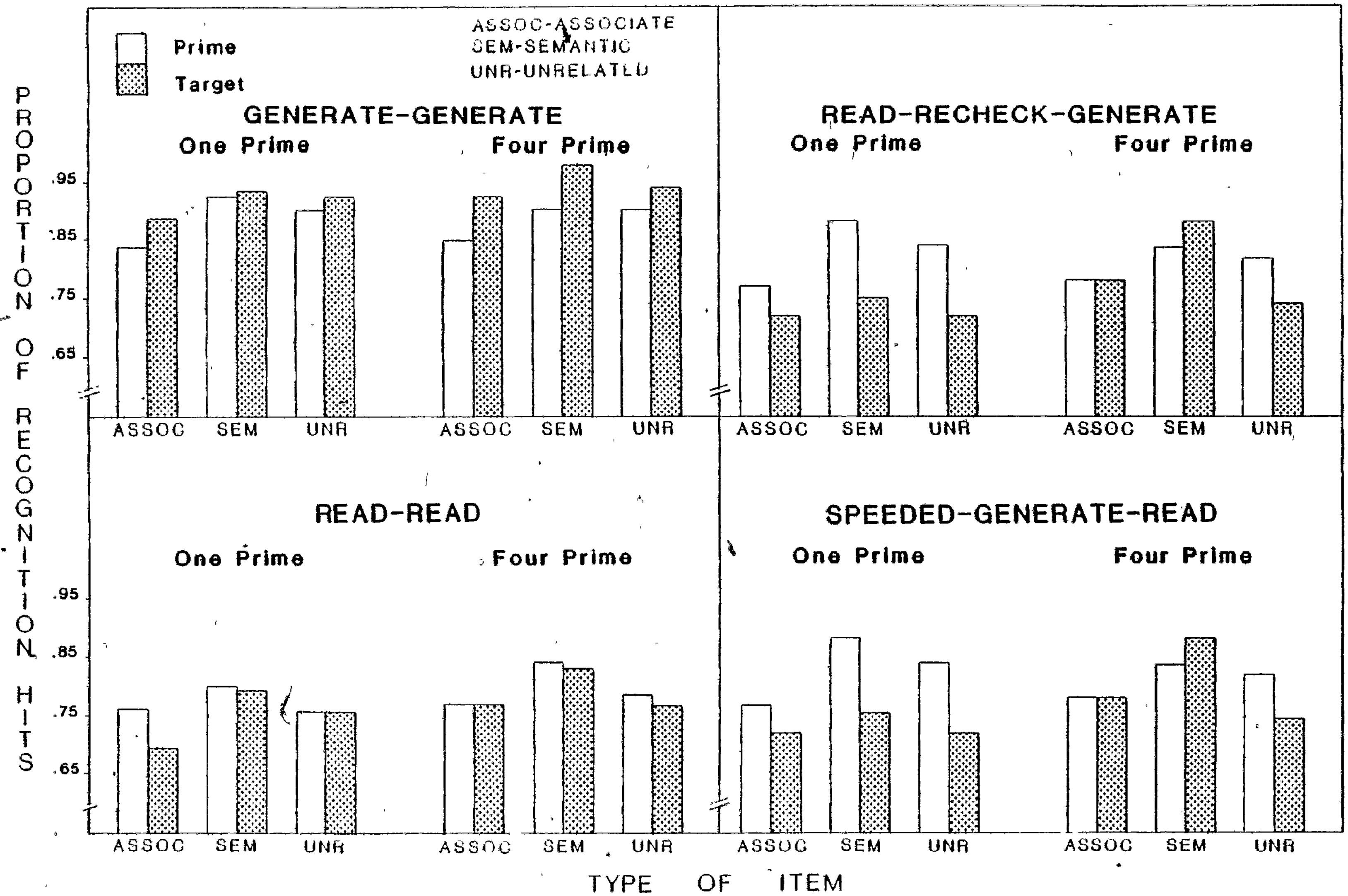
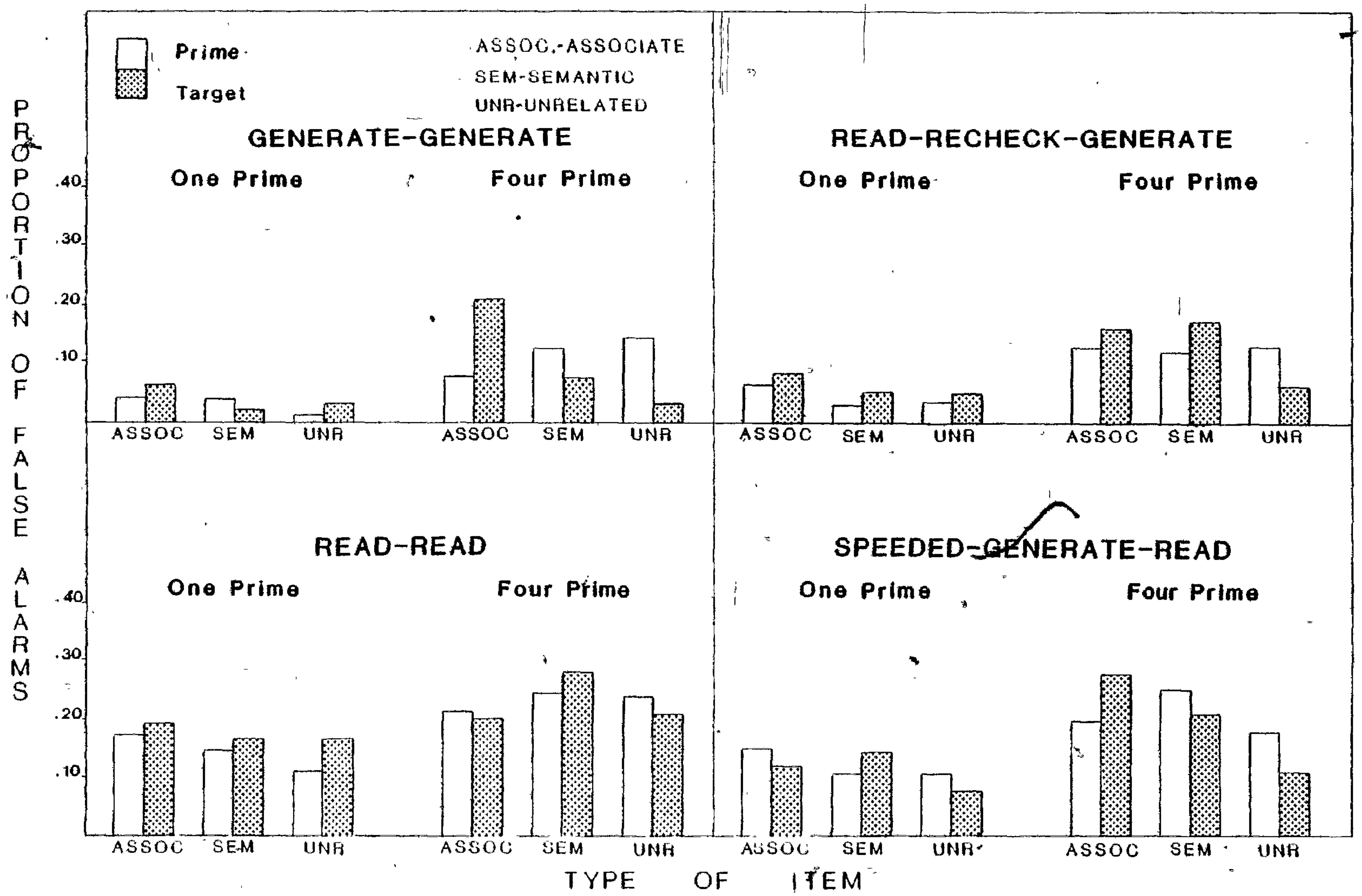

