Critical issues in interference theory*

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Critical issues in the theoretical and experimental analysis of interference processes in retention are reviewed. The evolution of classical two-factor theory is traced, and the strengths and weaknesses of the contemporary version of this position are examined. Recent critiques of current interference theories by Martin (1971a) and Greeno, James, and Da Polito (1971) are reviewed and examined. New conceptualizations of interference proposed by these authors, which place major emphasis on retrieval dependencies and on the role of encoding and retrieval processes, are considered and evaluated.

The classical two-factor theory of interference (Melton & Irwin, 1940), which for a long time had few serious rivals as a framework for the analysis of forgetting, has recently become a focus of important criticism and controversy. The purpose of this paper is to assess the present status of the theory and to examine some of the basic challenges which have been mounted against the classical position and its current modifications.

In the interest of clarifying the central issues, we will begin by restating briefly the guiding concepts and assumptions of two-factor theory as it has been interpreted by its proponents. The two factors which give the theory its name are, of course, unlearning and competition. Of these, the process of unlearning, which was made accessible to direct measurement by the introduction of the MMFR test (Barnes & Underwood, 1959), has been receiving primary attention in both theoretical discussions and experimental investigations. In the next section, we trace in broad outline the development of contemporary views of the conditions and characteristics of unlearning.

THE CONCEPT OF UNLEARNING

Original Formulations

There are two basic defining characteristics of the concept of unlearning: (a) The consequence of unlearning is reduced availability of the first-list response on a test for retroactive inhibition (RI); and (b) the temporal locus of the events responsible for unlearning is

during interpolated learning (IL), e.g., the acquisition of A-C in the A-B, A-C paradigm, rather than at recall. In the analysis of unlearning, the major theoretical question concerns the nature of the processes that come into play during IL and serve to lessen the availability of first-list responses. In the original formulation of the hypothesis of unlearning, Melton and Irwin tentatively identified the unreinforced or punished elicitation of first-list responses as errors during the transfer phase as the essential antecedent of unlearning. The occurrence of first-list intrusions during second-list learning provides direct evidence for the elicitation of errors that are followed by nonreinforcement. Given this fact, Melton and Irwin concluded that their data "clearly favor a theory that attributes a portion of the RI to a weakening or unlearning of the original S-R relationship during the interpolated learning [1940, p. 200]." Thus, unlearning was seen as contingent upon the evocation of old responses during the acquisition of a new task. While Melton and Irwin emphasized overt intrusion errors as determinants of unlearning, it was soon recognized that covert intrusions rejected by the S as inappropriate may lead to the same consequences (Thune & Underwood, 1943). Subsequently, it was shown that the ratio of overt to covert intrusions does not influence the level of RI (Keppel & Rauch, 1966). We shall, therefore, interpret the classical hypothesis as attributing unlearning to the consequences of the elicitation of both overt and covert intrusions during interpolated learning.

While Melton and Irwin were inclined to conclude that unlearning reflected the weakening of S-R associations, they also entertained an alternative interpretation, applying an hypothesis suggested earlier by Thorndike and by Wendt: "The inhibition or 'unlearning' of one response occurs when it is unreinforced or 'punished' because another incompatible response has been fixated [1940, p. 201]." According to this conception, unlearning of first-list responses occurs after the acquisition of second-list responses. Finally,

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Melton and von Lackum subsequently alluded to the possibility that unlearning is a consequence of response competition during IL. They suggested that the source of such competition may be nonspecific, which implies that the interference may operate at the list level: "If the unlearning factor is so interpreted, the competing responses established when an intrusion from the original list occurs without reinforcement during the learning of the interpolated list are not only the specific responses involved in the recitation of the interpolated list [1941, p. 172f]." Thus, while several alternative mechanisms of unlearning were considered in the original statements of two-factor theory, each of the interpretations proceeded from the assumption that the occurrence of interlist intrusions was the necessary antecedent condition.

Relationship Between Unlearning and Negative Transfer

Historically, the two-factor formulation was an extension of McGeoch's (1942) transfer theory of RI. McGeoch attributed negative transfer and RI to competition of responses during IL and at recall, respectively. In both cases, reproductive inhibition was seen as responsible for the decrements in performance. With the introduction of the factor of unlearning, the processes producing negative transfer and RI could no longer be considered identical except for their temporal locus of operation. Consequently, the adoption of the two-factor position entailed the systematic question of the relationship between negative transfer and unlearning. The analysis of Melton and Irwin carried the clear implication that unlearning was contingent upon the occurrence of negative transfer. This conclusion follows because the interlist intrusions that are assumed to activate the process of unlearning are a manifestation of negative transfer. While intrusions of A-B are expected to accompany the acquisition of A-C, it was definitely not assumed that the unlearning of A-B must precede the formation of the new A-C association. On the contrary, the possibility was left open that the unreinforced elicitation of A-B may follow as well as precede the acquisition of A-C. Whatever the exact temporal locus of the intrusions, the process of unlearning the first list was seen as likely to delay the learning of the second list (Melton & von Lackum, 1941, p. 173). The same point was made by Barnes and Underwood (1959) when they stated that negative transfer may result from the interference accompanying the unlearning process.

The fact that there is an inevitable interaction of first-list unlearning and second-list learning does not entail the conclusion that the latter depends on the former. Such an assertion could not be, and has not been, made by proponents of two-factor theory on both logical and empirical grounds. The logical objection is inherent in the two-factor formulation. If the acquisition

of the transfer task invariably consisted of the replacement of A-B by A-C, competition at recall would be entirely eliminated as a source of interference; either one or the other of the responses would be available but never both. The essence of two-factor theory is, of course, that both sources of interference can become effective at the time of recall, even after a high degree of interpolated learning which ensures the availability of all C responses. In a broader theoretical context, classical interference theory can be seen as more compatible with the concept of a habit-family hierarchy than with the all-or-none view of associative learning (Estes, 1960). The latter position does, of course, hold that two responses cannot be attached simultaneously to the same stimulus.

There are a number of compelling empirical objections to the assumption that the acquisition of A-C presupposes the unlearning of A-B. First of all, regardless of the degree of IL, unlearning is virtually never complete and in fact rarely exceeds about 50%. The relevance of this fact to the interpretation of unlearning was emphasized by Barnes and Underwood (1959) when they introduced the MMFR procedure of assessing the availability of first-list responses: "It does not seem that all items would be extinguished, even with an extremely large number of trials on A-C. . . . Thus, while the present data support an extinction hypothesis they do not indicate why items are not, nor are likely not to be, extinguished [p. 102]." The differential resistance of first-list items to unlearning, which has also been demonstrated in other studies (e.g., Postman, Stark, & Henschel, 1969), presents an important explanatory problem. At the same time, however, such findings rule out the assumption that the acquisition of A-C depends on the unlearning of A-B.

