Inhibition of Verbal Memory Retrieval

as a Consequence of Prior Retrieval

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Abstract

On each trial of the experimental procedure for this study, the words from a sentence were presented, one at a time, in scrambled order. After this, a recognition probe was presented. In the crucial condition, a noun occurred once early in the scrambled sentence and again as the last word in the sentence. The test word was another noun from the sentence. The test noun was recognized less well in this condition than when 1) the scrambled sentence was truncated before the repeated noun so that the test noun was presented immediately before the point at which the repeated noun would have occurred, 2) the repeated noun was replaced with an adverb, and 3) the repeated noun was replaced with a noun that had not occurred previously in the scrambled sentence. These results suggest that the test noun was inhibited in memory following the processing of repeated noun. The inhibition evidently occurred as a consequence of the retrieval of the earlier occurrence of the repeated noun. The same sort of inhibition may occur for non-antecedents following the processing of a repeated-noun anaphor.

Key Words: anaphor, antecedent, comprehension, inhibition, memory, retrieval

A wide array of processes are brought to bear in the comprehension of a discourse. Whereas some of these processes are presumably quite specialized and dedicated exclusively to the activity of comprehension, others may have more general application in the cognitive domain.

Memory processes are of particular interest in this regard. Memory is central to cognitive life, and it goes without saying that memory processes play a crucial role in comprehension. Accordingly, recent theoretical accounts of comprehension have tended to incorporate ideas from the study of memory (Graesser, Singer, & Trabasso, 1994; Just & Carpenter, 1992; McKoon & Ratcliff, 1998; O'Brien & Myers, 1999). It is not yet clear, however, exactly what role memory plays in comprehension.

One reason for the uncertainty is that memory phenomena are difficult to study in the context of comprehension. To do this, a memory task is typically administered within the framework of a comprehension task. For example, in the probe-recognition procedure, participants make recognition judgments with respect to probe words that are presented either while they are reading or after they have finished reading samples of discourse. When testing memory in the context of comprehension, the researcher must always be alert to the possibility that the participants are treating what is supposed to be a comprehension/memory task simply as a memory task. For example, participants in a probe-recognition experiment may not be processing the discourse samples as true instances of discourse but merely as sets of words upon which a memory test is to be administered (Gordon, Hendrick, and Foster, 2000). If this is what is happening, the researcher may be studying memory phenomena with no relevance to the actual process of comprehension.

Assuming that a memory phenomenon has been identified with relevance to comprehension, a further uncertainly concerns the degree of specialization in the underlying process. Does the phenomenon reflect a memory process that is specifically dedicated to the end of comprehension or does it reflect a more general memory process that is more provisionally harnessed toward that end? We need to answer this question to understand the role that the process plays in comprehension.

The present study explored one particular memory phenomenon with these issues in mind. The phenomenon in question is associated with anaphor comprehension. Over the course of a discourse, an entity may be mentioned many times. Repeated reference to the entity is established by means of anaphoric expressions. When one of these expressions is encountered, an antecedent must be located in the preceding discourse. At this point, the anaphor is said to be resolved (Garnham, 1985, 1987).

The role of memory in anaphor comprehension is indicated by accessibility shifts in the memory representation of the discourse. There is considerable evidence that an anaphor's antecedent becomes more accessible when the anaphor is resolved. It is often held that this accessibility increase reflects retrieval of the antecedent from memory (Cloitre & Bever, 1989; Corbett & Chang, 1983; Dell, McKoon, & Ratcliff, 1983; Gernsbacher, 1989; O'Brien, 1987; O'Brien, Duffy, & Myers, 1986; O'Brien, Plewes, & Albrecht, 1990). There is some evidence that other words of a discourse become less accessible when an anaphor is resolved (Corbett & Chang, 1983; Gernsbacher, 1989; MacDonald & MacWhinney, 1990; Nordlie, Dopkins, & Johnson, 2001).

A representative study of accessibility shifts in anaphor comprehension will be crucial for the present project. Gernsbacher (1989) conducted a series of experiments using the probe-recognition methodology with short, two-clause, sentences as stimulus material. In the first clause of each stimulus sentence, two characters were introduced, identified with proper nouns. At the beginning of the second clause, one of the characters was mentioned anaphorically. The anaphor consisted either of the proper noun that had originally been used to identify the character or a pronoun (e.g. Ann predicted that Pam would lose the track race, but Pam/she came in first very easily). The participant read the passage, word by word, and made a recognition judgment with respect to a test word that was presented at various points before and after the anaphor. The test word was one of the two proper nouns that had been used to identify the characters (e.g. Ann, Pam).

The point of the experiments was to track the accessibility of the character nouns. When the anaphor was a repeated noun, strikingly different patterns of results were observed for the two nouns.

The anaphor's antecedent was more accessible after than before the processing of the anaphor (the antecedent effect). In contrast, the other noun - the non-antecedent - was more accessible before than after the processing of the anaphor (the non-antecedent effect). When the anaphor was a pronoun, similar patterns were observed but in this case the differences were substantially smaller. Thus, processing of the anaphor caused different results depending on the type of anaphor and the type of test word: when probed following the anaphor, the antecedent was more accessible if the anaphor was a noun than if it was a pronoun and the non-antecedent was more accessible if the anaphor was a pronoun than if it was a noun (the anaphor-type effect).

For the present project, the most important aspect of Gernsbacher's results is the non-antecedent effect, the finding that a non-antecedent becomes less accessible as a consequence of the processing of a repeated-noun anaphor. Other studies have provided converging evidence of the reliability of this effect (Nordlie et al., 2001). Gernsbacher (1989, 1990) has interpreted the effect as evidence of a process that reduces the accessibility of non-antecedents when a repeated-noun anaphor is resolved. This process works in tandem with a process that increases the accessibility of the antecedent. The purpose of both processes is to increase the relative availability of information about the anaphor's referent, so that the anaphor may be more effectively resolved (Gernsbacher, 1990).