Prime
Target
ASSOC-ASSOCIATE
SEM-SEMANTIC
UNR-UNRELATED
GENERATE-GENERATE
One Prime
Four Prime
READ-RECHECK-GENERATE
One Prime
Four Prime
READ-READ
One Prime
Four Prime
SPEEDED-GENERATE-READ
One Prime
Four Prime
PROPORTION OF RECOGNITION HITS
.95
.85
.75
.65
ASSOC
SEM
UNR
TYPE OF ITEM

Figure 11. Mean proportion of false alarms of the four groups as a function of number of primes, type of item, and trial type.


Prime
Target
ASSOC.-ASSOCIATE
SEM-SEMANTIC
UNR-UNRELATED
GENERATE-GENERATE
READ-RECHECK-GENERATE
READ-READ
SPEEDED-GENERATE-READ
One Prime
Four Prime
PROPORTION OF FALSE ALARMS
.10
.20
.30
.40
ASSOC
SEM
UNR
TYPE OF ITEM

Appendix A

Semantic and associate items and cues

Semantic and associate items and cues
(for each semantic category or associate word, the cue is followed by the item. The target (denoted by *) is the last item in each case.

SEMANTIC ITEMS: LIST 1

AN ALCOHOLIC BEVERAGE
rye
rum
wine
vodka
*beer

A TYPE OF BUILDING
school
apartment
office
church
*store

A WEAPON
rifle
sword
bomb
cannon
*gun

A TREE
oak
birch
pine
elm
*maple

A MUSICAL INSTRUMENT
drum
guitar
trumpet
flute
*piano

A TYPE OF EXERCISE
jog
stretch
walk
jump
*run

A TYPE OF BIRD
sparrow
bluejay
crow
cardinal
*robin

A TYPE OF FISH
salmon
bass
cod
perch
*trout

A FOREIGN CURRENCY
pound
mark
peso
lire
*franc

AN ICE CREAM FLAVOUR
vanilla
strawberry
cherry
mint
*chocolate

A HEATING SUBSTANCE
oil
coal
electricity
wood
*gas

A CLEANING IMPLEMENT
mop
cloth
rag
sponge
*broom

A TYPE OF FASTENER
zipper
snap
hook
pin
*button

PART OF A WATCH
face
band
spring
stem
*band

AN ITEM OF FOOTWEAR
sock
slipper
sandal
boot
*shoe .

