Item-specific interference caused by cue-dependent forgetting

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Memory for A–B word pairs (e.g., *child-apple*) was tested by a cued recall test (e.g., *child-app*___). Showing an A–C “relative” (e.g., *child-bicycle*) reduced recall, especially if it was shown recently and was highly accessible (Experiments 1 and 2). In Experiment 3, a relative facilitated recall if it was semantically similar to the target (A–B’: *child-cookies*) but interfered if it was semantically dissimilar (A–C: *child-fever*). The best explanation for these results is that the relative primed features that affected the functional retrieval cue, and that interference occurred if the cue did not match the trace for the target (Martin, 1972). In other words, the interference effects are an example of cue-dependent forgetting. Neither blocking nor a discrimination process can account for these findings, although some evidence for a discrimination process has been found with other materials.

For many years, researchers have known that memory for an event is affected by learning other events. In particular, accuracy is greater if a target is followed by a dissimilar event rather than by a similar event. The similar event, which we will call a “relative” of the target, is said to reduce or “interfere with” memory for the target. Memory theorists have suggested that the relative interferes by changing the trace for the target (storage theories) or by affecting its retrieval (retrieval theories). We will briefly review evidence (Chandler, 1991, 1993a) against the idea that a representation can be changed by subsequent events (e.g., Loftus, 1979, p. 117; Loftus & Loftus, 1980). Then we will explore retrieval processes that could cause interference effects and describe a way to find out what retrieval processes are involved in a particular situation.

The reader may be wondering why the field has not resolved such basic issues, given the voluminous literature on interference effects. One reason is that most designs have introduced confounding variables (e.g., response bias, social demands, or a change in contextual cues) that could account for the effect (e.g., Chandler, 1989; McCloskey & Zaragoza, 1985). Of the studies that have eliminated the confounding variables, most have found interference effects (see Chandler, 1989, 1993a, for reviews), but it is not clear what process or processes are causing the effects. The problem is that the field lacks ways of determining whether any given interference effect is attributable to one process or another. In this article, we contrast the predictions made by hypothetical re-

trieval processes in order to derive rules that can be used to infer the presence of a particular retrieval process.

Although findings to date have not been able to pinpoint a cause of interference effects, they suggest that a stored trace is not changed by learning about a related event. Storage accounts of interference contend that the relative displaces the target (Loftus & Loftus, 1980) or alters its features (Loftus, 1979). Another view is that memory traces naturally disintegrate (or lose features) over time, and that the relative speeds up this process (Belli, Windschitl, McCarthy, & Winfrey, 1992). All storage accounts contend that information can never be recovered once the trace is changed. Therefore, if a change in the trace causes interference at a short retention interval, then an interference effect should also be found at a longer retention interval. Contrary to this prediction, interference has been found to disappear across a retention interval (Chandler, 1991, 1993a). The finding appears to be general, occurring in both a matching recognition test for given names and surnames (Chandler, 1993a) and a modified forced-choice recognition test for nature pictures (Chandler, 1991).

Additional evidence argues against the idea that a relative makes the target trace disintegrate more rapidly (Belli et al., 1992; see also Posner & Kosnick, 1966). The theory predicts that more interference should occur when the relative occurs *early* in the retention interval, because this allows more time for the trace to disintegrate. But Chandler (1993a) found more interference when a relative occurred *late* in a retention interval. Memory for target names (e.g., Robert Harris) was tested after a 30-min retention interval through provision of the first and last names of the targets for matching. The *later* the relative occurred (e.g., Robert Knight), the lower the accuracy on the matching test.

To date, the predictions of storage theories have not been supported, which indirectly implicates a retrieval process as causing these interference effects. In the pres-

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ent article, we entertain three retrieval processes and contrast their predictions. All of these retrieval processes assume that the trace for the target remains intact, and that interference effects arise during retrieval. Furthermore, these modern retrieval mechanisms all contend that the relative must be accessed in order to interfere with memory for the target. For example, the access-and-discriminate view contends that a relative interferes when its features combine with the target's features (e.g., Reinitz, Lammers, & Cochran, 1992) or when common features are emphasized during retrieval at the expense of unique features (e.g., Hintzman, 1986; see also Metcalfe, 1990). Blocking accounts contend that the capacity for retrieval is limited (see Anderson & Bjork, 1994), and that accessing (or sampling) the relative prevents one from sampling the target (e.g., Bjork & Bjork, 1988; Roediger, 1974, 1978; Rundus, 1973).