This interpretation may need to be qualified, however, in light of results that Gordon et al. (2000) have recently reported. Gordon et al. were primarily interested in Gernsbacher's anaphor-type effect. They presented participants sentences of the same sort as Gernsbacher except that the order of the words other than the proper nouns and the anaphors was scrambled. They probed at the ends of the scrambled sentences for what had, prior to the scrambling, been the antecedents and the non-antecedents. They observed results that paralleled Gernsbacher's anaphor type effect; the *antecedent* was more accessible when the *anaphor* was a proper noun than when it was a pronoun and the *non-antecedent* was more accessible when the *anaphor* was a pronoun than when it was a proper noun (for purposes of exposition, we will identify the different components of the scrambled sentence with the

functions that they played prior to the scrambling). Having observed these patterns using passages without discourse properties, Gordon et al. argued that the patterns might not be relevant to the processing of anaphors.

Gordon et al's results may also be relevant to interpretation of the non-antecedent effect. Of particular interest is their finding that the *non-antecedent* was more accessible when the *anaphor* was a pronoun than when it was a proper noun. Consider how this finding relates to the non-antecedent effect. In the non-antecedent effect, a non-antecedent in a sentence is less accessible when probed after a repeated-noun anaphor than when probed before that point. In the Gordon et al. results, a *non-antecedent* in a scrambled sentence is less accessible when probed after a repeated-noun *anaphor* than when probed after a pronoun *anaphor*. We can probably assume that a probe presented after a pronoun *anaphor* in the Gordon et al. study provided the same sort of baseline as a probe presented before the anaphor in studies of the non-antecedent effect; after all, the pronoun *anaphor* in the scrambled sentence was essentially empty of content. Thus, these results suggest a parallel to the non-antecedent effect, occurring with scrambled sentences: a noun in a scrambled sentence becomes less accessible as a consequence of the processing of another noun that has been repeated from earlier in the sentence.

We cannot conclusively draw this conclusion from Gordon et al.'s results, however. Gordon et al. did not test the significance of their finding that the *non-antecedent* was more accessible when the *anaphor* was a pronoun than when it was a proper noun. They reported only a significant interaction between the effects of probe type and anaphor type. This interaction had two components: the finding of interest – that the *non-antecedent* was more accessible when the *anaphor* was a pronoun than when it was a proper noun, and a complementary finding – that the *antecedent* was more accessible when the *anaphor* was a proper noun than when it was a pronoun. We cannot be sure, therefore, that the finding of interest is truly reliable. The first goal of the present study was to demonstrate this more conclusively.

If it can reliably be shown that a noun in a scrambled sentence becomes less accessible as a

consequence of the processing of another repeated noun, this may have implications for our understanding of the non-antecedent effect. To be clear about those implications, we need to know why the noun becomes less accessible. This may happen for several reasons. On one hand, the accessibility decrease may reflect a process of interference. According to this account, the crucial fact about the repeated noun is not that it is repeated but rather that it is a member of the same grammatical class as the test noun and that it has recently been processed. If the test noun is to be recognized, its memory record must be picked out among the records of the other words in the scrambled sentence. This is more difficult following the processing of the repeated noun because the records for the test noun and the repeated noun are easily confused. This is the case for two reasons. First, because the repeated and the test noun belong to the same grammatical class, their records have many of the same properties. Second, because the repeated noun has recently been processed, its record is likely to intrude. The record of the word's earlier occurrence may have been reactivated as a consequence of its recent processing, or a new record may have been created. In either case, the word's record is likely to intrude because the availability of records in the checking process depends on their strength in memory. According to this account, then, the test noun becomes less accessible as a consequence of interference from the repeated noun.

Alternatively, the accessibility decrease may reflect a process of inhibition. According to this account, the repeated noun is recognized as having occurred earlier in the scrambled sentence. As part of the recognition process, the earlier occurrence of the noun is retrieved. As a byproduct of this retrieval process, the test noun becomes less accessible. The proposed process is presumably reasonably general - when a word is repeated in a list, the earlier occurrence of the word is retrieved; as a byproduct of the retrieval process, similar words are inhibited. We cannot at this point specify the precise mechanism of the proposed inhibition. A plausible mechanism would resemble the one that has been proposed in interactive models of letter and word recognition (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982; Seidenberg & McClelland,1989). In order to determine whether a

word has occurred in a list, the word is checked against the memory records for all of the words in the list. The memory record for a word in the list becomes active to the degree that it matches the test word. The test word is judged to have occurred in the list if the level of activation for some memory record exceeds a threshold. To the degree that the memory record for a word becomes active during this recognition process, it inhibits the activation of records for similar words. The record for a noun, for example, inhibits the records for other nouns. Memory records that have been inhibited as part of the recognition process continue to be inhibited for some time subsequent to the conclusion of that process. According to this account, then, the test noun becomes less accessible as a consequence of a process of inhibition associated with the recognition of the repeated noun.

The two accounts that have been proposed of the present accessibility decrease have different implications for our understanding of the non-antecedent effect and of anaphor comprehension in general. If the accessibility decrease reflects a process of interference, it follows that the non-antecedent effect may not reflect anaphor comprehension. The interference that we see with scrambled sentences is presumably present when true sentences are used. Retrieval of a non-antecedent must consequently be relatively difficult following the processing of a repeated-noun anaphor. This retrieval difficulty reflects the processing of the repeated-noun anaphor in its capacity as a noun rather than its capacity as a repeated noun or as an anaphor.

If the accessibility decrease reflects a process of inhibition, the non-antecedent effect may reflect anaphor comprehension. In this case, however, our conception of the effect may require revision. Gernsbacher has proposed that the non-antecedent effect reflects an inhibitory process that is specialized for anaphor comprehension. If the accessibility decrease reflects a process of inhibition, the effect may reflect a more general memory process that is invoked during anaphor comprehension. The inhibition that we see with scrambled sentences is presumably present when true sentences are used. The same sort of memory retrieval must occur when a repeated word occurs in a scrambled sentence and when an anaphor occurs in a true sentence.