A TYPE OF READING MATERIAL
paper
novel
journal
article
*book

A UNIT OF MONEY
dime
dollar
quarter
penny
*nickel

A NUMBER
three
two
four
seven
*one

A HUMAN SENSE .
touch
hear
sight
taste
*smell

A CARPENTER'S TOOL
hammer
drill
wrench
screwdriver
*saw

A SPORT
baseball
hockey
soccer
tennis
*football

A HUMAN EMOTION
fear
happy
sad
anger
*love

A MEASURE OF DISTANCE
inch
yard
kilometre
foot
*mile

A PIECE OF HOCKEY EQUIPMENT
stick
glove
helmet
puck
*skate

A TYPE OF STORE
clothing
department
hardware
pet
*grocery

A VEGETABLE
cucumber
pea
tomato
potato
*carrot

A MEASURING DEVICE
tape
cup
scale
compass
*ruler

PART OF AN AIRPLANE
propellor
tail
cockpit
cabin
*engine

A FARM ANIMAL
dog
cow
pig
sheep
*horse

A HUMAN ORGAN
lung
brain
spleen
kidney
*heart

A GROOMING DEVICE
brush
toothbrush
hairdryer
curling-iron
*comb

A GEOMETRICAL SHAPE
circle
rectangle
hexagon
cube
*triangle

A FARM CROP
wheat
barley
oats
hay
*corn

A MEMBER OF THE CLERGY
minister
nun
rabbi
bishop
*priest

A GAME
scrabble
poker
bridge
bingo
*chess

AN ITEM OF MAKE-UP
powder
mascara
eyeshadow
blush
*lipstick

A WATER SPORT
ski
polo
scuba
surf
*swim

FOUND IN AN OFFICE
files
stapler
desk
blotter
*typewriter

A MINERAL
iron
silver
copper
zinc
*gold

A WOMAN'S UNDERGARMENT
slip
girdle
panties
nylons
*bra

SEMANTIC ITEMS: LIST 2

PART OF THE FACE
- mouth
- lip
- eye
- cheek
- *nose

FOUND IN A CIRCUS
- tent
- elephants
- trapeze
- acrobats
- *clowns

A UNIT OF TIME
- minute
- second
- month
- year
- *hour

AN ELECTRICAL APPLIANCE
- toaster
- fridge
- kettle
- oven
- *stove

PART OF A CAMERA
- light
- flash
- shutter
- screen
- *lens

ASSOCIATED WITH MAGIC
- hat
- wand
- magician
- trick
- *rabbit

A TYPE OF MEAT
- beef
- chicken
- veal
- ham
- *pork

A TYPE OF FUR
- raccoon
- fox
- beaver
- sable
- *mink

PART OF A CHURCH
- pew
- organ
- steeple
- cross
- *altar

A TYPE OF FLOWER
- tulip
- daisy
- carnation
- petunia
- *rose

A CITRUS FRUIT
- grapefruit
- lemon
- lime
- tangerine
- *orange

A GARDENING TOOL
- shovel
- rake
- hose
- spade
- *hoe

A NATURAL EARTH FORMATION
hill
river
valley
lake
*mountain

A GRAMMATICAL PART OF SPEECH
verb
adverb
pronoun
adjective
*noun

AN ARTICLE OF CLOTHING
sweater
dress
coat
skirt
*shirt

A MATHEMATICAL OPERATION
subtraction
integration
multiplication
division
*addition