A third retrieval process, which we call "cue-change," has been neglected in recent years. According to Martin (1972), the probability of recalling the target depends on the degree to which the functional retrieval cue matches the trace for the target. Studying a relative primes certain features that become part of the functional retrieval cue. If the relative primes features that do not match the target, this produces an interference effect. Martin sees interference as another example of cue-dependent forgetting. For example, suppose that "The child ate an apple" made you think of a young child, and that "The child rode the bicycle" made you think of an older child. The cue (child) takes on the features that were primed by the relative (older child). Thus, the functional retrieval cue is less likely to match the target event than if the subject encoded the target only.¹

A discrimination process, blocking, and cue-change make some of the same predictions but also some different ones. When all retrieval processes make the same prediction, it is impossible to tell what process produced the effect. In order to exemplify the problem, we performed the following experiment in our lab. Eighty students were shown pairs of words (e.g., *child-apple*) at a 10-sec rate and instructed to construct a sentence for each pair of words. Some of the A-B targets (e.g., *child-apple*) were unique (control condition), whereas others shared their stimulus word with an A-C relative (e.g., *child-bicycle*) that was presented either once (study 1 condition) or three times (study 3 condition). Memory for the A-B targets was tested 5 min later with a cued-recall test (e.g., *child-app*__).

The percentage of targets recalled was 71% in the control condition, 71% in the study 1 condition, and 64% in the study 3 condition. In other words, an A-C item interfered more if it was shown three times than if it was shown once. All three retrieval processes can account for the finding, because the study 3 relatives are more likely to be accessed, which may (1) introduce a need to discriminate between the target and the relative, (2) increase the chance that the relative will block the target, or (3) increase the chance that the relative will bias the functional retrieval cue (cue-change).

In the present article, we develop rules by which the cause of an interference effect can be inferred in a given experiment. We accomplish this goal by identifying manipulations for which the retrieval processes predict different effects, and by comparing the experimental findings to those predictions. We suggest two such manipulations and show how they can be used to diagnose the cause of interference effects found in Experiments 1, 2, and 3. In the general discussion section, we describe how we have used the same rules to diagnose the cause of interference using other materials and tests.

In Experiments 1, 2A, and 2B, we present the A-C relative either in the study list or on the test. If the relative interferes most when it is shown *at study*, that would implicate a discrimination process. The result can be explained as follows: It is more difficult to discriminate between memory traces (A-B and A-C) that share contextual and temporal features (both shown *at study*) than to discriminate between traces that do not have these features in common.

All other retrieval processes predict that the relative will interfere more if it is shown *at test*. Placing the relative on the test makes it more recent and consequently more accessible. A recent relative is more likely to affect the interpretation of the retrieval cue (cue-change) or to be sampled at the expense of the target (blocking). The "access" portion of an access-and-discriminate view could account for the effect because A-C must be accessed in order for a discrimination problem to arise. Thus, if A-C interferes most when it is shown *at test*, then it will not be possible to pinpoint the precise cause of the effect. However, the opposite finding would provide unambiguous support for a discrimination process.

Experiments 3A and 3B are designed to test another set of contrasting predictions made by the retrieval accounts. In both experiments, the target and relative emphasize either similar semantic attributes (A-B, A-B': *child-apple*, *child-cookies*) or different semantic attributes (A-B, A-C: *child-apple*, *child-bicycle*). According to the cue-change view, a relative interferes by biasing the meaning of the cue so that it does not match the target. Therefore, a relative should interfere only if it emphasizes semantic attributes that differ from those of the target (A-B, A-C). In contrast, access-and-discriminate accounts predict more interference when the target and relative share semantic features (A-B, A-B'), because shared features make it more difficult to discriminate between the traces. Blocking accounts predict that the relative should interfere regardless of its semantic similarity to the target.

EXPERIMENT 1

Method

Subjects and Design

The subjects were 54 undergraduates at Washington State University who participated in order to fulfill a research requirement for their psychology class. Every subject participated in each of the three conditions defined next and in Table 1.

Control. The A-B targets were not related to any other items.

Study 1. Each of the A-B targets was related to an A-C item by its stimulus word. The A-C relatives were shown in the study phase.

Test 1. Each of the A-B targets was followed by one A-C item that appeared on the test prior to the cue (*child-app*).