In brief, if the present accessibility decrease reflects a process of interference, then the non-antecedent effect may tell us nothing about anaphor comprehension. If the accessibility decrease reflects a process of inhibition, then the non-antecedent effect may reflect a general memory process that is harnessed to serve anaphor comprehension. The second goal of the study was to choose between these two possibilities.

To summarize, the first goal of the study was to demonstrate an accessibility decrease that paralleled the non-antecedent effect using scrambled sentences. The second goal was to choose between two accounts of this accessibility decrease - two accounts that had very different implications for our understanding of the non-antecedent effect.

Experiment 1

The object of this experiment was to demonstrate a result that paralleled the non-antecedent effect, using scrambled sentences. The strategy was to recreate as closely as possible the conditions in which the effect has been observed, with the difference that the stimulus sentences were scrambled. On each trial, the participant read a scrambled sentence and indicated, with respect to a probe word that was presented immediately after the sentence ended, whether that word had been contained in the sentence. The stimulus materials for the crucial trials were based a set of sentences, each of which mentioned two characters, identified with either proper or common nouns, and each of which ended with a repeated-noun anaphor that referred to one of the characters. The words in the sentences were randomly re-ordered with the constraint that the two character words and the anaphor in a given sentence maintained the same positions in the scrambled version that they had held in the original version. The probe word was the noun that had been the anaphor's non-antecedent in the original sentence. On some trials, the scrambled sentence was presented in its entirety. On other trials, the last word of the sentence was removed. Thus, on the former trials, the probe word was presented immediately after the noun that had been the anaphor in the original version and was simply repeated in the scrambled version. On the latter trials, the probe word was presented immediately before the point

at which that noun would have occurred if the scrambled sentence had continued. The object was to show that the test noun was more accessible when probed before than after the repeated noun.

As described so far, the present experiment differs most obviously from past experiments exploring the non-antecedent effect in that the stimulus sentences were scrambled. The experiment may differ from past experiments in another respect as well. Upon encountering an anaphor in a sentence of a past experiment, a participant was likely to retrieve the anaphor's antecedent. Upon encountering the second occurrence of a repeated word in a scrambled sentence of the present experiment, a participant may be less likely to retrieve the earlier occurrence of the word. Because the goal of the present experiment was to recreate the conditions of past experiments as closely as possible, a secondary task was included to induce participants to retrieve the earlier occurrence of the repeated word. Participants were required to report after processing each scrambled sentence whether it contained a repeated word. Those readers concerned about the role of this repeated-word task in the present results will be reassured to learn that a later experiment followed the current experiment in all respects except that it dispensed with the repeated-word task. This experiment produced essentially the same results as the present experiment.

In summary, two independent variables were tested in this experiment: 1) Item Type: whether the repeated and test nouns were Proper or Common nouns, and 2) Probe Position: whether the probe word was presented Before or After the repeated noun. The experiment sought an effect of Probe Position, such that responses were faster and/or more accurate in the Before than the After condition.

Method

Participants. The participants were 30 students at the George Washington University. They received extra credit in a psychology course in exchange for their efforts.

Design. The Item Type variable (Proper Noun/Common Noun) was manipulated within participants and between items. The Probe Position variable (Before/After) was manipulated within participants and within items.

Materials. There were 36 experimental items. They were based on sentences from an earlier study of the non-antecedent effect (Nordlie et al., 2001). Each of these earlier sentences mentioned two characters and ended with an anaphoric reference to one of the characters. Both of the characters in a given sentence were identified with either proper or common nouns. The anaphor that ended the sentence consisted in the reappearance of the noun that had initially been used to identify one of the characters. Half of the time it was the first noun in the sentence that reappeared; half of the time it was the second noun. The words in these sentences were scrambled with the constraint that the two character nouns and the final anaphoric noun continued to hold the same serial positions. Thus, a given experimental item contained (at least) two nouns, with one of the nouns being repeated at the end of the item. Table 1 shows samples of the items in the Proper and Common Noun conditions.

The probe word for a given experimental item was the noun that was not repeated (the noun that had been the non-antecedent in the original sentence). The probe word was presented after the item was processed. Across participants, each item was presented half of the time in its entirety and half of the time with the final repeated noun removed. Thus, across participants, each test noun was presented half of the time after the repeated noun and half of the time before the point at which the repeated noun would have occurred if the item had been presented in its entirety. The 36 items were rotated through the two probe conditions in such a way as to produce two materials sets. The experimental items were randomly intermixed with 41 filler items for which the probe words were verbs, adjectives, and words from earlier items (to which a negative response was correct). 32% of the filler items contained repeated words.

Insert Table 1 about here

Procedure. Participants were randomly assigned to the different materials sets. The scrambled sentences were presented on a computer monitor, according to a procedure derived from Gernsbacher (1989). The participant started the presentation of each sentence by pressing the space bar of the computer. The sentence was presented word by word, with each successive word appearing alone in

the middle of the screen for an amount of time that was calculated according to the formula: Presentation Time = (450 ms) + ((16.667 ms) X (number of letters)). Gernsbacher used the same mode of presentation except that the base time was 300 rather than 450 ms and an inter-word interval of 150 ms occurred between each successive word and the preceding one. Thus, the only difference between the two presentation procedures is that the participant saw each word for 150 ms more in the present procedure whereas he/she saw an extra 150 ms of blank screen between words in the Gernsbacher procedure. The rate of presentation was the same in the two cases.

After the scrambled sentence had been presented, the probe word appeared at the top of the screen, in capital letters. The word remained on the screen until the participant responded. At this point, a prompt appeared on the screen, asking whether the scrambled sentence had contained any repeated words. The participant was instructed to respond positively to the test word only if it belonged to the current item. He/she was instructed to respond positively to the repeated-word question only if the repeated word was a content word (ie. noun, verb, adjective, or adverb). Note that the participant did not have to indicate which word had been repeated, only whether or not a word had been repeated. The participant was instructed to respond as quickly as possible to the probe word, without sacrificing accuracy, but to strive only for accuracy in answering the repeated-word question.