Experiments on probabilistic learning, in which two different responses are learned concurrently to the same stimulus, provide equally strong evidence that the establishment of A-C is not contingent on the elimination of A-B. As Popp and Voss (1965) have shown, negative transfer and unlearning do occur under these circumstances but depend critically on the pattern of alternation of the B and C responses: the more frequent the changes from one response to the other, the lower are the amounts of negative transfer and unlearning. Frequent shifts serve to maintain the availability of both responses. Using an arrangement in which the successive lists were separated, Postman and Parker (1970) found that the original associations can be maintained during transfer learning with little loss in efficiency of performance. There was only a moderate reduction in the absolute speed of A-C acquisition and no significant change in the amount of negative transfer relative to a C-D baseline condition when Ss were required to recall both B and C responses to each of the A terms during the transfer phase. Furthermore, this procedure virtually eliminated RI on a terminal test of recall. Related findings are those of Dallett and

D'Andrea (1965), who instructed one group of Ss to use the B responses as mediational aids in A-C learning and another group to unlearn the B responses in order to reduce associative interference. While the Ss reported that they tried to comply with the instructions, the overall speed of second-list learning was not affected. The attempts at mediation appear to have been largely unsuccessful, since they produced only a moderate effect on the amount of RI. The critical point for purposes of the present discussion is, however, that deliberate attempts either to maintain or to unlearn first-list associations did not influence the speed of transfer learning. The studies which we have just reviewed converge on the conclusion that some associative interference is inevitable whenever new responses are attached to old stimuli, regardless of whether the old responses are maintained or discarded.

On the basis of all the available evidence, it is safe to conclude that the unlearning of A-B is not a necessary condition of A-C learning. As we have emphasized, such an assumption has never been part of the hypothesis of associative unlearning or two-factor theory. In speculations about the mechanisms of unlearning, the guiding assumption has rather been that the acquisition of A-C provides an opportunity for the unreinforced elicitation of A-B. Whether and how frequently such elicitations occur, determining differential resistance of individual items to RI, is a question to which experimental analyses have so far failed to yield a satisfactory comprehensive answer. We will return to this problem below when we discuss experimental tests of the elicitation hypothesis.

The Extinction Analogy

What Melton and Irwin called Factor X and tentatively identified as a process of unlearning soon came to be seen as functionally analogous to the experimental extinction of conditioned responses. Failure to reinforce a conditioned response results in extinction, and the same may be conveniently assumed for verbal associations (Underwood, 1948a, b). It has been recognized, however, that the interference paradigm A-B, A-C is more comparable to the operations of counterconditioning, in which a new conditioned response is substituted for the old one, than to experimental extinction where the reinforcement is withheld (Barnes & Underwood, 1959, p. 97). In any event, extinction and associative unlearning have been used as interchangeable concepts in most recent discussions of the mechanisms of RI. In spite of its obvious limitations and inadequacies (cf. Keppel, 1968, p. 194ff), the analogy has proved heuristically useful as a guide to the systematic exploration of the functional properties of unlearning. The investigation of the spontaneous recovery of unlearned associations is the most important case in point. Since such studies were first initiated, the evidence for recovery has been far

from consistent (for summaries see Keppel, 1968; Postman, Stark, & Fraser, 1968). Recent experiments indicate, however, that rises in first-list recall are likely to be observed after intervals of the order of half an hour (Forrester, 1970; Kamman & Melton, 1967; Martin & Mackay, 1970; Postman, Stark, & Fraser, 1968; Postman, Stark, & Henschel, 1969; Shulman & Martin, 1970). The conditions under which recovery may be expected after intervals of a day or more (e.g., Abra, 1969; Ceraso & Henderson, 1965, 1966; Silverstein, 1967) remain to be fully specified. Taken together, the demonstrations of the phenomenon have been sufficiently frequent, and in the most recent studies consistent and predictable, to support the historical and pragmatic usefulness of the extinction analogy.

The extinction analogy also provided a theoretical underpinning for the elicitation hypothesis which has remained an important point of departure in the analysis of the mechanism of unlearning. If the unreinforced elicitation of errors is, indeed, the essential antecedent of unlearning, then some process akin to extinction must be postulated to account for the weakening of the intruding associations. In the next section, we consider the implications of recent tests of the elicitation hypothesis.

Tests of the Elicitation Hypothesis

The elicitation hypothesis represents an explicit statement of the assumption that unlearning is the consequence of the intrusion of first-list responses during the acquisition of the transfer list. From the beginning, the hypothesis has suffered from the apparent weakness that the absolute frequency of overt interlist intrusions is typically quite low, so that the occurrence of covert intrusions had to be postulated to account for the magnitude of the observed retroactive effects. Tests of the elicitation hypothesis had of necessity to be indirect. The approach adopted in many investigations was to manipulate conditions which could reasonably be assumed to influence the frequency of covert if not overt intrusions. The general prediction is, of course, that any variable that lowers the probability of intrusions should reduce the level of RI. Studies of the effects of the form-class similarity of the responses in the successive lists are a case in point: the greater the similarity, the more frequent and persistent the interlist intrusions should be and hence the greater the RI. This expectation has been confirmed (Friedman & Reynolds, 1967; Postman, Keppel, & Stark, 1965); the fact that a shift in form class influences RI under unmixed- but not under mixed-list conditions (Birnbbaum, 1968a) adds weight to the original interpretation of these findings. The hypothesis also received apparent support from Goggin's (1967) demonstration that interpolated learning by the method of prompting, which reduces the opportunities for intrusion errors, serves to lower the level of RI as compared to the conventional anticipation procedure.

On the other hand, the results have been mixed and inconclusive in experiments testing the prediction that, with the number of transfer trials held constant, interlist intrusions should be more frequent and RI greater under conditions of multiple-list than single-list interpolation (Birnbaum, 1968b; Goggin, 1968; Postman, 1965; Weaver & Danielson, 1969).

For purposes of the present discussion, the most important implication of the elicitation hypothesis is that RI should be related inversely to the speed of second-list learning. The more rapidly an A-C item is acquired, the less likely it becomes that an erroneous A-B association will be elicited in the course of transfer learning. That is, the presence of a strong A-C protects A-B from unlearning. This relationship should hold for variations in speed of learning related to type of materials, S ability, and item difficulty. Although Postman and Stark (1965) found some evidence for the expected correlation with S ability, other tests have yielded little or no empirical support for this prediction. Two relevant findings may be cited here. Varying the type of interpolated materials, Birnbaum (1968c) found that transfer lists composed of normative associates which were acquired extremely fast did not produce less RI than lists of weakly associated pairs which were learned relatively slowly. The results are not consistent with the elicitation hypothesis, although speed of acquisition and terminal degree of interpolated learning were confounded since a fixed number of interpolated trials was given.

The same confounding, which is difficult to avoid, is present in Runquist's (1957) analysis of the relationship between the degree of second-list learning of individual items and the level of RI for corresponding first-list items. The lack in reduction of RI as a function of speed of List 2 learning derives added importance from the fact that for paradigms of stimulus identity such as A-B, A-C there is often a positive correlation between the speed of first-list and second-list learning of corresponding items (e.g., Postman & Warren, 1972; Wichawut & Martin, 1971). When items are pooled across Ss, individual differences in learning ability become an additional source of positive correlation. These factors should have favored the expected covariation between the rank of List 2 items and recall of first-list associations, but failed to do so in Runquist's results. On the other hand, Wichawut and Martin (1971) have recently reported a positive relationship between B and C recall when items are ranked according to speed of first-list learning. There are measurement problems here that await solution, since full account has to be taken of the terminal probability of both responses to evaluate the extent to which the levels of recall are interdependent.

Another reason for expecting a positive correlation between B and C recall should be mentioned here, although it does not bear directly on the elicitation hypothesis. It has been postulated that the process of

unlearning may delay, albeit temporarily, the acquisition of A-C. It follows that the more unlearning an A-B item undergoes, the greater should be the delay in the acquisition of A-C. Consequently, at the end of IL, both A-B and A-C would be weaker if the period of extinction had been protracted than if it had been brief, and this would contribute to a positive correlation between A-C strength and A-B recall.