For any given subject, there were six A-B targets in each condition. Counterbalancing ensured that, across subjects, each of the A-B targets appeared in each condition equally often.

Procedure

Small groups of subjects (4–15 people) were shown pairs of words at a 10-sec rate via an overhead projector. As an orienting task, the subjects constructed a sentence using both words in a pair. Because of the fast presentation rate, there was not enough time to write the sentences. To ensure that the subjects were engaged in this orienting task, we asked them to rate their ability to construct each sentence on a 5-point scale. The 18 A-B targets were shown first and were followed without a break by 6 A-C relatives.

A creativity task occupied the participants for the next 15 min. Memory for the target items was then assessed via presentation of cues (e.g., *child-app*) for recall. The cues were numbered and were shown for 5 sec each via an overhead projector, and the subjects wrote their answers next to the corresponding numbers on their answer sheets.

During the test phase of the experiment, the subjects also continued to generate sentences. On six occasions (test 1 condition), an A-C pair (e.g., *child-bicycle*) appeared, and the subjects were given 15 sec to write down a sentence that related the A-C words. All of the subjects were able to write a sentence within the 15-sec limit. Later in the test phase, the subjects were given a cue (e.g., *child-app*) and were asked to recall the A-B pair.

It is possible that the act of switching from the sentence generation task (*The child rode the bicycle*) to a recall task (*child-app*) might have been disruptive. Any disruption would be greatest for an item that is tested immediately after generating a sentence (0 lag). We equalized disruption in the three conditions by testing equally often the control target, study 1 target, and test 1 target at lags of 0, 1, and 2 sec.

Materials

All of the words used in the experiment were common English words between 4 and 10 letters long.

A-B targets. The targets were 18 pairs of words (e.g., *child-apple*) that had a low preexperimental association (Graf & Schacter, 1987). The A-B targets were randomly assigned to position on overhead transparencies and were printed in large capital letters.

A-C relatives. We created 18 A-C relatives by pairing the stimulus word of each target (e.g., *child*) with one new low associate (e.g., *child-bicycle*). Any given subject would see six A-C relatives in the study 1 condition. The six A-C relatives for a given subject were printed in large capital letters and placed on an overhead transparency in random order.

Test materials. The test provided a cue for each of the 18 A-B targets. Each cue provided the stimulus word and the first three letters of the response word (e.g., *child-app*). Each three-letter

stem could potentially be completed to form 10 common English words, only one of which occurred in the experiment. On six occasions, an A-C relative (e.g., *child-bicycle*) preceded the cue (e.g., *child-app*) in the test sequence, defining the test 1 condition.

The test form for any given subject was printed on overhead transparencies in large capital letters.

Results and Discussion

The act of generating a sentence just before being tested was *not* disruptive. The lag between generating a sentence and attempting to recall a target had no effect on the percentage of items recalled. Recall was the same regardless of whether 0, 1, or 2 items intervened between the sentence and the test (68%, 72%, and 69%, respectively). Because lag did not affect recall, we did not include it as a factor in the analyses reported below.

The mean percentage of targets recalled is shown by condition in Table 1. Each mean is based on 324 observations (54 subjects responding to six items each). We made a priori comparisons using a separate analysis of variance (ANOVA) for each comparison. For each ANOVA, we entered the number of items that the subject recalled in each of two conditions. Keppel (1991) advocated this approach because it ensures that the error term (MS_e) is not biased by the amount of variation in other conditions. We set the family-wise error rate at $\alpha = .05$ using a Bonferroni procedure.

We measured interference by comparing performance in the control condition to each condition in which an A-C relative was shown. There was no significant interference from an A-C item shown during study, but an A-C item shown during the test did interfere. There was no significant difference in the number of items recalled in the control condition and the number of items recalled in the study 1 condition [$F(1,53) = 1.923$, $MS_e = 1.083$]. However, recall was significantly higher in the control condition than in the test 1 condition [$F(1,53) = 14.455$, $MS_e = 1.868$]. Also, recall was significantly higher in the study 1 condition than in the test 1 condition [$F(1,53) = 9.897$, $MS_e = 1.423$].

There was no hint of a discrimination problem in this experiment. Recall was actually higher if the target and relative were *less* discriminable (study 1 condition) than if they were more discriminable (test 1 condition). Instead, the findings suggest that A-C interfered to the extent that it was *recent* and accessible. Thus, the findings are consistent with a blocking or cue-change interpretation.