A PIECE OF FISHING EQUIPMENT
pole
lure
reel
bait
*rod

AN ITEM OF JEWELLERY
bracelet
earring
watch
brooch
*necklace

PART OF A HOUSE
roof
wall
porch
attic
*door

A RELATIVE
uncle
mother
brother
cousin
*aunt

A TOY
car
truck
ball
block
*doll

PART OF A BICYCLE
tire
gears
spokes
pedals
*wheel

PART OF A BOAT
stern
bow
rudder
mast
*sail

A DISEASE
mumps
measles
malaria
polio
*cancer

A PIECE OF FARMING EQUIPMENT
combine
thrasher
reaper
plow
*tractor

AN EATING UTENSIL
fork
spoon
plate
cup
*knife

A PLANET
- Venus
- Jupiter
- Earth
- Pluto
- *Mars

A CONSTRUCTION MATERIAL
- cement
- steel
- plaster
- concrete
- *brick

A WEATHER PHENOMENON
- hail
- sleet
- hurricane
- tornado
- *rain

A SURGICAL INSTRUMENT
- forceps
- scissors
- needle
- clamp
- *scalpel

A TYPE OF CHEESE
- swiss
- cream
- sharp
- mozzarella
- *cheddar

A UNIT OF LIQUID MEASURE
- gallon
- pint
- liter
- ounce
- *quart

A TYPE OF CLOTHING MATERIAL
- silk
- polyester
- velvet
- satin
- *cotton

A WRITING DEVICE
- crayon
- pencil
- marker
- chalk
- *pen

A REPTILE
- lizard
- alligator
- crocodile
- turtle
- *snake

A CRIME
- rape
- kidnapping
- assault
- arson
- *murder

FOUND IN A RESTAURANT
- menu
- waitress
- food
- chef
- *silverware

A CHEMICAL ELEMENT
- hydrogen
- nitrogen
- carbon
- sodium
- *oxygen

A TYPE OF DANCE
- twist
- square
- folk
- tango
- *waltz

PART OF A TELEPHONE
- dial
- cord
- number
- bell
- *receiver

ASSOCIATE ITEMS

ASSOCIATED WITH DOCTOR
sick
hospital
medicine
health
*nurse

ASSOCIATED WITH WATER
water
soap
tub
shower
*clean

ASSOCIATED WITH BUTTER
yellow
soft
fat
food
*bread

ASSOCIATED WITH BED
sheet
pillow
blanket
rest
*sleep

ASSOCIATED WITH COLD
warm
snow
winter
ice
*hot

ASSOCIATED WITH HAIR
long
blonde
brown
cut
*head

ASSOCIATED WITH OYSTER
stew
sea
clam
pearl
*shell

ASSOCIATED WITH LION
jungle
roar
cage
cub
*tiger

ASSOCIATED WITH BUTTERFLY
insect
wing
bird
wing
*moth

ASSOCIATED WITH KING
England
crown
throne
George
*queen

ASSOCIATED WITH TOBACCO
cigarette
pipe
cigar
juice
*smoke

ASSOCIATED WITH TRAIN
whistle
travel
fast
station
*track

ASSOCIATED WITH CANDY
bar
apple
cane
baby
*sweet

ASSOCIATED WITH SHEEP
lamb
animal
mutton
goat
*wool

ASSOCIATED WITH NIGHT
moon
cool
owl
air
*day

ASSOCIATED WITH BLACK
dark
magic
light
night
*white

ASSOCIATED WITH TOWN
country
small
house
village
*city

ASSOCIATED WITH THIEF
robber
crook
burglar
money
*steal

ASSOCIATED WITH SEA
salt
blue
green
shore
*ocean

ASSOCIATED WITH CHAIR
leg
seat
sit
cushion
*table

Appendix B

Participant Instructions and Debriefing

INSTRUCTIONS FOR GROUPS 1, 2, 3, AND 4.

This experiment is part of an ongoing series of studies in which we hope to learn more about how people process information. In this particular experiment, the information you will be asked to deal with is common English words and phrases.

Your task is quite straightforward.

GENERATE-GENERATE (GROUP 1)...We will show you a word with some letters missing. Your task is to say what that word is. In order to help you determine the correct word, we will provide you wth some information about the word prior to actually presenting the word itself.

READ-READ (GROUP 2)...We will show you a word on the screen. Your task is to read the word. We will also provide you with some information about the word prior to actually presenting the word itself.

SPEEDED-GENERATE-READ (GROUP 3)...We will show you some words with some letters missing. Your task is to say what that word is. In order to help you determine the correct word, we will provide you with some information about the word, prior to actually presenting the word itself. We will also be showing you some complete words. These words you will simply have to read.

READ-RECHECK-GENERATE (GROUP 4)...We will show you some words on the screen. some words you will have to read. We will provide you with some information about the word prior to actually presenting the word itself. Other words will be presented with some letters missing. Your task will be to say what the word is. To help you determine what the correct word is, we will provide you with information prior to presenting these letters.

For example, the following sequence might occur. First, some information about a word will appear. (SHOW FIRST EXAMPLE CUE). You are to read this aloud as soon as it appears on the screen. This information will appear on the screen only briefly and will be replaced by the word itself. (SHOW FIRST EXAMPLE TARGET).

(GROUP 1)...Once you have determined what the entire word is, you are to say it aloud as quickly as possible. After the word has been on the screen for 5 sec, it will be removed and information about another word will be presented.

(GROUP 2)...You are to read this word aloud as quickly as possible. After the word has been on the screen for 5 sec, it will be removed and information about another word will be presented.

(GROUP 3)...Now you will have to determine what the word is as quickly as possible, since it wll only be displayed for a little more than 1 sec...The words that you have to read will be displayed for 5 sec.

(GROUP 4)...When you see a complete word which you are to read, you will also be required to check how closely the word related to the information given. You will rate the word on a 7 point scale. As you can see, "0" is no relation , while "6" is very closely related. You will circle the response that is most appropriate. The words that you have to read and then rate will be shown for 5 sec, and then information about another word will be presented...As you can see, this time some of the letters are missing, and you will have to determine what the word is. Such letters will also be shown for 5 sec.