It is fair to conclude that the evidence for the elicitation hypothesis, insofar as it entails a positive correlation between the absolute frequency of interlist intrusions and the amount of RI, is far from impressive. The original assumption that the development of unlearning is monotonically tied to the repeated elicitation of first-list associations is, therefore, in doubt. It should be recognized at the same time that critical tests of the hypothesis have been difficult to devise, partly because of the rare occurrence of overt intrusions and partly because assessments of the effects of speed of acquisition have been confounded with variations in degree of learning. For purposes of the discussion that follows below, however, it is important to emphasize that the elicitation hypothesis has been viewed as entailing a positive rather than inverse correlation between the speed of acquisition (and strength when correlated with speed) of second-list items and the recall of corresponding first-list items on a test of RI. The weakness of the evidence for a direct relationship between the frequency of intrusions and the amount of unlearning suggests that the unreinforced elicitation of errors may be a condition that triggers other processes—not in a one-to-one fashion—which become operative in reducing response availability. We will return to this possibility when we discuss the hypothesis of response-set interference.

Component Analysis of Unlearning

A major step in the verification of the unlearning hypothesis was the introduction of the MMFR test, which made it possible to obtain estimates of the availability of first-list responses independently of specific competition. At about the same time, the component analysis of transfer, which is based on a two-stage conception of associative learning, was applied to the measurement of unlearning (McGovern, 1964). The point of departure is the assumption that the unlearning of responses *per se* and of specific associations are in large measure independent processes whose effects summate to determine the level of first-list recall. Differences in the amounts of RI observed under standard paradigms of transfer can be satisfactorily predicted on the basis of this assumption, with the loss of responses as such referred to the unlearning of contextual associations and the loss of pairwise associations to the unlearning of specific S-R connections. Component analysis has made it possible to subsume a large body of data on RI under the principle

of associative unlearning. As a descriptive and predictive device, the hypothesis has, therefore, continued to be successful. On the other hand, attempts to specify the exact mechanisms of associative unlearning have met with only indifferent success. The explanatory power of two-factor theory does not, of course, rest on the unlearning hypothesis alone. The analytic usefulness of the concept of competition, as applied in conjunction with the principle of unlearning, must also be considered.

THE CONCEPT OF COMPETITION

Specific vs Generalized Competition

In the transfer theory of RI formulated by McGeoch (1942), competition was the result of incompatible responses being attached to the same stimulus. Both responses were assumed to remain available. Competition was seen as leading to the blocking of correct responses and interlist intrusions at recall. As already noted, owing to the rare occurrence of interlist intrusions, reproductive inhibition remained largely a hypothetical construct rather than an observable fact. The majority of the errors contributing to RI, even on paced tests of recall, were failures to respond. A reasonable explanation of the high frequency of omissions was offered when Newton and Wickens (1956) introduced the concept of generalized response competition, i.e., the tendency to continue to give second-list responses on the retention test for the first list. Thus, a distinction came to be made between specific and nonspecific response competition—the former referring to the blocking of individual responses in the sense described by McGeoch, and the latter to the persistence of a set to give the responses learned last.

Extension of the Hypothesis of Generalized Response Competition: The Hypothesis of Response-Set Interference

The hypothesis of response-set interference (Postman, Stark, & Fraser, 1968) represents an extension and elaboration of the basic principle of generalized response competition. According to this hypothesis, unlearning results from the operation of a mechanism of response selection which exerts its primary effect on the entire class of first-list responses rather than on specific stimulus-response associations. The essential steps in the argument are as follows: (a) During the acquisition of the first list, a selector mechanism (Underwood & Schulz, 1960) serves to activate the appropriate responses and to inhibit the occurrence of the inappropriate ones. (b) In the transfer phase, the operation of the selector mechanism results in the activation of the newly prescribed responses and the inhibition or suppression of the earlier ones. (c) The selector mechanism is characterized by a certain amount

of inertia. The tendency to give the responses learned last persists on a test of recall after the end of IL. The consequent impairment of the S's ability to shift back to the repertoire of first-list responses is designated as response-set interference. Response suppression during IL and response-set interference at recall are complementary effects of the operation of the selector mechanism during transfer learning. The temporal locus of the suppression of the first-list responses is during IL; the continuing dominance of the second-list repertoire during recall constitutes response-set interference. Logically, response-set interference can occur even if the first-list repertoire is not suppressed as long as there is a strong disposition to give the responses learned last. It is assumed, however, that first-list suppression during IL and second-list dominance at recall are correlated. Furthermore, the degree of suppression and subsequent response-set interference are taken to be a function of the level of negative transfer, e.g., to be greater for A-C than for C-D. The latter relationship is postulated on the assumption that the elicitation of first-list errors serves to intensify and sustain the operation of the process of response selection. (d) Response selection is assumed to be a reversible process, and absolute rises in first-list recall are expected as the interval between the end of IL and the test for RI is lengthened. (It is only a fair recognition of historical developments that the extinction analogy generated the prediction of spontaneous recovery, whereas the hypothesis of response-set interference and other positions discussed later made assumptions postdicting the phenomenon.)

There were a number of experimental findings which gave apparent support to the hypothesis. The most important among these were: (a) RI under the A-C paradigm is typically substantial when recall of the responses is required but is relatively small or absent altogether when a recognition procedure, which eliminates the requirement of response recall, is used during the acquisition of the successive lists and on the test of first-list retention (Postman & Stark, 1969). (b) Absolute recovery is observed under both the A-C and C-D paradigms (Postman, Stark, & Henschel, 1969). Furthermore, regardless of the initial level of RI, there is evidence of recovery only when there is a change in responses (Postman & Warren, 1972). Thus, at least that portion of the total RI which is reversible appears to reflect the loss of responses *per se* rather than the weakening of specific associations. Other findings, e.g., those related to the similarity of successive response classes, are consistent with the hypothesis but can also be accommodated, as was shown earlier, by a theory of associative interference with the aid of some reasonable assumptions.

There have been numerous recent experiments designed to test the hypothesis of response-set interference. Before these can be discussed, it is necessary to make explicit the scope and limitations of the hypothesis as it was originally formulated. (a) The

loss of responses per se is attributed to the operation of a mechanism of selection rather than to the unlearning of contextual associations. (b) The hypothesis is concerned entirely with the mechanisms governing response availability per se. It is taken for granted that the placement of responses at the time of test remains under stimulus control, just as it is in acquisition. In fact, the possibility of a mechanism of response suppression was initially suggested by the apparent stability of the associative component of recall. (c) The possibility that associative losses may contribute to RI is not being denied in toto, particularly in view of the heavy interference found under the A-Br paradigm. Thus, it was suggested that first-list associations which continue to be elicited during interpolated learning because of failures of the selector mechanism may be weakened progressively (Postman & Stark, 1969, p. 176). What is being questioned are the generality and extent of associative unlearning under various conditions of negative transfer, e.g., under the A-C paradigm. (d) Contrary to the usage adopted by Martin (1971a), this is not a hypothesis of list differentiation in the conventional sense of accuracy of identification of list membership. It is likely that the effective operation of a selector mechanism entails a high degree of list differentiation. However, the critical factor is not the S's ability to identify the list membership of whatever responses do occur but rather the mechanism governing the availability of alternative response repertoires for recall.