Of course, it is possible that a discrimination process is important under other circumstances. For example, discrimination may be more problematic if several relatives are shown than if only one relative is shown. In Experiments 2A and 2B, we presented five relatives (A-C, A-D, A-E, A-F, A-G) in the study phase (study 5 condition) to see whether they would interfere more than one A-C relative shown on the test (test 1 condition). If a discrimination process occurs at all with this task, then presenting five relatives at study should interfere more than presenting one relative at test.

Table 1
Percentage of Targets (e.g., *child-apple*) Recalled
(to *child-app*) in Each Condition of Experiment 1

Condition	Study Phase (Relative)	Test Phase (Relative and Cue)	% Recalled	SD (%)
Control	none	<i>child-app</i>	77	20
Study 1	<i>child-bicycle</i>	<i>child-app</i>	73	24
Test 1	none	<i>child-bicycle</i> <i>child-app</i>	61	28

EXPERIMENTS 2A-2B

Method

Subjects and Design

Another 60 undergraduates participated in Experiment 2A and another 80 participated in Experiment 2B. In both experiments, every subject participated in each of the four conditions.

Control. The A-B target was not related to any other items.

Study 5. The A-B target was related to five A-C items that were shown in the study phase.

Test 1. The A-B target was followed by one A-C item that appeared on the test immediately before the cue.

Study 5 + Test 1. The target was related to five A-C items that were shown in the study phase. One of the A-C items reappeared on the test immediately before the cue.

For each subject, there were six A-B targets in each condition. But across subjects, each target appeared in each condition equally often. Examples for each condition are provided in Table 2.

Materials and Procedure

As in Experiment 1, the subjects generated sentences for pairs of words that were presented at a 10-sec rate. In Experiment 2A, 24 A-B targets were shown first and were followed (without a break) by 60 A-C relatives. In Experiment 2B, the A-C relatives were shown before the targets.

Each subject saw 24 A-B pairs (six per condition) that were presented in a random order. In addition, any given subject saw 60 A-C relatives, 30 in the study 5 condition and 30 in the study 5 + test 1 condition. We created the A-C relatives in these conditions by pairing the stimulus word of each target (e.g., *child*) with five new low associates (e.g., *child-truck*, *child-inspector*, *child-girl*, *child-bicycle*, *child-fever*).

A distractor task occupied the subjects for the next 15 minutes before they were tested for recall of the A-B targets. The task was to generate the name of a city for each letter of the alphabet (e.g., *Atlanta*, *Baton Rouge*, etc.). We then assessed memory for the target items by presenting cues (e.g., *child-app__*) for recall at a 5-sec rate.

During the test, the subjects continued to generate sentences. On 12 occasions (test 1 and study 5 + test 1 conditions), the subjects saw an A-C relative (e.g., *child-bicycle*) and constructed a sentence for it (e.g., *The child rode the bicycle*). The A-C item was chosen at random from the list of 5 A-C relatives. Fifteen seconds after the A-C item was shown, the subjects attempted to recall the A-B target.

Results

The mean percentage of targets recalled is shown by condition in Table 2. In Experiment 2A, each mean is based on 360 observations (60 subjects contributed 6 observations in each condition). In Experiment 2B, each mean is based on 480 observations per condition (80 subjects contributed 6 observations per condition).

The pattern of results was the same for both experiments. We assessed interference by comparing performance to that in the control condition. The least interference occurred when five relatives were presented in the study list, and the most interference occurred when one relative was presented during the test. Showing relatives at both study and test did not add any additional interference (see Table 2). Each of these observations was supported by the results of the statistical comparisons described next.

Significant interference effects were found when five relatives were shown in the study phase. More targets were recalled in the control condition than in the study 5 condition in both Experiment 2A [$F(1,59) = 10.16$, $MS_e = 1.005$] and Experiment 2B [$F(1,79) = 9.65$, $MS_e = .705$]. Significant interference effects were also found when one relative was shown in the test phase. More targets were recalled in the control condition than in the test 1 condition in both Experiment 2A [$F(1,59) = 20.75$, $MS_e = 1.398$] and Experiment 2B [$F(1,79) = 60.58$, $MS_e = 1.032$].