After the word has been on the screen for 5 sec (1200 msec for primes in Group 3), it will be removed and information about another word will be presented. (SHOW SECOND EXAMPLE CUE). Again you are to read this aloud as soon as it appears. The next word will then be presented (SHOW SECOND EXAMPLE TARGET) and you are to say (read) the word aloud as soon as you know what it is.

Please note that the computer will be timing how long it takes for you to read the word aloud from the time that the word appears on the screen. Once the word appears, it is very important that the only thing you say is the correct word, since any verbal response will be picked up by the microphone. (FEEDBACK FOR GROUPS 1, 3, AND 4)

The words you have to determine from the information will be shown on the screen for 5 sec (or 1200 msec). At the end of this time, if you have not supplied a word, or have made an error, I will tell you what the word should be. The next word will then be presented.

Do you have any questions about the procedure? Please remember that both the speed and accuracy of your response to the word are important.

We will begin now.

RECOGNITION TEST

For the last part of this experiment, I would like to test your memory of the words you have just generated. In this booklet are listed some words which you read and other words which you did not see in the lists. Your task is to circle all those words which you read in the preceding task. To help you, there are exactly 15 words on each page which you read. Thus, you should circle exactly 15 words on each page. This part of the experiment is not timed.

Do you have any questions?

DEBRIEFING

That is the end of the experimental session. Because we want to keep the procedure as confidential as possible, we ask that you do not discuss any part of this experiment with anyone else. Along the same lines, we wish to wait until all experimental testing is completed before we inform the participants of the complete logic and purpose of the experiment. We anticipate that the running of subjects should be completed by April 30. At that time, we will send you a complete description of the logic and results of the experiment.

Thank you for your participation.

Appendix C

Analysis of Variance

Percentage of Errors as a function of Group, Number of Primes,

Type of Item, and Trial Type

ANALYSIS OF VARIANCE

PERCENTAGE OF ERRORS AS A FUNCTION OF GROUP, NUMBER OF PRIMES, TYPE OF ITEM AND TRIAL TYPE

SOURCE	SS	df	MS	F
MEAN	152199.14	1	152199.14	233.88*
GROUP(G)	52187.76	3	17395.92	26.73*
ERROR	93708.10	144	650.75	
NUMBER(N)	330.98	1	330.98	5.20*
N X G	891.47	3	297.15	4.67*
ERROR	9158.06	144	63.59	
ITEM(I)	31.79	1	31.79	0.56
I X G	358.57	3	119.52	2.11
ERROR	8140.64	144	56.53	
N X I	58.86	1	58.86	0.95
N X I X G	21.03	3	7.01	0.11
ERROR	8947.60	144	62.14	
TRIAL(T)	23190.54	1	23190.54	118.15*
T X G	80431.93	3	26810.64	136.60*
ERROR	28264.04	144	196.28	
N X T	1.49	1	1.49	0.02
N X T X G	368.95	3	122.98	1.81
ERROR	976 0.56	144	67.79	
I X T	3.67	1	3.67	0.06
I X T X G	175.52	3	58.51	0.97
ERROR	8701.30	144	6 0.79	
N X I X T	35.14	1	35.14	0.63
N X I X T X G	54.73	3	18.52	0.33
ERROR	799 0.12	144	55.48	

*$p < .05$

Appendix D

Analysis of Variance

Percentage of Errors for associate items as a function of Group, Number of Primes, and Trial Type

ANALYSIS OF VARIANCE

PERCENTAGE OF ERRORS FOR ASSOCIATE ITEMS AS A FUNCTION OF GROUP, NUMBER OF PRIMES, AND TRIAL TYPE

SOURCE	SS	df	MS	F
MEAN	122762.88	1	122762.88	277.14*
GROUP(G)	55401.03	3	18467.01	41.69*
ERROR	63786.84	144	442.96	
NUMBER(N)	11.64	1	11.64	0.22
N X G	496.84	3	165.61	3.12*
ERROR	7646.27	144	53.09	
TRIAL(T)	30726.73	1	30726.73	198.98*
G X I	72218.18	3	24072.73	155.89*
ERROR	22236.84	144	154.43	
N X T	1.84	1	1.84	0.03
N X T X G	203.64	3	67.88	1.08
ERROR	9056.27	144	62.89	

*$p < .05$

Appendix E

Analysis of Variance

Median target reaction time.