The hypothesis of response-set interference represents a modification or elaboration of two-factor theory, not an alternative to it. The main changes lie in the assumption that response loss results from the operation of a selector mechanism and the relative weight assigned to list-related as opposed to item-specific interference. The term item-specific here refers not only to pairwise associations, but also to individual response terms. A component analysis such as McGovern's implies that there are associations between each individual response and the experimental context, and it is the unlearning of these multiple contextual associations which results in the loss of responses per se. By contrast, the principle of response-set interference holds that the mechanism responsible for response loss operates at the list level. As for the unlearning of specific S-R associations, this type of item-specific interference could obviously not be ruled out on the basis of the available evidence.

Recent critics have placed the concepts of associative unlearning and response-set interference in sharp opposition as hypothetical mechanisms of RI. They do, to be sure, represent different mechanisms, but they are not mutually exclusive. Even with the incorporation of a principle of response suppression, a dual locus of retroactive effects—during interpolated learning and at the time of recall—continues to be assumed. Furthermore, associative interference retains its status as a significant antecedent of the degree of response suppression.

Tests of the Hypothesis of Response-Set Interference

The evidence accumulated thus far in support of the hypothesis of response-set interference is certainly not conclusive, and there are some experimental results which pose genuine difficulties for the hypothesis. On the other hand, there are also a number of findings offered in refutation of the hypothesis which cannot be regarded as critical at the present juncture. Without attempting to present an exhaustive review, we will consider some of the relevant findings with reference to a series of systematic points bearing on the principle of response-set interference.

(1) The usual difference in retention loss between the A-C and C-D paradigms does not in itself bear on the question of the relative weight of response-set interference and item-specific unlearning in determining RI. The degree of suppression of the first-list repertoire and consequent dominance of second-list responses are expected to be related to the amount of negative transfer. The fact that RI is observed under the C-D paradigm is, however, evidence for interference with response recall per se. The existence of such a process was brought out clearly in a recent study by Lehr, Frank, and Mattison (1972). Considerably greater RI and spontaneous recovery in A-B recall were observed after an interpolation of an A-C list than after free-recall learning of an equivalent number of C responses. However, the latter treatment did produce a significant amount of interference followed by recovery. Thus, some response-set interference occurs in the absence of associative transfer, but the retroactive effects are greatly enhanced when such transfer is present. The fact that the difference between A-C and C-D is greater when recall is stimulus-cued rather than free (Keppel, Henschel, & Zavortink, 1969; Postman, Stark, & Fraser, 1968, Experiment IV; Weaver, Rose, & Campbell, 1971) is understandable on the assumption that the presence of the A terms maintains the selective set established during interpolated learning. It must be noted, however, that comparisons between the two types of test are complicated by the fact that stimuli are less available as implicit mediators of response recall after C-D than after A-C interpolation (Weaver et al, 1971), presumably because there is more frequent exposure to the A terms in the latter case.

Differences in RI between the two paradigms assume systematic importance when they are observed, as they have been in several studies, under conditions of mixed-list interpolation (Delprato, 1971; Weaver et al, 1971; Wichawut & Martin, 1971). It has been argued that such differences should not be found if the entire repertoire of first-list responses is suppressed. Hence, superior retention under C-D has been interpreted as pointing to item-specific interference. The argument is reasonable, but before it is accepted as definitive, it must be determined whether response-set interference can be selective with respect to readily identifiable subgroups of items within a list. In a previous study of transfer with a

mixed-list test (Postman, 1966), an analysis of misplaced responses showed that items with old stimuli were consistently differentiated from items with new stimuli. The assertion that the mechanism of response selection operates on the entire repertoire of first-list responses was made with reference to the conventional arrangement in which all the items in the interpolated list conform to the same paradigm. The conditions of interference under mixed-list interpolated learning present new analytic problems. The question now arises whether paradigm differences point to differential suppression of subgroups of items or specific unlearning. One obvious approach to this problem is the manipulation of similarity relations between paradigmatic subgroups within a list.

A related point is that the incidence of response suppression, and in particular its operation at the list level, cannot be considered independent of the length of the interpolated task. The selection criteria established during interpolated learning will reflect the number and characteristics of the items in the transfer list. This point bears on the experiments of Birnbaum (1970, 1972) which investigated the effects on RI of the omission of first-list stimuli from the interpolated list. While the results were variable, the net outcome was that the omission of first-list stimuli served to reduce the amount of RI for corresponding first-list pairs. It is possible that these findings imply item-specific interference. Again, the conclusion cannot be definitive until the boundary conditions of response-set interference are defined more precisely. For example, would such interference be expected if all but one or two of the first-list stimuli were omitted? The intuitive answer to this question would appear to be in the negative. Hence, the quantitative relationship between amount of stimulus overlap and evidence for item-specific RI needs to be examined.

(2) While there is obviously no reason to press the null hypothesis that item-specific interference never occurs under the A-C paradigm, there definitely are conditions which minimize such interference. With reference to the principle of response-set interference, it is noteworthy that these conditions appear to be related to the distinctiveness of the successive response repertoires. There are clear indications that unlearning is essentially eliminated when the degree of distinctiveness is either very low or very high: (a) Using a paired-associate procedure in which A-B, A-C, and control items were intermingled during the presentation phase, Da Polito (1966) found no RI on an MMFR test of recall, although there was negative transfer and apparent proactive inhibition (PI). Under these conditions, a mechanism of response selection obviously cannot operate. (b) When acquisition trials on A-B are widely distributed and followed by massed practice on A-C, there is not only a marked reduction of PI in the recall of A-C, but also a virtual absence of unlearning of A-B even after very heavy amounts of interpolated learning (Underwood &

Ekstrand, 1966, 1967). The reduction of PI has been attributed to the increased differentiation resulting from the change in the temporal schedule of practice. The presence of highly effective temporal cues may also facilitate the shift from one set of responses to another on an unpaced MMFR test. (It is interesting to note that recall of A-B remained virtually perfect even when some A-B pairs were carried over into the A-C list, although this procedure reduced differentiation and led to substantial PI on a paced test for A-C. It was suggested that repeated and nonrepeated pairs were set apart in the second list, and this factor may account for the continued full availability of the A-B responses on an unpaced test.) These failures to obtain RI, which occurred under widely different experimental conditions, make it clear that item-specific RI under the A-C paradigm is far from inevitable.

(3) The observation that specific associations appear to be highly resistant to interference under the A-B, A-C paradigm has given face validity to the principle of response-set interference, even though the two processes are not mutually exclusive. Some important questions have been raised recently about the validity of the inference that specific associations are relatively immune to retroactive interference. The empirical findings at issue can be briefly summarized as follows. When acquisition is by a recall procedure and retention is tested by associative matching, some RI is typically found, although of a smaller order of magnitude than on an MMFR test (e.g., Delprato, 1971; Garskof, 1968; Garskof & Sandak, 1964; Sandak & Garskof, 1967). Such measures suffer from the difficulty that there is a shift in procedure between acquisition and the test of retention, which may possibly have more adverse effects on an experimental group learning two lists than on a control group learning a single list. If taken at their face value, these results show that the unlearning of specific associations develops slowly as compared with the loss of response availability. When both acquisition and retention are by the multiple-choice method, the amount of RI is likely to be slight and fall short of significance (Anderson & Watts, 1971; Postman & Stark, 1969).