Results and discussion

The results of the experiment are summarized in Table 2. Responses were faster in the Before than the After condition, $F1(1,28) = 5.77$, $MSe = 47{,}290$, $F2(1,32) = 5.69$, $MSe = 37{,}754$. (F1 and F2 report the results of tests against the participant and item variability, respectively. Unless otherwise indicated, all effects were tested at the .05 level). Response time did not differ as a function of Item Type, $F1(1,28) = 3.82$, $MSe = 42{,}419$, $F2(1,32) < 1$. The interaction of the effects of Item Type and Probe Position and was not significant in the response time data, $F1(1,28) < 1$, $F2(1,32) < 1$.

The error rate was lower in the Before than the After condition, $F1(1,28) = 14.09$, $MSe = .012$, $F2(1,32) = 20.95$, $MSe = .005$. Error rate did not differ as a function of Item Type, $F1(1,28) <$

1, $F2(1,32) = 1.18$. The interaction of the effects of Item Type and Probe Position and was not significant in the error-rate data, $F1(1,28) < 1$, $F2(1,32) < 1$.

Insert Table 2 about here

Recognition responses were faster and more accurate in the Before than the After condition. A noun from a scrambled sentence was less accessible after another noun had been repeated in the sentence than before that point. The size of the accessibility decrease did not differ for proper and common noun items.

Experiment 2

We would like to interpret the accessibility decrease of Experiment 1 as evidence that a noun in a scrambled sentence becomes less accessible as a consequence of the processing of another noun that has been repeated from earlier in the sentence. Thus, we would like to attribute the observed accessibility decrease to the fact that the repeated noun was processed before the probe word in the After but not the Before condition. A less interesting account of these results focuses on the temporal differences between the After and the Before conditions. More time passed, in the After condition, between the point at which the test noun initially appeared in the scrambled sentence and the point at which it was presented as the probe word. It is possible that the strength of the memory record for the test noun decayed more in the After than the Before condition. This may have rendered the noun less accessible in the After condition.

Experiment 2 sought to clarify the interpretation of the accessibility decrease of Experiment 1. The experiment sought to show the accessibility decrease against a slightly different baseline. Participants read scrambled sentences and responded to recognition probes as in Experiment 1. Two types of scrambled sentences were used. In the Repetition condition, the items were exactly as in Experiment 1. In the Control condition, the items differed in that an adverb with the same number of characters was inserted in place of the repeated noun. In both conditions, the probe points and test words were exactly as in Experiment 1.

The plan was to test in both conditions for an accessibility decrease - to find out whether responses were faster and/or more accurate in the Before than the After condition. The results were to be interpreted according to the following logic. In the Repetition condition, the After condition differs from the Before condition in two respects: 1) a repeated noun is processed in the After but not the Before condition, and 2) more time passes, in the After than the Before condition, between the original occurrence of the test noun and the point at which it is presented as the recognition probe. In the Control condition, the After condition differs from the Before condition in only the second respect. This is because the inserted adverb takes just as long as the repeated noun to process but has none of the same content. An accessibility decrease that is larger in the Repetition than the Control condition must reflect the first of these differences. Thus, this pattern suggests that the accessibility decrease of Experiment 1 reflected the processing of the repeated noun. An accessibility decrease that is equally large in the Repetition and the Control conditions must reflect the second of the differences. Thus, this pattern suggests that the accessibility decrease of Experiment 1 reflected a process of decay. The goal of the experiment was to show an accessibility decrease that was larger in the Repetition than the Control condition and thereby provide evidence that the accessibility decrease of Experiment 1 reflected the processing of the repeated noun.

In summary, two independent variables were tested in this experiment: 1) Item Type: whether the item contained a repeated noun or an adverb, and 2) Probe Position: whether the probe word came Before or After the repeated noun/adverb. The experiment sought to show an interaction of the effects of Item Type and Probe Position, such that the effect of Probe Position was stronger in the Repetition than the Control condition.

Method

Participants. The participants were 36 students at the George Washington University. They received extra credit in a psychology course in exchange for their efforts.

Design. The Item Type (Repetition/Control) and Probe Position (Before/After) variables were

manipulated within participants and within items.

Materials. The experimental items were the same as were used in Experiment 1, The 36 items were rotated through the four experimental conditions in such a way as to produce four materials sets. The experimental items were randomly intermixed with 41 filler items of the same sort used in Experiment 1.

Procedure. The procedure was the same as for Experiment 1.

Results and discussion

The results of the experiment are summarized in Table 3. Recognition responses were faster in the Control than the Repetition condition, $F1(1,32) = 4.83$, $MSe = 35{,}720$, $F2(1,32) = 5.86$, $MSe = 25{,}953$. Responses were faster in the Before than the After condition, $F1(1,32) = 5.80$, $MSe = 26{,}875$, $F2(1,32) = 6.79$, $MSe = 34{,}332$. The interaction of the effects of Item Type and Probe Position was significant in the response-time data, $F1(1,32) = 4.45$, $MSe = 36{,}728$, $F2(1,32) = 4.21$, $MSe = 42{,}189$. The difference between the Before and After conditions was only present in the Repetition condition.

The error rate did not differ in the Repetition and the Control conditions, $F1(1,32) = 7.44$, $MSe = .007$, $F2(1,32) = 1.42$, $MSe = .01$. The error rate was lower in the Before than the After condition, $F1(1,32) = 17.22$, $MSe = .01$, $F2(1,32) = 11.39$, $MSe = .015$. The interaction of the effects of Item Type and Probe Position was not significant in the error-rate data, $F1(1,28) < 1$, $F2(1,32) = 3.60$, $MSe = .005$.