More important was the fact that showing one relative on the test (test 1 condition) interfered more than showing five relatives during the study phase (study 5 condition). The comparison was marginally significant in Experiment 2A [$F(1,59) = 4.344$, $MS_e = 1.105$], and the effect was significant in Experiment 2B [$F(1,79) = 26.56$, $MS_e = 1.06$].

Seeing a relative on the test produced a large amount of interference, and presenting the relative in the study phase did not add to the effect. In Experiment 2A, recall

Table 2
Percentage of Targets (e.g., *child-apple*) Correctly Recalled (to *child-app__*)
in Each Condition in Experiments 2A and 2B

Condition	Study Phase (Relatives)	Test Phase	Design			
			2A: Retroactive		2B: Proactive	
			% Recalled	SD (%)	% Recalled	SD (%)
Control	None	<i>child-app__</i>	67	25	75	20
Study 5	<i>child-truck</i>	<i>child-app__</i>	57	19	68	21
	<i>child-inspector</i>					
	<i>child-girl</i>					
	<i>child-bicycle</i>					
	<i>child-fever</i>					
Test 1	None	<i>child-bicycle</i>	51	23	54	26
		<i>child-app__</i>				
Study 5 + Test 1	<i>child-truck</i>	<i>child-bicycle</i>	53	22	55	20
	<i>child-inspector</i>	<i>child-app__</i>				
	<i>child-girl</i>					
	<i>child-bicycle</i>					
	<i>child-fever</i>					

was equally low in the test 1 and study 5 + test 1 conditions [$F(1,59) = .34$, $MS_e = 1.550$]. Experiment 2B led to the same conclusion [$F(1,79) = .12$, $MS_e = 1.270$].

Discussion

A discrimination process did not appear to play a role in producing interference in Experiments 2A and 2B. More interference was found when the traces were temporally and contextually dissimilar (test 1 condition) than when they were similar (study 5 condition). Even when access to the A–C relative is held constant, the evidence still does not suggest a discrimination process. In the study 5 + test 1 condition, re-presenting an A–C item on the test should reactivate its trace, which must then be discriminated from the trace for A–B. Discrimination should be more problematic in this condition than in the test 1 condition, in which the traces do not share temporal and contextual features. But performance was equal in the study 5 + test 1 and test 1 conditions. Either it was not difficult to discriminate between the contextually similar traces, or the effect was overshadowed.

Instead, the findings suggest that an A–C relative is more likely to interfere with recall of an A–B target if it is recent and accessible. Thus, a relative interfered more if it was shown in the test phase rather than in the study phase.

Experiments 3A and 3B were designed to pinpoint the major cause of interference with our word-pair materials. In these experiments, targets (e.g., *child–apple*) were followed by a “relative” (either A–C or A–B’) that was shown on the test. The meaning of the relative was either similar to the target (A–B’: *child–cookies*) or dissimilar to the target (A–C: *child–bicycle*). Martin’s (1972) cue-change theory predicts that a relative will interfere to the extent that it emphasizes features that differ from those of the target. If cue-change causes our interference effects, then there should be more interference in the different-meaning (A–C) condition than in the similar-meaning (A–B’) condition. A discrimination process would produce the opposite result. Traces that share many features (similar-meaning condition) are more difficult to discriminate than are traces that share few features (different-meaning condition). Therefore, more interference should occur in the similar-meaning condition than in the different-meaning condition. Finally, a blocking mechanism would produce an equal amount of interference in the two conditions because any strong item will block a weaker one.

EXPERIMENT 3A

Method

Subjects and Design

Another 66 undergraduates participated in each of three conditions. In the control condition, the target was not related to any other word pairs in the experiment. In the similar-meaning and different-meaning conditions, the target (*child–apple*) shared its stimulus word (*child*) with a relative that appeared on the test. The relative shared semantic features with the target in the similar-meaning condition (A–B’: *child–cookies*) and shared fewer se-

mantic features with the target in the different-meaning condition (A–C: *child–bicycle*). Across subjects, every A–B target appeared in each condition equally often.

Procedure

As in our other experiments, the subjects generated sentences for the A–B targets, which were presented at a 10-sec rate. A distractor task (generating city names) occupied the subjects for the next 3 minutes, and then cues were provided (at a 5-sec rate) to recall each of the targets.

During the test, the subjects also generated some sentences for A–B’ relatives (similar-meaning condition) and for A–C relatives (different-meaning condition). The intention was to introduce information that might interfere with recalling the target. The subjects were given 15 sec to write down a sentence for each A–B’ or A–C pair.