It has now been suggested that the high level of performance on a matching or multiple-choice test is mediated by intact backward associations which S is able to utilize even when the forward associations have been unlearned. Evidence in support of this conclusion was first presented by Merryman (1971), who used a mixed-list design in which the conditions of unlearning were unidirectional (A-C) for some pairs and bidirectional (A-C and B-E) for others. The interpretative difficulties posed by such a mixed-list design have been discussed elsewhere (Postman & Stark, 1972). More recently, Greenberg and Wickens (1972) carried out a similar study. Acquisition of the successive lists was by the anticipation method, and an associative matching test was used to measure RI. The comparison

of primary interest is between a condition of bidirectional unlearning (alternating trial blocks of A-D and B-C or A-D and C-B) and "double unilateral" conditions (A-D and A-E, C-B and E-B, or B-C and B-E) in which the total number of interpolated trials was held constant. Performance on the matching test was worse in the former than in the latter case, although the difference fell short of significance. The levels of retroaction were relatively low in absolute terms, namely, about 20% and 10%, respectively. As was true for Merryman's experiment, the procedure was necessarily complex, and it is uncertain whether the factor of directionality as such was adequately isolated. For example, under the bidirectional treatment there were changes in both the stimuli and the responses in alternating trial blocks, whereas in the unidirectional condition one or the other set of terms remained constant. What the effects of such recurrent shifts in the item pool are is not known. It is not apparent how such problems of design can be avoided. The interpretation of the results is complicated further by the fact that forward and backward unlearning produced exactly equal decrements in A-B retention, which does not agree with the findings obtained under conventional arrangements (e.g., McGovern, 1964). However that may be, it is fair to conclude that mediation by intact backward associations, if it is effective, enhances performance only moderately at best. The conclusion that losses in the accuracy of associative matching under the A-B, A-C paradigm are relatively small, especially when there is no change in the method of testing between acquisition and recall, can be allowed to stand for the time being.

(4) To the extent that RI reflects the suppression of the repertoire of first-list responses, the reinstatement of these responses prior to the test of retention should reduce the level of interference. In a series of experiments designed to evaluate this prediction, Cofer, Failie, and Horton (1971) introduced presentations and free recalls of the first-list responses following IL and during first- and second-list learning. These procedures served to reduce, but not eliminate, RI. The results lend some support to the response-suppression hypothesis but leave room for item-specific associative unlearning. As the authors indicate, it is uncertain whether such procedures as free-recall learning are optimal for the reinstatement of the ensemble of responses in a paired-associate list. There was evidence that subjective organization of the responses developed in the course of the special training procedures which may have interfered with subsequent associative recall. A similar conclusion was reached by Postman, Burns, and Hasher (1970) in an investigation of the effects of response relearning on the long-term recall of a single list of paired associates.

If the suppression of the repertoire of original responses contributes to RI, successive recall trials may be expected to reinstate the set to give first-list responses

and to reduce the level of interference. There is only moderate support for this expectation. First-list recall has been shown to increase over repeated tests, but in general it fails to eliminate RI (Delprato, 1970; Greenbloom & Kimble, 1965, 1966; Postman, Stark, & Fraser, 1968; Richardson & Gropper, 1964; Weiss & Lazar, 1968). The fact that there is improvement indicates that the loss of availability is at least partially reversible. The recent demonstration by Adams, Marshall, and Bray (1971) that there are substantial gains in recall as the retrieval time for each item is extended gives further support to this conclusion. On the other hand, the persistence of RI over successive trials shows at the very least that there is resistance to the reinstatement of the original set. The ease of reinstatement may, of course, depend on the degree of response suppression during IL. Consistent with this interpretation is Delprato's (1970) finding of substantial gains over successive MMFR tests for the C-D paradigm but of only minor ones for the A-C paradigm.

(5) The hypothesis of response-set interference specifies only one of the mechanisms which should be considered as potentially operative within the framework of two-factor theory. If the mechanism is, indeed, operative, it reduces response availability; under certain conditions, it may account for most of the observed retention loss, with specific associations remaining largely intact. That is not to deny by any means that the second factor, namely, specific competition, will come into play under appropriate circumstances. This point seems to have been misunderstood by Anderson and Watts (1971), who showed that the juxtaposition of first-list and second-list responses on a multiple-choice test of recognition produced a significant amount of interference, whereas no RI was found when all the alternatives on the test were from within the list. That finding in no way invalidates the conclusion that the specific first-list associations remained intact. In fact, the absence of RI under the noncompetitive treatment shows exactly that. What is demonstrated is that a process akin to competition (or list differentiation) can influence the recognition of specific associations as well as recall.

It would clearly be premature to draw any definitive conclusions at the present time regarding the validity of the principle of response suppression. The existing evidence is mixed, although some of the arguments against it have been based on failures of predictions not necessarily entailed by the hypothesis. Some of the interpretative difficulties stem, of course, from the fact that the characteristics and parameters of the suppression process have not been specified precisely as yet. The suppression hypothesis, or some equivalent formulation, can probably not be discarded so long as there is evidence for interference effects that operate at the list rather than at the item level. If response suppression does occur, its weight in determining RI under a given paradigm and on a particular test of

retention remains a quantitative question to be answered empirically.

THE CONCEPT OF LIST DIFFERENTIATION

We turn now to an examination of the concept of list differentiation which is closely tied to two-factor theory, although it is not an integral part of that theory. In the context of analyses of RI and PI, differentiation has conventionally denoted the discrimination of the list membership of responses. Underwood (1945) assumed that differentiation in that sense was a function of the absolute and relative strengths of the competing associations and the length of the time interval since the end of interpolated learning. For more recent investigations of factors influencing differentiation, see Winograd (1968) and McCrystal (1970).

Loss of differentiation was considered a condition of overt specific response competition, e.g., interlist intrusions would occur when the discrimination of the list membership of responses broke down. The question of whether degree of differentiation would influence the amount of retention loss was originally left open; it might determine only the ratio of covert to overt intrusions, i.e., the number of failures to respond. However, in the absence of time pressure, the rejection of an intrusion might make it possible to emit the correct response if it was available. Thus, loss of differentiation was seen as conducive to overt specific response competition and as a potential contributor to the total amount of interference, particularly on paced tests of recall. The most convincing support for the latter prediction has come from studies of PI where strong temporal cues to differentiation have been shown to eliminate or drastically reduce the level of interference in the recall of the most recent list (Underwood & Ekstrand, 1966, 1967; Underwood & Freund, 1968).

Whereas a high degree of differentiation reduces specific competition, the opposite relationship may be expected to hold for generalized competition. The S's disposition to limit himself to responses from the list learned last will be facilitated when the first- and second-list repertoires are clearly differentiated. Generalized competition is conducive to RI but lowers PI because it favors recall of the list learned last (cf. Postman, 1961). Hence, a loss of differentiation should lead to a reduction of that component of RI attributable to generalized competition and to a corresponding increase in PI. The fact that the level of differentiation has opposing consequences for specific and for generalized competition appears not to have been always understood. It is also important to recognize, for purposes of subsequent discussion, that for a given list the degree of differentiation and response availability are not necessarily correlated. Under certain conditions, only a small proportion of first-list responses may be available, but these may or may not be easily

differentiated from the second-list responses, depending on such factors as the relative strength of the alternative associations, the length of the retention interval, and the presence of other effective cues to list membership. This point is well documented by the fact that on MMFR tests showing heavy retroactive losses, the accuracy of identification of the first-list responses that remain available is almost invariably very high (e.g., Barnes & Underwood, 1959). We do not think that it is useful to extend the connotations of the concept of differentiation too far beyond the original definition which referred to the accuracy of the identification of the list membership of responses. Thus, we prefer not to classify interpretations of interference at the list level as differentiation theories (Martin, 1971a).