Insert Table 3 about here

The response-time data showed an accessibility decrease in the Repetition but not the Control condition. In the Repetition condition, probe responses were faster in the Before than the After condition. In the Control condition, response time did not differ in the Before and After conditions. By implication, the accessibility decrease of the present experiment and Experiment 1 was at least partially a reflection of the processing of the repeated noun. The error-rate data showed a slightly different

pattern. Here, an accessibility decrease was present in both the Repetition and the Control conditions. In both conditions, probe responses were more accurate in the Before than the After condition. Although the decrease was seemingly greater in the Repetition than the Control condition, the interaction of the effects of Item Type and Probe Position was not significant. By implication, the accessibility decrease of the present experiment and Experiment 1 also reflected a process of decay. The key point, however, is that the decrease was at least partially a reflection of the processing of the repeated noun.

Experiment 3

We wish to tie the accessibility decrease of Experiments 1 and 2 to the processing of the repeated noun and to interpret this accessibility decrease as a parallel to the non-antecedent effect. The role of the repeated-word task in the experimental procedure is problematic for this interpretation. Perhaps it was the burden of this task that made the test noun less accessible. Perhaps the noun was less accessible in the After condition because cognitive resources were diverted to the task of noting the noun's repetition. The key issue here is the manner in which the repeated noun was processed. We wish to tie the accessibility decrease to the processing of the repeated noun as a word in the scrambled sentence. We wish to rule out the possibility that the accessibility decrease reflected the processing of the repeated noun as a target in the repeated-word task. Experiment 3 attempted to do this.

If the accessibility decrease reflected the processing burden of the repeated-word task, then all cognitive operations should be affected. Performance of all cognitive tasks should be slower and/or less accurate immediately after the repeated noun has been processed. On the other hand, if the decrease reflected processing of the noun as part of the scrambled sentence, then it is more likely that only memory retrieval is affected.

A key situation in choosing between these two possibilities is that in which a negative recognition probe is presented. This situation differs from that of Experiments 1 and 2 only in that the test word is not present in the current scrambled sentence. Thus, if an accessibility decrease is not observed, this refutes the notion that the decrement occurs for all cognitive operations and suggests that the decrease

reflects processing of the repeated noun as part of the scrambled sentence.

Experiment 3 explored this situation. The experiment was the same as Experiment 1 except that the recognition probes on the crucial trials were nouns from previous scrambled sentences, to which a negative response was appropriate. No distinction was made between proper and common noun sentences. In summary, a single independent variable was tested in the experiment: Probe Position - whether the probe came Before or After the repeated noun. If an effect of Probe Position occurs, such that responses are faster and/or more accurate in the Before than the After condition, this suggests that the accessibility decrease of Experiments 1 and 2 reflected the processing burden of the repeated-word task.

Method

Participants. The participants were 30 students at the George Washington University. They received extra credit in a psychology course in exchange for their efforts.

Design. The Probe Position variable (Before/After) was manipulated within participants and items.

Materials. The experimental items were the same scrambled sentences as were used as in Experiment 1. The test word for each item was a noun from the previous item. In other respects, the materials were the same as for Experiment 1 except that the filler trials requiring a negative response were replaced with trials on which a positive response was required.

Procedure. The procedure was the same as for Experiment 1.

Results and discussion

Response time in the Before (1360 ms) and After (1384 ms) conditions did not differ, $F1(1,28) < 1$, $F2(1,34) < 1$. A power analysis showed that the experiment had sufficient power (.92) to have detected a moderately-sized response-time difference (110 ms) if one had been present. At the same time, error rate showed a trend toward being greater in the Before condition (Before: .24; After: .20), $F1(1,28) = 4.08$, $MSe = .006$, $p = .053$, $F2(1,34) = 1.52$, $MSe = .02$. Thus, there was no hint of the

sort of accessibility decrease seen in Experiments 1 and 2.

These results suggest that the accessibility decrease of Experiments 1 and 2 reflected the processing of the repeated noun as part of the scrambled sentence rather than as a target in the repeated-word task.

Experiment 4

The results of Experiment 3 are somewhat problematic in that they represent a null effect. We can argue more conclusively against the processing-burden account by showing that the accessibility decrease occurs when the repeated-word task is not part of the experimental procedure. Experiment 4 explored this possibility. The experiment was the same as Experiment 1 except that the participant was not required to monitor for repeated words. The question of interest was again whether an accessibility decrease would be observed. It was reasoned that such a decrease, if observed, could be interpreted even more conclusively as reflecting the processing of the repeated noun as part of the scrambled sentence. The absence of an accessibility decrease was, of course, understood to be less conclusive. It was reasoned that this might indicate an association between the accessibility decrease and the processing burden of the repeated-word task. Alternatively, it might indicate that retrieval of the earlier occurrence of the repeated word was necessary for the occurrence of the accessibility decrease and that such retrieval did not occur in the absence of the repeated-word task. There was some reason to expect that the accessibility decrease would occur in the absence of the repeated-word task. As has been noted, Gordon et al. observed results that prefigure the present results. These results were observed in the absence of a repeated-word task.

In summary, two independent variables were tested in this experiment: 1) Item Type: whether the repeated and test nouns were Proper or Common nouns, and Probe Position: whether the probe came Before or After the repeated noun. 2) The experiment sought an effect of Probe Position, such that responses were faster and/or more accurate in the Before than the After condition.

Method

Participants. The participants were 26 students at the George Washington University. They received extra credit in a psychology course in exchange for their efforts.

Design. The design was the same as for Experiment 1.

Materials. The materials were the same as for Experiment 1.

Procedure. The procedure was the same as for Experiment 1 except that the repeated-word questions were removed.

Results and discussion

The results of the experiment are summarized in Table 4. Recognition responses were faster in the Before than the After condition, $F1(1,24) = 7.35$, $MSe = 32{,}646$, $F2(1,32) = 6.18$, $MSe = 33{,}352$. Response time did not differ as a function of Item Type, $F1(1,24) < 1$, $F2(1,32) < 1$. The interaction of the effects of Item Type and Probe Position and was not significant in the response-time data, $F1(1,24) < 1$, $F2(1,32) = 1.27$, $MSe = 33{,}352$.