Materials

The 18 targets were the same as those used in Experiment 1. For each target (e.g., *child–apple*), two relatives were constructed that shared their stimulus word with the target (e.g., *child–cookies* and *child–bicycle*). One of the relatives shared semantic features with the target (A–B’) and the other did not (A–C). The words that were paired together always had a low preexperimental association.

The test form contained cues for each of the 18 targets (e.g., *child–app__*) arranged in a random order. On six occasions, the A–B’ relative preceded the cue (similar-meaning condition), and on six occasions, the A–C relative preceded the cue (different-meaning condition).

EXPERIMENT 3B

Method

In Experiment 3B, the stimuli were sentences (e.g., *The child ate the apple*) rather than word pairs (e.g., *child–apple*). Using sentences allowed us to control the semantic meaning that the subjects encoded about the target.

Materials

A target sentence was constructed for each of the targets from Experiment 1 (e.g., *The child ate the apple*). Each sentence was constructed so that the stimulus word (*child*) was the agent of the sentence and the response word (*apple*) was the subject of the sentence.

For each target (e.g., *The child ate the apple*), three relatives were constructed. The agent of the sentence (*child*) was the same for each sentence. In one sentence, the meaning differed from the target (e.g., *The child rode the bicycle*). The meaning of the other two sentences was similar to that of the target, and either the same verb was used (e.g., *The child ate the cookies*) or a similar verb was used (e.g., *The child devoured the cookies*).

Subjects and Design

Another 110 volunteers participated in Experiment 3B. Each subject contributed observations to the four conditions described next and in Table 3.

Control. The target sentence was unrelated to other sentences in the experiment.

Similar-meaning. The target and relative sentences had the same agent and verb (e.g., *The child ate the apple*. *The child ate the cookies*) and approximately the same meaning.

Different-meaning. The target and relative sentences had the same agent, but the sentences emphasized different semantic features (e.g., *The child ate the apple*; *The child rode the bicycle*).

Similar action. The target and relative sentences had approximately the same meaning. The sentences had the same agent, but a different verb (e.g., *The child ate the apple*; *The child devoured the cookies*).

Table 3
Percentage of Targets (e.g., *The child ate the apple*) Correctly Recalled (*child-app*__)
in Each Condition of Experiments 3A and 3B

Condition	Test Phase (Relatives)	% Targets Correctly Recalled			
		Construct Own Sentences 3A		Read Sentences 3B	
		% Recalled	SD (%)	% Recalled	SD (%)
Control	None	83	16	62	23
Similar-meaning	<i>The child ate the cookies</i>	90	15	73	24
Similar action	<i>The child devoured the cookies</i>			68	26
Different-meaning	<i>The child rode the bicycle</i>	65	23	56	26

Across subjects, every target appeared in every condition equally often.

Procedure

The 24 target sentences were presented at a 10-sec rate via an overhead projector, and the subjects were asked to rate the meaningfulness of each sentence on a 5-point scale. Then, the subjects generated city names as a distractor task for 3 min before being tested.

The test provided the usual cues (e.g., *child-app*__) presented at a 5-sec rate. During the test, whole sentences were also interspersed among the cues. When a whole sentence appeared, the subjects were to form an image for the sentence and to rate their ability to do so on a 5-point scale. Each whole sentence was shown for 10 sec.

Results and Discussion

The mean percentage of targets recalled is shown by condition in Table 3. Each mean is based on 396 observations in Experiment 3A, and on 660 observations in Experiment 3B. Planned comparisons were made via separate ANOVAs for each comparison. The family-wise error rate was set at .05 for each experiment.

Compared to performance in the control condition, recall improved if an A-B' relative was shown. Targets were recalled more often in the similar-meaning (A-B') condition than in the control condition in Experiment 3A [$F(1,65) = 9.544$, $MS_e = .537$] and in Experiment 3B [$F(1,99) = 19.417$, $MS_e = 1.191$]. In Experiment 3B, there was a marginally significant tendency to recall more targets in the similar action condition than in the control condition [$F(1,99) = 4.734$, $MS_e = 1.369$].