THE PRESENT STATUS OF TWO-FACTOR THEORY

Two-factor theory, elaborated within the framework of a component analysis of transfer and supplemented progressively by such principles as differentiation, generalized competition, and response-set interference, has been able to account for a large range of empirical phenomena, and particularly for paradigmatic differences in the level of RI. In stimulating experimentation on spontaneous recovery, it has focused attention on the reversibility of interference over time. In a descriptive sense, the factors of unlearning and competition contingent on loss of differentiation have been repeatedly verified. The exact mechanisms of unlearning remain far from clear, e.g., the exact conditions responsible for the loss of responses per se. The relative weight of associative unlearning and response loss in determining the retention deficits after IL under various paradigms of transfer also remains a subject for investigation.

It must be admitted that the theory cannot account satisfactorily for the total range of phenomena of PI. According to the classical view, PI is determined entirely by response competition at recall. Increases in PI over time have been attributed to the recovery of prior associations and the loss of differentiation. As we have noted, there is persuasive evidence that on paced tests of recall, the level of PI is critically determined by the degree of list differentiation. Proactive inhibition has, however, been consistently observed on MMFR tests where list differentiation is presumably not required (e.g., Ceraso & Henderson, 1965; Houston, 1967b; Koppenaal, 1963; Postman, Stark, & Fraser, 1968). Recovery of the set to give earlier responses may be invoked to account for such results, but only with the additional assumption that the simultaneous arousal of two response repertoires gives rise to output interference (cf. Postman & Hasher, 1972). The possibility must also be considered that in learning the second response to a given stimulus, the S is forced to rely on less effective mediational devices than in learning the first response.

As a consequence, the second association is less well learned than the first, or it is less stable, and hence more subject to being forgotten. One interesting implication of the latter hypothesis is that PI and RI may not be in all respects complementary manifestations of the same underlying processes. The resolution of these uncertainties is one of the many tasks facing interference theory.

MARTIN'S CRITIQUE OF CURRENT INTERFERENCE THEORIES

In spite of the experimental history of two-factor theory which has yielded a not unfavorable mixture of empirical successes and failures, Martin (1971a) concluded in a recent review that neither the hypotheses of associative interference and unlearning nor the principle of response suppression is any longer tenable and that the entire problem of the mechanisms of retroaction and proaction is in need of drastic reformulation. Martin arrived at his conclusion on the basis of what he considered certain crucial experimental findings which he views as invalidating some of the basic assumptions of current views of interference. In the next section, we examine these findings and the conclusions which they entail according to Martin's argument.

The Independent Retrieval Phenomenon

As Martin points out correctly, a basic assumption of the principle of associative interference is that during the formation of a specific A-C association there is a concomitant weakening of the corresponding A-B association. It is this assumption which he believes to have been decisively invalidated by what he calls the "independent retrieval phenomenon." His reasoning is as follows: "If learning an A-C association entails unlearning the corresponding A-B association, and if the likelihood of recalling C indexes the A-C association strength, then we must expect the following inequality: $P(B/C) < P(B/\bar{C})$; that is, it must be that the recall of B is less likely when C is recalled than when C is not recalled [1971a, p. 316]."

In short the probability of recall of B and C on an MMFR test should be inversely related when successive lists conform to the A-B, A-C paradigm. A series of chi-square tests based on the data of a number of different experiments (summarized by Greeno, James, & Da Polito, 1971; Martin, 1971a) have failed to provide evidence for the expected dependency relationship. The probabilities of recall of B and C appear to be, in general, independent. According to Martin, "... the independent retrieval phenomenon denies associative unlearning because the idea of associative unlearning implies a conditional *pairwise* relation between B and C availability, but the phenomenon itself is that there is no such relation [1971a, p. 319]."

We consider first the deduction from the principles of

associative unlearning which leads to the prediction of a conditional pairwise relation between B and C availability. The point of departure in the deductive argument is the statement that "learning an A-C association entails unlearning of the corresponding A-B association." The term *entails* signifies that the unlearning of A-B is a necessary or inevitable accompaniment of the acquisition of A-C. Furthermore, it is postulated that the more strongly A-C is learned, the more thoroughly A-B should be weakened. The latter assumption is obviously necessary to predict a conditional pairwise relation in the recall of B and C. As we have made clear in our earlier discussion, a reciprocal relation between increments in the strength of A-C and decrements in the strength of A-B is not in fact a necessary implication of the principle of associative unlearning. Furthermore, we have shown that if any pairwise relation between B and C recall is to be expected, it is positive rather than negative. The support for the latter deduction is, to be sure, weak, but the opposite prediction simply does not follow from current views of the conditions and characteristics of unlearning.

We consider next the measurement procedures by which Martin and Greeno have attempted to establish the independent retrieval phenomenon. Their analyses consisted of chi-square tests of independence of B and C recall. Each S item was entered into a 2 by 2 contingency table showing the frequencies of the four possible combinations of recall and nonrecall of B (B and $\bar{B}$) and recall and nonrecall of C (C and $\bar{C}$). As noted previously, the tests based on data from numerous experiments have, in general, failed to yield any evidence of interdependence. We will not dwell on the fact that such chi-square tests are not appropriate, since the assumption of independence of observations is violated. As Hintzman (1972) pointed out, Martin was not correct in his assertion that this violation of the assumptions of the test can only inflate, and not depress, the value of the statistic. Rather, we will address ourselves to the logic underlying the construction of the contingency tables and to the question of the potential sensitivity of such tests even if the necessary statistical assumptions were met.

The contingency tables comprise four cells: BC, $B\bar{C}$, $\bar{B}C$, and $\bar{B}\bar{C}$. According to Martin and Greeno's theoretical deduction, the frequencies of $B\bar{C}$ and $\bar{B}C$ should be higher than expected. The latter is the combination derived from the authors' interpretation of the sequence of events in unlearning. If all items were unlearned, presumably all cases would be concentrated in the $\bar{B}\bar{C}$ cell. Such is, however, never the case, and the evaluation of the hypothesis of independent retrieval is based on the configuration of entries in all four cells. Given this state of affairs, we must ask what psychological interpretation is to be given to the cases in which C is not recalled, viz, $B\bar{C}$ and $\bar{B}\bar{C}$. The failures of C recall can be attributed to two primary reasons: (a) C was not learned during the acquisition of the

interpolated list; and (b) C was indeed learned but was forgotten for some reason outside the range of the experimental manipulations, e.g., due to extraexperimental interference. If C was not learned, then the interpolated learning failed to have the expected effect, and there was no opportunity for unlearning. If C was learned and forgotten for reasons outside the defining operations of the experiment, then the same must be true for some cases of B. Thus, the cells in the contingency table represent frequencies of events whose distribution is not uniquely determined by the postulated dependency relationship between the unlearning of A-B and the acquisition of A-C. Consequently, even if one were to accept the deduction that as a consequence of unlearning there should be an inverse relationship between B and C recall, the contingency tables are not in principle suitable for testing it.