Error rate did not differ as a function of Item Type, $F1(1,24) = 3.03$, $MSe = .014$, $F2(1,32) = 1.65$, $MSe = .018$, or Probe Position, $F1(1,24) = 2.09$, $MSe = .013$, $F2(1,32) = 2.01$, $MSe = .009$. The interaction of the effects of Item Type and Probe Position was not significant in the error-rate data, $F1(1,24) < 1$, $F2(1,32) < 1$.

Insert Table 4 about here

Recognition responses were faster in the Before than the After condition. Nouns from a scrambled sentence were again less accessible after a noun had been repeated in that sentence than before that point. These results argue more conclusively that the accessibility decrease of Experiments 1 and 2 reflected the processing of the repeated noun as part of the scrambled sentence rather than as a target in the repeated-word task. It is noteworthy that the accessibility decrease occurred in the absence of an explicit requirement that repeated words be monitored. This will be discussed later.

As in Experiment 1, the size of the accessibility decrease did not differ for proper and common noun items. Furthermore, in contrast to Experiment 1, where the accessibility decrease was (non-

significantly) larger for proper than for common nouns, here the decrease was (non-significantly) larger for common than for proper nouns. Taken together, these results imply that proper and common nouns are equally susceptible to the accessibility decrease. This, too, will be discussed later.

Experiment 5

The results of Experiments 1 - 4 suggest that a noun in a scrambled sentence becomes less accessible as a consequence of the processing of another noun that is repeated from earlier in the sentence. The pattern is similar to the non-antecedent effect that has been observed in studies of anaphor comprehension. In order to know the implications of the present accessibility decrease for anaphor comprehension, we need to better understand why it occurs. We need to know what it is about the processing of the repeated noun that makes the test noun less accessible. On one hand, the accessibility decrease may reflect a process of interference. The test noun may become less accessible because the repeated noun belongs to the same grammatical class, and, having just been processed, interferes with the retrieval of the test noun. Alternatively, the accessibility decrease may reflect a process of inhibition. The test noun may become less accessible because it has been inhibited as a byproduct of the process by which the repeated noun is recognized as having occurred before in the scrambled sentence. As was detailed in the introduction, the accessibility decrease has more relevance for anaphor comprehension if it reflects a process of inhibition.

Experiment 5 was conducted to gather evidence that the present accessibility decrease reflects a process of inhibition. Participants read scrambled sentences and responded to recognition probes as in the earlier experiments. Two types of scrambled sentences were used. The experimental items for the Repeated Noun condition were the same as were used in Experiment 1. The items for the New Noun condition differed in that the repeated noun was replaced with a noun that had not occurred previously in the sentence. In both conditions, the probe points and test words were exactly as in Experiment 1.

The plan was to test in both conditions for an accessibility decrease - to find out whether responses were faster and/or more accurate in the Before than the After condition. The results were to

be interpreted according to the following logic: In the Repeated Noun condition, the After condition differs from the Before condition in three respects: 1) in the After but not the Before condition, a repeated noun is processed prior to the presentation of the recognition probe, 2) in the After but not the Before condition, a word from the same grammatical category as the test noun is processed prior to the presentation of the test noun as the recognition probe, and 3) more time passes in the After than the Before condition between the point at which the test noun occurs in the sentence and the point at which it is presented as the probe. In the New Noun condition, the After condition differs from the Before condition in only the latter two respects. An accessibility decrease that is larger in the Repeated Noun than the New Noun condition must reflect the first of these differences. In this case, the accessibility decrease provides evidence of a process of inhibition. An accessibility decrease that is equally large in the Repeated Noun and the New Noun conditions may reflect either the second or the third of these differences. If the accessibility decrease reflects the second of the differences, it provides evidence of a process of interference. If the decrease reflects the third of the differences, it provides evidence of a process of decay. The goal of the experiment was to show an accessibility decrease that was larger in the Repeated Noun than the New Noun condition and thereby provide evidence that the present accessibility decrease reflects a process of inhibition.

In order to insure that participants recognized the repeated words as having occurred before in the scrambled sentences, participants were required to perform the repeated-word task. In order to insure that the burden of performing this task did not interfere with the recognition judgment, a delay was inserted between the point at which the last word in the scrambled sentence disappeared from the screen and the point at which the probe word was presented. On experimental trials in the Repeated Noun/After condition, in which the scrambled sentence ended with a repeated noun, this interval gave participants time to register the fact that a word had been repeated in the sentence before the probe word was presented.

In summary, two independent variables were tested in this experiment: 1) Item Type: whether

the scrambled sentence contained a repeated noun or a new noun, and 2) Probe Position: whether the probe came Before or After the repeated/new noun. The experiment sought to show an interaction of the effects of Item Type and Probe Position, such that the effect of Probe Position was stronger in the Repeated Noun than the New Noun condition.

Method

Participants. The participants were 32 students at the George Washington University. They received extra credit in a psychology course in exchange for their efforts.

Design. The Item Type (Repeated/New Noun) and Probe Position (Before/After) variables were manipulated within participants and within items.

Materials. The experimental items were the same as were used in Experiment 1. The 36 items were rotated through the four experimental conditions in such a way as to produce four materials sets. The experimental items were randomly intermixed with 41 filler items of the same sort used in Experiment 1.

Procedure. The procedure was the same as for Experiment 1 except that an interval of 1000 ms was inserted between the point at which the last word of the scrambled sentence disappeared from the screen and the point at which the probe word was presented.