In contrast, recall decreased if an A-C relative was shown that differed in meaning from the target. The targets were recalled more often in the control condition than in the different-meaning condition in Experiment 3A [$F(1,65) = 39.208$, $MS_e = .974$], and a marginally significant effect was found in Experiment 3B [$F(1,99) = 3.995$, $MS_e = 1.282$].

The results support Martin's (1972) cue-change theory, which asserts that a relative interferes to the extent that it emphasizes features that differ from those of the target. It does so by influencing the retrieval cue, which is then less likely to match the trace for the target event. In contrast, a relative that shares semantic features with those of the target shifts the meaning of the retrieval cue toward the target and increases recall.

Martin (1972) viewed cue-change in terms of the Estes (1955a, 1995b) stimulus fluctuation model. According to the model, the target primes features that lose

their emphasis over time. If another event primes different features, then the retrieval cue takes on these features and is less likely to match the memory trace for the target. If another event primes features that match the memory trace, this can actually facilitate recall of the target.

The effects can be attributed neither to a discrimination process nor to a blocking process. According to the discrimination view, it is more difficult to discriminate between semantically similar traces (similar-meaning condition) than it is to discriminate between semantically dissimilar traces (different-meaning condition). If a discrimination process had been causing the interference, then performance would have been lower in the similar-meaning condition than in the different-meaning condition, but the opposite was found. The effects also cannot be attributed to blocking. Because any strong item would block a weaker item, a relative should interfere regardless of whether its meaning is similar to that of the target or different from it.

GENERAL DISCUSSION

The present experiments show that cued recall for an A-B target (e.g., *child-apple*) is not always affected by seeing an A-C relative (e.g., *child-bicycle*). A greater interference effect was found if the A-C relative (1) occurred recently, during the test phase, rather than during the study phase; and (2) emphasized semantic features that differed from those of the target. Recall of the target was facilitated by showing an A-B' relative that emphasized similar semantic features.

These interference effects are best explained by Martin's (1972) cue-change theory. Modeled after the Estes (1955a, 1995b) stimulus fluctuation model, Martin's theory assumes that the A-B target primes certain features, and that these features gradually lose their emphasis over a retention interval. When a retrieval cue is presented, it takes on whatever features are still primed. If only the A-B target is shown, then the cue tends to take on its features. If another item (e.g., A-C) is shown, it primes features that determine how the retrieval cue is interpreted. In essence, these primed features become the functional retrieval cue. Because A-C emphasizes different features than does A-B, the functional retrieval cue emphasizes features that do not match those of the target trace, and cue-dependent forgetting occurs (see also Tulving & Thomson, 1971, 1973).

The cue-change theory can also explain why studying A-B' facilitates recall of A-B. Showing the A-B target emphasizes certain features, but these features lose some of their priming over the retention interval. Showing an A-B' item primes some of these same features again. The primed features determine the functional retrieval cue, which now matches the trace better than the cue in the A-B only condition.

Thus, the cue-change theory can explain why showing A-B' facilitated recall of A-B and why showing A-C inhibited recall of A-B (Experiments 3A and 3B). The cue-change view can also explain why A-C interfered more when it was shown on the test than when it was shown at study (Experiments 1, 2A, and 2B). Recently primed features were more likely to influence the functional retrieval cue.

Other theories of interference cannot explain all of our findings. According to blocking theories (e.g., Roediger, 1974, 1978; Rundus, 1973), a relative interferes because it is sampled instead of the target. A blocking process can account for our first finding. Because a recent relative (shown on the test) is more likely to be sampled, it is more likely to interfere than a relative that occurs in the study phase. The theory cannot explain our second finding, however. If a relative interferes by preventing the target (*child-apple*) from being sampled, then it should interfere even if it matches the meaning of the target. However, our Experiments 3A and 3B show that a relative interferes to the extent that its meaning differs from that of the target's. If the target and its relative share many semantic features, then the relative facilitates recall of the target. Clearly, blocking cannot explain these effects.

The "access" part of access-and-discriminate theories (e.g., Hintzman, 1986; Metcalfe, 1990; Reinitz et al., 1992) is consistent with our findings in Experiments 1, 2A, and 2B. In those earlier studies, A-C interfered more when it was shown at test than at study. Such findings are consistent with the idea that in order for a discrimination problem to occur, both the relative and the target trace must be activated. Showing A-C at test rather than at study increases the probability that its trace will be activated and opens the door for a discrimination problem.