ANALYSIS OF VARIANCE

MEDIAN TARGET REACTION TIME

SOURCE	SS	df	MS	F
MEAN	586046046.01	1	586046046.01	3980.11*
GROUP(G)	25245252.02	3	8415084.01	57.15*
ERROR	21203084.65	144	147243.64	
NUMBER(N)	22362.64	1	22362.64	0.87
N X G	128535.04	3	42845.01	1.66
ERROR	3709784.76	144	25762.39	
ITEM(I)	125354.07	1	125354.07	4.87*
G X I	135035.29	3	45011.76	1.75
ERROR	3703010.57	144	25715.35	
N X I	3998.28	1	3998.28	0.18
N X I X G	74330.50	3	24776.83	1.14
ERROR	3133941.41	144	21763.49	

*$p < .05$

Appendix F

Analysis of Variance

Median target reaction time of associate items

ANALYSIS OF VARIANCE

MEDIAN TARGET REACTION TIME OF ASSOCIATE ITEMS

SOURCE	SS	df	MS	F
MEAN	331877896.88	1	331877896.88	2958.63*
GROUP(G)	21225985.32	3	7075328.44	63.08*
ERROR	16152901.29	144	112172.93	
NUMBER(N)	99684.54	1	99684.54	2.97
N X G	131227.36	3	43742.46	1.30
ERROR	4829573.09	144	33538.70	

*$p < .05$

Appendix G

Analysis of Variance

Median prime and target reaction time;

separate four prime analysis

ANALYSIS OF VARIANCE

MEDIAN PRIME AND TARGET REACTION TIME:

SEPARATE FOUR PRIME ANALYSIS

SOURCE	SS	df	MS	F
MEAN	1548703336.11	1	1548703336.11	5095.65*
GROUP(G)	84019797.84	3	28006599.28	92.15*
ERROR	43765396.69	144	303926.36	
ITEM(I)	170817.57	1	170817.57	2.60
I X G	32362.57	3	10787.53	0.16
ERROR	9444242.80	144	65585.02	
TRIAL(T)	820039.02	4	205009.76	5.30*
T X G	9244168.60	12	770347.38	19.90*
ERROR	22299721.47	576	38714.79	
I X T	244634.84	4	61158.71	1.86
I X T X G	702748.62	12	58562.39	1.78
ERROR	18919892.84	576	32847.04	

*$p < .05$

Appendix H

Analysis of Variance

Median target reaction time of the read-read group with semantic and unrelated items

ANALYSIS OF VARIANCE

MEDIAN TARGET REACTION TIME OF THE READ-READ

GROUP WITH SEMANTIC AND UNRELATED ITEMS

SOURCE	SS	df	MS	F
MEAN	88659378.04	1	88659378.04	903.86*
ERROR	3531233.64	36	98089.82	
NUMBER(N)	331.50	1	331.50	0.16
ERROR	73656.18	36	2046.00	
ITEM(I)	5155.42	1	5155.42	0.89
ERROR	208460.76	36	5790.57	
N X I	598.01	1	598.01	0.22
ERROR	98820.17	36	2745.00	

*$p < .05$

Appendix I

Analysis of Variance

Median prime and target reaction time; separate four prime analysis of associate items

ANALYSIS OF VARIANCE

MEDIAN PRIME AND TARGET REACTION TIME:

SEPARATE FOUR PRIME ANALYSIS OF ASSOCIATE ITEMS

SOURCE	SS	df	MS	F
MEAN	866094490.80	1	866094490.80	4049.81*
GROUP(G)	70946242.24	3	23648747.41	110.58*
ERROR	30795911.91	144	213860.49	
TRIAL(T)	505309.36	4	126327.34	1.95
G X T	5218239.68	12	434853.31	6.71*
ERROR	37323791.76	576	64798.25	

*$p < .05$

Appendix J

Analysis of Variance

Proportion correct recognition

Overall recognition hits

ANALYSIS OF VARIANCE

PROPORTION CORRECT RECOGNITION

OVERALL RECOGNITION HITS

SOURCE	SS	df	MS	F
MEAN	842.967	1	842.967	11936.30*
GROUP(G)	4.397	3	1.466	20.76*
ERROR	9.604	136	0.070	
NUMBER(N)	0.071	1	0.071	2.91
N X G	0.033	3	0.011	0.45
ERROR	3.353	136	0.025	
ITEM(I)	0.365	1	0.365	14.00*
I X G	0.084	3	0.027	1.07
ERROR	3.554	136	0.026	
N X I	0.033	1	0.033	1.34
N X I X G	0.024	3	0.007	0.32
ERROR	3.365	136	0.025	
TRIAL(T)	0.000	1	0.000	0.04
T X G	0.632	3	0.632	13.92*
ERROR	2.060	136	0.015	
N X T	0.122	1	0.122	8.24*
N X T X G	0.110	3	0.037	2.48
ERROR	2.025	136	0.015	
I X T	0.034	1	0.034	1.78
I X T X G	0.022	3	0.007	0.38
ERROR	2.586	136	0.019	
N X I X T	0.043	1	0.043	2.11
N X I X T X G	0.033	3	0.011	0.54
ERROR	2.806	136	0.020	