Results and discussion

The results of the experiment are summarized in Table 5. Recognition responses were faster in the Before than the After condition, $F1(1,28) = 6.11$, $MSe = 25{,}867$, $F2(1,32) = 9.32$, $MSe = 33{,}738$. Response time did not differ in the Repeated and New Noun conditions, $F1(1,28) = 4.09$, $MSe = 26{,}617$, $F2(1,32) = 3.90$, $MSe = 31{,}197$. The interaction of the effects of Item Type and Probe Position was significant in the response-time data, $F1(1,28) = 8.10$, $MSe = 20{,}512$, $F2(1,32) = 7.05$, $MSe = 27{,}999$. The difference between the Before and After conditions was only present in the Repeated Noun condition.

The error rate was lower in the Before than the After condition, $F1(1,28) = 5.84$, $MSe = .01$,

$F2(1,32) = 5.85$, $MSe = .012$. The error rate did not differ in the Repeated and New Noun conditions, $F1(1,28) < 1$, $F2(1,32) < 1$. The interaction of the effects of Item Type and Probe Position was not significant in the error-rate data, $F1(1,28) = 1.55$, $MSe = .008$, $F2(1,32) < 1$.

Insert Table 5 about here

The response-time data showed an accessibility decrease in the Repeated Noun but not the New Noun condition. In the Repeated Noun condition, probe responses were faster in the Before than the After condition. In the New Noun condition, response time did not differ in the Before and After conditions. By implication, the present accessibility decrease was at least partially a reflection of a process of inhibition. The error-rate data showed a slightly different pattern. Here, an accessibility decrease was present in both the Repeated Noun and the New Noun conditions. In both conditions, probe responses were more accurate in the Before than the After condition. Although the decrease was seemingly greater in the Repeated Noun than the New Noun condition, the interaction of the effects of Item Type and Probe Position was not significant. By implication, the present accessibility decrease reflected either decay, interference, or some combination of the two, in addition to inhibition.

The additional factor was probably simple decay. Recall that an accessibility decrease was observed in the error-rate data for the Control condition of Experiment 2. It is unlikely that this decrease reflected interference. In the Control condition of Experiment 2, the recognition probe was presented before and after an adverb. As a word from a different syntactic category, the adverb should not have interfered with recognition of the test word. Thus, the decrease of the Control condition of Experiment 2 probably reflected simple decay. If decay occurred in Experiment 2, it presumably also occurred in the present experiment. Given that the accessibility decrease in the New Noun condition of the present experiment was approximately the same size as the accessibility decrease of the Control condition of Experiment 2, it is likely that the present results reflect simple decay rather than a combination of decay and interference.

The key point, in any case, is that the present decrease was at least partially a reflection of a

process of inhibition. The accessibility decrease in the Repeated Noun condition most likely did not reflect the burden of the repeated-word task because a delay of 1000 ms occurred between the processing of the repeated noun and the presentation of the recognition probe.

General Discussion

Each trial in the present study consisted of a memory test. The participant read a scrambled sentence and made a recognition judgment with respect to a probe word that was presented immediately thereafter. On some trials, the scrambled sentence ended with a repeated noun. The results of Experiments 1 – 4 suggested that another test noun from the sentence became less accessible as a consequence of the processing of this repeated noun. In Experiment 1, a test noun was less accessible when the scrambled sentence ended with a repeated noun than when it was truncated immediately prior to that point. Experiment 2 showed that the accessibility decrease of Experiment 1 reflected more than a simple process of decay. A test noun was again less accessible when the scrambled sentence ended with a repeated noun than when it was truncated prior to that point. The accessibility decrease was smaller when the repeated noun was replaced with an adverb. Experiments 3 and 4 showed that the accessibility decrease of Experiments 1 and 2 did not reflect a burden associated with processing the repeated noun under the repeated-word task. Experiment 3 showed that the accessibility decrease did not occur for words from the previous scrambled sentence, to which a negative response was appropriate. Thus, all cognitive operations were not impeded by the repeated-word task. Experiment 4 showed that the accessibility decrease occurred even when the repeated-word task was not performed.

These results confirm the existence of the effect that was implied in the data of Gordon et al. (2000). As was noted earlier. Gordon et al. did not focus on the effect. They showed it against only one baseline and did not specifically test its statistical significance. The present results show the effect to be real, against two different baselines that have been taken as crucial in demonstrating accessibility effects (MacDonald & MacWhinney, 1990).

Experiment 5 tested two accounts of the accessibility decrease that was observed in

Experiments 1– 4. The interference account attributed the decrease to the fact that the repeated noun belonged to the same grammatical class as the test noun and therefore interfered with its retrieval, having recently been processed at the point that the test noun was presented as the recognition probe. The inhibition account attributed the decrease to the fact that the test noun was inhibited as a byproduct of the process by which the repeated noun was recognized as having occurred before in the scrambled sentence. The results of Experiment 5 argued for the inhibition account. The test noun was again less accessible when the scrambled sentence ended with a repeated noun than when it was truncated prior to that point. The accessibility decrease was smaller when the repeated noun was replaced with a noun that had not occurred previously in the sentence.

These results suggest the existence of a phenomenon of inhibition associated with the repetition of a word in a list. Recognition of similar words from the list is inhibited at this point. The most plausible explanation is that the repeated word is recognized as having occurred earlier in the list, that the earlier occurrence of the repeated word is retrieved as part of the recognition process, and that retrieval of similar words is inhibited as a byproduct of the retrieval of the earlier occurrence of the repeated word.

The proposed inhibition occurred when a repeated-word task was included to draw attention to repeated words (Experiments 1, 2, and 5) and when no such task was included (Experiment 4). The implication is that the repetition of a word in a list triggers an incidental recognition process. It is noteworthy that retrieval occurs as part of the proposed recognition process. According to several of the models that have been proposed of recognition memory, recognition of an item may reflect either the judgment that the item is familiar or the retrieval of a record of the earlier occurrence of the item (Jacoby & Brooks, 1984; Mandler, 1980). The recognition process suggested in the present results evidently does not consist solely of a familiarity judgment.