However, our findings do not support the "discrimination" aspect of access-and-discriminate theories. Suppose that access is facilitated when A-C is presented during the test (the test 1 and study 5 + test 1 conditions). A-C should interfere to the extent that it shares features with the target. For example, it should be more difficult to discriminate between traces if they share temporal and contextual features than if they do not. Therefore, more interference should occur when the target and relatives are all shown in the study phase (study 5 + test 1 condition) than when a relative is shown in the test phase only (test 1 condition). However, an equal amount of interference occurred in the two conditions (Experiments 2A and 2B).

In addition, it should be more difficult to discriminate between traces if they share many semantic features (e.g., *child-apple* and *child-cookie*) than if they share few

semantic features (e.g., *child-apple* and *child-bicycle*). Therefore, more interference should be found when the relative and target share semantic features. But the opposite result occurred in Experiments 3A and 3B. In fact, the relative facilitated recall when its meaning was similar to that of the target. Again, the idea of cue-change provides the only viable account of our findings.

GENERALITY OF THE FINDINGS

Although cue-change best explains our findings, the possibility remains that other factors cause interference with other materials or tests. Several authors have suggested that accessing the trace is problematic for recall but not for recognition (see Tulving & Thomson, 1971, for a review). Contrary to that view, context effects have been found in recognition, which suggests that accessing the trace can be difficult in recognition tests (e.g., Light & Carter-Sobell, 1970; Thomson, 1972; Tulving & Thomson, 1973). Using materials that were similar to ours, Tulving and Thomson (1973) found that recognition of targets (e.g., *art-girl*) suffers if the context word is removed (*girl*) or changed (*adult-girl*). Cue-change can account for the effect if one assumes that a change in context shifts the meaning of the retrieval cue away from the encoded trace.

In hindsight, it makes sense that cue-change interferes with remembering pairs of meaningful words. It is widely acknowledged that semantic context (e.g., *apple*) determines the meaning of common words (e.g., *child*) and which semantic features are encoded (see, e.g., Dalton, 1993). Furthermore, it is known that both recall and recognition are higher if the retrieval cue matches the features that were encoded about a target (e.g., Tulving & Thomson, 1973). It is not difficult to extend the argument by saying that context, in the form of features primed by A-C, changes the functional retrieval cue and causes cue-dependent interference effects.

Although our findings are best explained by a cue-change process, other retrieval processes may produce interference effects with other tasks or materials.² In an earlier study in which the same logic as that outlined in Experiments 1 and 2 of this article was used, evidence was found for a discrimination process (Chandler, 1993b). The subjects studied nature pictures (e.g., Lake A) and were tested using a forced-choice recognition test (Did you see Lake A or Lake C?). The subjects rated the pleasantness of a related picture (e.g., Lake B) that was shown at study, at test, at both study and test, or not at all. The relative interfered with recognition of the target only when it was shown in the study phase of the experiment. In other words, the relative interfered only if it shared its temporal and contextual features with the target. When it was difficult to discriminate between two traces (Lake A and Lake B) based on these features, the target was chosen less often in the forced-choice recognition test (Lake A vs. Lake C).

A discrimination process may have been important for recognition of nature pictures because the traces for

Lake A and Lake C share so many perceptual features. Each of these landscapes contained a similar set of perceptual details (e.g., water, edges, curves, the angle of tree branches) that differed primarily in spatial orientation and density. It is easy to imagine how features from two such traces could combine during the retrieval process to form a composite memory (see, e.g., Metcalfe, 1990; Reinitz et al., 1992), especially if the trace for Lake A could be selected on the basis of temporal or contextual features.

These results (Chandler, 1993b) emphasize that not all interference effects are caused by the same retrieval process. Instead, different retrieval processes appear to be important in different tasks. The real challenge now is to figure out why.

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NOTES

1. Although cue-change is not a popular explanation of item-specific interference, list-general interference is often attributed to a shift in *contextual* cues. In the list-general design, a control group learns the target list while an experimental group learns an additional list. Interference may occur because the additional list shifts the contextual cues so that they do not match what was encoded (see, e.g., Postman, Stark, & Fraser, 1968).

Our work focuses on causes of item-specific interference that, by definition, cannot be explained by a change in contextual cues. In the item-specific design, contextual cues are equated via alternation of the control and experimental items within the studied list (see, e.g., Delprato, 1971).

2. Discrimination may be more problematic for tokens than for types (see Mandler, 1979, p. 286).

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