*$p < .05$

Appendix K

Analysis of Variance

Proportion correct recognition

Overall recognition hits of associate items

ANALYSIS OF VARIANCE

PROPORTION CORRECT RECOGNITION

OVERALL RECOGNITION HITS OF ASSOCIATE ITEMS

SOURCE	SS	df	MS	F
MEAN	391.866	1	391.866	7124.79*
GROUP(G)	2.173	3	0.724	13.16*
ERROR	7.480	136	0.055	
NUMBER(N)	0.712	1	0.712	26.93*
N X G	0.000	3	0.000	0.00
ERROR	3.596	136	0.026	
TRIAL(T)	0.021	1	0.021	0.96
T X G	0.439	3	0.146	6.44*
ERROR	3.094	136	0.022	
N X T	0.017	1	0.017	0.97
N X T X G	0.114	3	0.038	2.06
ERROR	2.506	136	0.018	

*$p < .05$

Appendix L

Analysis of Variance

Proportion of false alarms

ANALYSIS OF VARIANCE

PROPORTION OF FALSE ALARMS

SOURCE	SS	df	MS	F
MEAN	18.329	1	18.329	274.51*
GROUP(G)	3.614	3	1.204	18.04*
ERROR	9.081	136	0.067	
NUMBER(N)	1.864	1	1.864	88.96*
N X G	0.036	3	0.011	0.58
ERROR	2.850	136	0.021	
ITEM(I)	0.221	1	0.221	9.43*
I X G	0.041	3	0.014	0.59
ERROR	3.172	136	0.023	
N X I	0.057	1	0.057	3.42
N X I X G	0.036	3	0.036	0.72
ERROR	2.275	136	0.016	
TRIAL(T)	0.053	1	0.053	3.58
T X G	0.211	3	0.070	4.72*
ERROR	2.030	136	0.015	
N X T	0.209	1	0.209	11.43*
N X T X G	0.061	3	0.020	1.09
ERROR	2.492	136	0.018	
I X T	0.137	1	0.137	8.29*
I X T X G	0.067	3	0.022	1.37*
ERROR	2.251	136	0.016	
N X I X T	0.131	1	0.131	7.49*
N X I X T X G	0.027	3	0.009	0.53
ERROR	2.388	136	0.017	

*$p < .05$

Appendix M

Analysis of Variance

Proportion of false alarms to associate items

ANALYSIS OF VARIANCE

PROPORTION OF FALSE ALARMS TO ASSOCIATE ITEMS

SOURCE	SS	df	MS	F
MEAN	6.121	1	6.121	202.17*
GROUP(G)	1.699	3	0.566	18.71*
ERROR	4.118	136	0.030	
NUMBER(N)	0.062	1	0.062	3.15
N X G	0.011	3	0.004	0.19
ERROR	2.694	136	0.019	
TRIAL(T)	0.011	1	0.011	0.74
T X G	0.009	3	0.003	0.20
ERROR	2.144	136	0.015	
N X T	0.003	1	0.003	0.20
N X T X G	0.047	3	0.016	0.96
ERROR	2.247	136	0.016	

*$p < .05$

Appendix N

Analysis of Variance

Median target reaction time of the generate-generate group with semantic and unrelated items

ANALYSIS OF VARIANCE

MEDIAN TARGET REACTION TIME OF THE GENERATE-GENERATE GROUP WITH SEMANTIC AND UNRELATED ITEMS

SOURCE	SS	df	MS	F
MEAN	2089119283.89	1	208119283.89	1362.99*
ERROR	5496953.23	36	152693.15	
NUMBER(N)	138593.52	1	138593.52	7.11*
ERROR	701482.85	36	19485.63	
ITEM(I)	197319.03	1	197319.03	5.50*
ERROR	1292304.34	36	35897.34	
N X I	61992.17	1	61992.17	2.03
ERROR	1101165.96	36	30588.49	

*$p < .05$

Appendix O

Calculation of Statistical Power

The power of a statistical test is the probability that the test will lead to the rejection of the null hypothesis, i.e., the probability that it will result in the conclusion that the phenomenon exists. Power is conventionally set at .80 (Cohen, 1977). The power of a statistical test depends upon three parameters; significance criterion (alpha), ES (effect size) and sample size (n).

Significance Criterion

The significance criterion represents the standard of proof that the phenomenon exists, or the risk of mistakenly rejecting the null hypothesis. The present experiment had an alpha level of .05.

Effect Size

Effect size (ES) can be treated as a parameter which takes the value zero when the null hypothesis is true, and some other specific nonzero value when the null hypothesis is false. The ES serves as an index of the degree of departure from the null hypothesis. In a test of an interaction, the ES (f) represents the standard deviation of standardized means, the standardization being accomplished by division by the appropriate sigma σ. σ is the square root of the variance being estimated by the error mean square of the F test.

The larger the ES (f), other things being equal (e.g., significance criterion, sample size), the greater the power of the test. Similarly, the larger the ES (f), other things being equal, the smaller the sample size necessary to detect it.

Sample Size

The larger the sample size, the smaller the error, and the greater the reliability of the results. The test on interactions in factorial designs requires that n' be used for table entry.

$$n' = \frac{\text{denominator df}}{u + 1} + 1$$

u'-the number of degrees of freedom (df): For a two-way interaction, u is the product of the dfs of its constituent factors; (r - 1)(c - 1). The n' values for interactions will generally be smaller than those for the main effects. This means for any given size of effect (f), and significance criterion (alpha), the power of the interaction tests in a factorial design will on average be smaller than that of main effects, except in 2^k designs, where they will be the same.