In all cases, the present inhibition occurred for a certain type of noun after the repetition of another noun of the same type. Common nouns were inhibited following the repetition of common nouns and proper nouns were inhibited following the repetition of proper nouns. One might ask how extensive

the inhibition is following the repetition of a given type of noun. Is the inhibition that occurs following the repetition of a proper noun limited to proper nouns, to nouns in general, or does it extend to all words? Further research will be needed to answer this question. It is significant, however, that no difference was observed in the amounts of inhibition for proper and common nouns. Proper nouns are somewhat more distinctive than common nouns; they stand out to a greater degree from the background than common nouns. The fact that no more inhibition was observed for the more salient nouns suggests that the inhibition is possibly at least somewhat extensive.

More generally, the present results suggest that items from a memory set are inhibited when an item from the set is retrieved. The existence of similar processes has been inferred in studies of recall memory on the basis of aggregate accuracy data (Anderson & Neely, 1996; Anderson & Spellman, 1995; Neely et al., 1983). The existence of such processes has been inferred from the success of interactive models of letter and word recognition (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982; Seidenberg & McClelland,1989). The present study is the first to show such a process operating in recognition memory, at the level of the individual retrieval.

These results may be informative not only about memory but also about anaphor comprehension. In particular, they may be informative about the non-antecedent effect. Aside from the fact that it used scrambled sentences, the present study followed the same procedures as studies of the non-antecedent effect. And the present study produced the same basic pattern of results as studies of the non-antecedent effect. In such studies, the non-antecedent of an anaphor becomes less accessible with the processing of the anaphor. In the present study, a noun from a scrambled sentence became less accessible with the processing of a word that was repeated from earlier in the sentence. Parsimony suggests that the same processes were operating in the two cases.

What, then, do these results say about the non-antecedent effect? Current thought about this effect has been shaped by Gernsbacher (1989), who has proposed that the effect reflects a process of inhibition and that this inhibitory process is specifically dedicated to the task of comprehension. The

present results support the first part of Gernsbacher's proposal. The results of Experiment 5 suggests that, although the effect may reflect a process of decay, it also reflects a process of inhibition, as Gernsbacher as proposed. At the same time, the present results call into question the second part of Gernsbacher's proposal, suggesting that the inhibitory process in question is more general than Gernsbacher has proposed. These results suggest that non-antecedent inhibition is produced by a general memory process that is harnessed to serve the needs of anaphoric processing while comprehension is occurring. With the retrieval of a member of a memory set, the process inhibits other members of a memory set. With the retrieval of an antecedent during a study of anaphor comprehension, the process inhibits non-antecedents.

Of course, one may question whether the non-antecedent effect has anything to do with anaphor comprehension. Gordon et al. (2000) have argued that participants often treat the discourse materials that are used as stimuli in the probe-recognition task as little more than lists of words. To the extent that this is the case, probe-word recognition data may tell us little about anaphor comprehension. The non-antecedent effect is observed in the probe-word recognition task. It follows, according to the argument, that the non-antecedent effect may tell us little about anaphor comprehension.

We believe that this argument does not diminish the importance of the present results for anaphor comprehension. The key point is that the present results suggest the existence of a general memory process that inhibits items in a memory set following the retrieval of an item in the set. In the present study, the process was shown to be operative when participants recognized words from simple lists. The process may also be operative during anaphor comprehension. Memory retrieval must undeniably occur as a part of anaphor comprehension. The reader/listener is given the anaphor and must retrieve its antecedent. In the case of repeated-noun prior anaphors, the anaphor and antecedent match; the reader/listener must simply recognize the anaphor as having occurred earlier. The recognition process is very similar to the recognition process that occurred in the present study with our scrambled sentences. In the case of pronoun anaphors, antecedent retrieval involves a process of recall rather than

recognition. Here, the present results may not be as relevant.

If the present results reflect the operation of a general memory process, arguments against the recognition-probe task have little bearing on them. The proposed process may be operative when words are recognized in lists and when antecedents are recognized in discourse. Thus, the process may be operative regardless of whether participants in probe-recognition tasks treat the stimulus items as word lists or as true samples of discourse.

In summary, the present study demonstrated a pattern that paralleled the non-antecedent effect using scrambled sentences as stimulus items. The accessibility decrease that was observed evidently reflected a process of inhibition. When a noun was recognized as having occurred earlier in a scrambled sentence, another noun was inhibited. It was suggested that the same process may be operative when people process repeated-noun anaphors in normal discourse.

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Table 1

Sample stimuli from Experiment 1

<u>Proper Noun</u>

Denise
down
Angela
to
then
below
ushered
cabin
a
private
and
^
Angela
^ Probe word: DENISE

<u>Common Noun</u>

light
hypnotist
at
glare
the
witness
in
the
the
of
examination
and
peered
the
^
hypnotist
^ Probe word: WITNESS

Note. ^ indicates a probe point.

Table 2

Results of Experiment 1

	ITEM TYPE			
	Proper Noun		Common Noun	
PROBE POSITION				
	RT (ms)	ER	RT (ms)	ER
Before	1185	(.09)	1143	(.10)
After	1312	(.16)	1207	(.18)
Difference	-127	(-.07)	-64	(-.08)

Table 3

Results of Experiment 2

	ITEM TYPE			
	Repetition		Control	
PROBE POSITION				
	RT (ms)	ER	RT (ms)	ER
Before	1260	(.07)	1258	(.06)
After	1393	(.15)	1257	(.10)
Difference	-133	(-.08)	1	(-.04)

Table 4

Results of Experiment 4

	ITEM TYPE			
	Proper Noun		Common Noun	
PROBE POSITION				
	RT (ms)	ER	RT (ms)	ER
Before	1200	(.11)	1127	(.15)
After	1271	(.14)	1248	(.19)
Difference	-71	(-.03)	-121	(-.04)

Table 5

Results of Experiment 5

	ITEM TYPE			
	Repeated Noun		New Noun	
PROBE POSITION				
	RT (ms)	ER	RT (ms)	ER
Before	1081	(.10)	1094	(.11)
After	1223	(.16)	1092	(.13)
Difference	-142	(-.06)	2	(-.02)