The difficulties do not end here. Apart from the logical objections, many of the available contingency tests are vitiated by a lack of sensitivity. In most experiments on RI in which the A-B, A-C paradigm is used, recall of the second list is typically very high if not perfect when interpolated learning is carried to a degree sufficient to produce a substantial amount of unlearning. Under these circumstances, a dependency relationship between B and C recall could hardly be detected even if it were present. Martin and Greeno place major emphasis in their discussions on a cumulative distribution of chi-square statistics obtained from a variety of experimental findings. It is not possible to say in how many of these cases the possibility of a significant chi square was all but precluded by the high level of recall of C. We can, however, comment on some of the tests for which the cell frequencies are reported.

Consider first the results of an experiment by Abra (1969) which Martin (1971a, p. 317) presents as a prototype of the tests of the independent retrieval phenomenon. In this study, the MMFR tests were given either immediately or 24 h after the end of IL. On the immediate test, the mean number of C responses recalled was 8.1/10, i.e., not far from the ceiling of perfect recall which would enforce complete independence of B and C. After 24 h the mean recall of the second list dropped to 5.6, but at the same time the mean score for the first list rose from 5.4 to 7.7 (apparent spontaneous recovery). Now it is the high level of performance on the first list which constrains deviations from independence.

A second set of contingency data available for detailed examination was recently reported by Wichawut and Martin (1971). The major independent variable was the degree of second-list learning in the A-B, A-C paradigm. This variable was manipulated by varying the proportion of A-C and C-D trials given during the transfer phase: 4/12, 8/12, or 12/12. A-C recall increased, of course, as a function of the number of interpolated trials. Interestingly enough, the chi-square values decreased concomitantly from 1.46 to .42 to .00.

At the lowest level of second-list learning there was a trend toward an inverse relationship between B and C recall. The authors suggested that a retrieval dependency might arise when both A-B and A-C are weak. They did not, however, consider the problem of sensitivity which is here confounded with A-C availability. The validity of the tests at the two higher levels of A-C learning was clearly minimized by the high levels of C recall, viz, 79% and 85%. The latter value was accompanied by 72% of B recalls; it is not surprising, then, that the chi-square value for that condition was literally zero. These results have to be considered in light of the further fact that Wichawut and Martin observed a significant positive correlation between speed of second-list learning and strength of corresponding first-list pairs; consequently, the probability of A-C recall must have varied directly with the strength of A-B pairs. This correlation would obviously militate against the emergence of an inverse relationship between B and C recall.

One other set of data inviting comment is that obtained by Da Polito (1966) in which the independent retrieval phenomenon was first brought to the fore. Under some of the conditions of that experiment, the levels of both A-B and A-C recall were moderate, so that these particular contingency tests are not open to the criticism of lack of sensitivity. However, the tests were beside the point so far as an assessment of the mechanisms of unlearning is concerned: Da Polito failed to find any RI whatsoever in his experiment! It is not usual to draw inferences about the mechanisms governing a phenomenon from data in which the phenomenon has failed to materialize.

In a recent note, Martin and Greeno (1972) took cognizance of Hintzman's (1972) objection that the postulated inverse relationship between B and C recall may be masked by factors making for a positive correlation between the test outcomes for corresponding items, in particular differences in stimulus difficulty and S ability. Using the measures obtained in the experiment of Wichawut and Martin (1971), they stratified both Ss and items according to the level of first-list performance. Deviations from independence were found to be relatively small and inconsistent for the various combinations of classes of Ss and items. Martin and Greeno acknowledged, however, that item and S differences might in principle render the tests ambiguous. This state of affairs led them to draw the following conclusion: "Associative interference theory, when coupled with reasonable considerations of subject and item effects, allows for any relation between B and C response that might occur in the data.... Accordingly, this form of associative interference theory is essentially untestable: it has far less empirical content than is acceptable or warranted by present knowledge.... *Without* consideration of possible subject and item effects, we have every reason to reject it ... *with* allowance for possible subject and item effects, it is too open-ended to test and hence of little, if

any, theoretical interest [1972, p. 267]."

These conclusions appear to us to be based on rather unusual and untenable premises. Let us grant (for the sake of the argument only) that the hypothesis of associative interference does imply a negative relationship between B and C recall on MMFR tests. The inherent lack of sensitivity of contingency tests under the arrangements of RI experiments, and the regrettable but nevertheless real and demonstrable presence of S and item differences, make it difficult at this time to devise an appropriate test of this prediction. When the vitiating factors are disregarded in toto, the prediction appears to fail, and the grosser the violation of the requirements of an appropriate test, the more complete the apparent failure is. Hence, the theory is to be rejected! An insistence that major variables known to influence the outcome be considered in the interpretation of the tests is viewed as making the hypothesis too open-ended and hence of little theoretical interest. The posture, then, is that the viability of the hypothesis must be judged entirely by the outcome of one gross statistical test of uncertain validity. Such a position might possibly be defensible, at least pending the development of more appropriate tests, if the negative correlation between B and C recall was the only, or by far the most critical, implication of the principles of associative interference and unlearning. As we have tried to show, however, such is not the case; in fact, the deduction is in error. Thus, we cannot accept the conclusion based on the results of the contingency tests that "neither proaction nor retroaction can be attributed to associative interference or unlearning [Wichawut & Martin, 1971, p. 320]." At this juncture in the history of interference theory, that is a sweeping conclusion indeed, and to be justified it would have to be founded on truly crucial experimental tests. On logical, methodological, and statistical grounds, the contingency tests of the independent retrieval phenomenon fail even to approximate this criterion.

Critique of the Hypothesis of Response-Set Interference

According to Martin, the lack of pairwise contingency between B and C recall makes it necessary to look for mechanisms other than "stimulus-response associative interaction" to account for retroaction, proaction, and spontaneous recovery. What he calls "list-differentiation theory" (the hypothesis of response-set interference) appeared to provide one possible avenue of approach. (Martin views this approach as continuous, or at least as congruent, with McGeoch's principles of independence and response dominance. However, McGeoch's concepts applied, for basic systematic reasons, to specific associative pairings and not to response sets or list repertoires. Hence, the analogy is misleading.) The essential assumptions of the hypothesis of response-set interference have been outlined above. Since the mechanism of response selection is seen as exerting its

main effect on the entire class of first-list responses, a pairwise contingency of B and C recall is not expected. However, as Martin sees it, another kind of retrieval dependency is implied: "The idea of list suppression, or how response dominance comes about, entails response-set organization in memory—the Sets B and C are memorial categories [1971a, p. 321]." Given this formulation, he then generates the following prediction: After A-B, A-C learning, on a test of free recall for the responses in the absence of the stimuli, there should be significant clustering according to list membership reflecting the existence of response-set organization. This prediction was tested in an experiment by Martin and Mackay (1970). Contrary to the deduction, list-determined clustering was not found (although it was observed under the C-D paradigm). There was, however, some marginal evidence of stimulus-determined clustering such that responses paired with the same stimulus tended to be reproduced together. The results were taken to signal a critical failure of the "list-differentiation hypothesis" (Martin, 1971a, p. 321; Wichawut & Martin, 1971, p. 320).