The power of an interaction as a function of alpha, Es, and n.

The size (power) of an interaction in a factorial design can be determined as a function of alpha, ES (f), and n. The standardized ES measure of interaction is equal to.

$$f_{R \times C} = \frac{\sigma_x}{\sigma} = \frac{\sqrt{\frac{\Sigma x_{ij}^2}{r\,c}}}{\sigma} \tag{1}$$

The separate analysis of the generate-generate group obtained this value as follows. The 2 (Number of Primes) X 2 (Type of Item) ANOVA had 4 cell population means. The means for the Number of Primes component were the R means ($m_i.$), and the means for the Type of Item component were the C means ($m._j$), with a grand mean (m..). These means are outlined below.

	C_1	C_2	$m_i.$
R_1	1098.26	1212.22	1155.24
R_2	1200.39	1232.49	1216.44
$m._j$	1149.33	1222.35	1185.84 = m..

These values comprise the ES for the effects of R, C, and R X C. For the R X C interaction, the interaction effects for each cell are determined with the following formula:

$$x = m_{ij} - m_{i\cdot} - m_{\cdot j} + m_{\cdot\cdot}$$

This formula is applied to the cell means as follows:

$$x_{11} = 1098.26 - 1155.24 - 1149.33 + 1185.84 = (-20.47)$$

$$x_{12} = 1212.22 - 1155.24 - 1222.35 + 1185.84 = (\ 20.47)$$

$$x_{21} = 1200.39 - 1216.44 - 1149.33 + 1185.84 = (\ 20.47)$$

$$x_{22} = 1232.49 - 1216.44 - 1222.35 + 1185.84 = (-20.47)$$

Thus, x_{ij} values for the 2 X 2 table of means are:

	C_1	C_2
R_1	-20.47	20.47
R_2	20.47	-20.47

These values must sum to zero in every row and column. These constraints are what result in the df for the R X C interaction being u = (r - 1)(c - 1). The u value for the present interaction was (2 - 1)(2 - 1) = 1.

Applying formula (1) to these values:

$$\sigma_x = \frac{\sqrt{(-20.47)^2 + (20.47)^2 + (20.47)^2 + (-20.47)^2}}{(2)\ (2)} = 20.47$$

This value is standardized (f) if it is divided by σ.

$$\sigma = \sqrt{\text{MSe of the R X C interaction}} = \sqrt{30588.49} = 174.89$$

$$f_{R \times C} = \frac{\sigma_x}{\sigma} = \frac{20.47}{174.89} = .12$$

Based on this standardized (ES) f (.12), the significance criterion (.05), and the n' which was determined to be 19:

$$\frac{N - 1}{u + 1} + 1 = \frac{36}{2} + 1 = 19$$

The appropriate table (Cohen, 1977) will contain the power of the interaction. Using these values, the power of the interaction of the separate 2 X 2 ANOVA was determined to be .14, indicating that with 37 participants, there was only a fourteen percent chance of detecting the interaction.

This effect size f (.12) is conventionally defined as a small effect. Cohen (1977) has suggested that a small effect requires a large sample size to be detected. As previously mentioned, 360 participants would have been required to detect the interaction 80% of the time. However, had the f value been larger, (e.g. .40) a sample size of 37 would already have had power of .76, which is very close to the conventional power of .80. Cohen also indicates that unless a large ES (f) is posited (e.g., .40), power is generally poor. He suggests that with an ES (f) no larger than what is conventionally defined as small (e.g., .10), there is little point in carrying out the experiment. Unless unusually large experiments are undertaken, (e.g., with 300 participants), tests of small effects have abysmally low power.

As a final note, Cohen (1977) also suggests that in considering a completed experiment which led to the nonrejection of the null hypothesis, an analysis which finds the power was low should lead one to regard the negative results as ambiguous since failure to reject the null hypothesis cannot have much substantive meaning, when even though the phenomenon exists to some given degree, the apriori probability of rejecting the null hypothesis was low.

Appendix P

Analysis of Variance

Median target reaction time of the generate-generate group with semantic and unrelated items (conditional)

ANALYSIS OF VARIANCE

MEDIAN TARGET REACTION TIME OF THE GENERATE-GENERATE GROUP WITH SEMANTIC AND UNRELATED ITEMS (CONDITIONAL)

SOURCE	SS	df	MS	F
MEAN	201154826.39	1	201154826.39	1253.99*
ERROR	5774831.54	36	160411.98	
NUMBER(N)	9608.48	1	9608.48	0.17
ERROR	2020457.45	36	56123.82	
ITEM(I)	47467.23	1	47467.23	0.59
ERROR	2917283.71	36	81035.66	
N X I	300645.19	36	300645.75	6.19*
ERROR	1749738.19		48603.84	

*$p < .05$