We will now consider the logic of the prediction of Martin and Mackay and the results of their experiment. First, does the principle of response suppression really entail the prediction of list-determined clustering in free recall? The hypothesis at issue is concerned with the mechanisms governing response availability *per se*; predictions about the order of reproduction of the responses that fail to be suppressed are outside the scope of the hypothesis. However, for those specific associations that remain intact, stimulus control over output would be expected to be maintained just as it was during the acquisition of the successive lists. Any other assumption would in fact not be reasonable, since any theory of RI must start with the empirical fact that on a conventional MMFR test, Ss are frequently able to give in succession both of the responses to a particular stimulus. To the extent that Ss are able to generate the stimulus terms implicitly, the situation should be the same during free recall of the responses. Thus, the prediction tested by Martin and Mackay confuses two analytically separable questions: what is responsible for the reduced availability of a set of responses, and what are the principles governing the order of output of those responses that remain available?

Furthermore, a measure of clustering cannot be used as a final criterion for determining whether or not two sets of responses have been differentiated or form "memorial categories." The reason is, of course, that clustering reflects an output strategy which is potentially under the S's control. It is always possible for a S to scan available responses and to reproduce them in accordance with the demands of a particular test of retention. In the situation used by Martin and Mackay, Ss had just finished learning two successive lists by the paired-associate method, undoubtedly were able to recall many of the stimuli, and hence would be expected to

behave in free recall very much as they would on an MMFR test. In this connection, it is important to note, as Martin (1971a, p. 320f) also did, that accuracy of list identification typically remains very high after IL. By that criterion, the responses in the two lists clearly do form "memorial categories," and there is every reason to believe that they could be segregated or "clustered" in output under appropriate instructions.

As far as the specific analyses of Martin and Mackay are concerned, there are indications that their measures of clustering lacked sensitivity. In particular, this conclusion is suggested by a juxtaposition of their measures of output order and clustering. On the immediate test of retention, the mean recall frequencies were 5.5 for B responses and 8.0 for C responses. The measures of output order showed that, on the average, C items preceded B items by 3.1 positions. It is apparent that a difference of this magnitude could be obtained only if at some point in recall a string of C items was reproduced in succession, perhaps those for which the corresponding B responses were not available. The measure of clustering had, of course, to take account of the absolute frequencies of recalls from the two sets, so that the occurrence of strings of C items would be expected "by chance." However, such an interpretation is not psychologically meaningful in an analysis of retroaction where the difference between the frequencies of B and C is the essential result of the experimental manipulation. The picture which emerges is that there was clustering by both lists and stimuli and that the separate analyses considering each type of organization by itself did not yield convincing evidence for either.

The experiment by Martin and Mackay has been discussed in detail because it has been used as a major argument against the viability of the hypothesis of response suppression. We believe that the results bear only tangentially if at all on that hypothesis. The situation is thus similar to that encountered in Martin's critique of the principle of unlearning. An observation regarding retrieval dependencies regarded by the author as a sufficient basis for the rejection of an entire theoretical position turns out to have uncertain implications and to be far from crucial. An overriding emphasis on retrieval dependencies may be ill-advised in pursuing the question of whether a complex theory of transfer and forgetting with many empirical ramifications is in principle tenable. Correlations between responses to corresponding stimuli are multiply determined, and output order is a characteristic of performance under the S's control. There is no reason to view retrieval dependencies as more decisive than other empirical implications derived more directly and unequivocally from the theoretical positions at issue.

THE ROLE OF ENCODING PROCESSES IN TRANSFER AND INTERFERENCE

In this final section, we consider alternative

conceptualizations of transfer and interference advanced by critics of current positions, notably Martin (1971a) and Greeno et al (1971). These approaches share a major emphasis on the role of encoding processes in creating conditions conducive to negative transfer and interference. There are, however, some important differences between the positions outlined by Martin and Greeno, and we will comment on each of them in turn.

Martin's Analysis of Interference Processes

Martin's reading of the empirical facts led him to the conclusion that an adequate theoretical explanation must encompass the following pattern of results observed on tests of retention after A-B, A-C learning: (a) There is a dominance relation between B and C producing retroaction and proaction; (b) in view of the independence retrieval phenomenon, such dominance cannot be attributed to pairwise associative interference and unlearning; yet (c) according to the output dependencies observed in free recall, Bs and Cs cluster by stimuli so that retention losses cannot be attributed to suppression of sets of responses. Martin believes that these apparently divergent facts can be understood on the basis of certain assumptions about the characteristics of stimulus encoding in the successive stages of the A-B, A-C paradigm.

The main steps in the argument are as follows: (a) The nominal stimulus A possesses a variety of separate and distinctive features which differ in their saliency for the learner and hence are not equally likely to be sampled. (b) The probabilities with which stimulus components are sampled are independent; this characteristic of independence does not change in the course of acquisition of either A-B or A-C. That is, stimulus components do not become associated with each other in the course of associative learning. (c) The features that are most salient and hence most likely to be sampled change when the response C is substituted for B. This change occurs because, as Greeno et al (1971) have postulated, the characteristics of the response significantly influence the sampling probability distribution over the feature set. (d) Retroactive inhibition occurs because the feature-sampling bias established during A-C learning persists on the test of recall for A-B. As Martin notes, this assumption is an application of the concept of generalized competition—but to feature sampling rather than to response recall (1971a, p. 328). (It is worth noting that this last point may be classified as a version of "list-differentiation theory" insofar as the sampling bias affects the entire array of first-list stimuli. Something like stimulus-feature suppression seems to be implied!) As the feature-sampling distribution reverts to its original shape, spontaneous recovery is observed. Proaction is to be expected to the extent that some of the features dominant during the acquisition of A-B continue to be sampled during the recall of A-C. (e) On

Table 1
Probability of Recall of One or Two Additional Stimulus
Elements Given Recall or Nonrecall of the Response
(from Postman & Greenbloom, 1967)

Recall	Single-Letter Cue					
	First		Second		Third	
	P	N	P	N	P	N
R	.673	248	.871	178	.827	179
$\bar{R}$	.408	76	.219	146	.221	145

Note—*N* = number of cases.

an MMFR test, the *S* takes random samples of the features of the nominal *As*. In these samples, the presence of features relevant to the recall of *Bs* and *Cs* is not correlated; consequently, the retrieval of responses from the two lists is independent. While the samples are said to be random, a bias in favor of the second-list features is assumed to operate to account for the dominance of *Cs* over *Bs* (biased random sampling?). (f) *As* for the clustering of responses by stimuli in free recall (Martin & Mackay, 1970), the assumptions that are made are best stated in Martin's own words: "If AB_1 and AB_2 are two stimuli in A-B learning and AC_1 is the A-C learning version of AB_1 , then certainly AB_1 will be more similar to AC_1 than to AB_2 Accordingly, if in free recall . . . the response B_1 is recalled, then via mediation through AB_1 the subject is more likely to follow up with recall of C_1 than with B_2 [1971a, p. 329]." In short, the similarity of the functional versions of the same nominal stimuli is taken to be responsible for the observed dependency in the free recall of the responses attached during acquisition to the same stimuli.

Stimulus-Component Independence?

Before considering the explanatory and predictive value of this theoretical schema, we will focus explicitly on the assumption of stimulus-component independence which is of pivotal importance in the development of the theoretical argument. This assumption is based largely on the results of studies by Wichawut and Martin (1970) and Martin (1971b). These investigators used paired-associate lists in which the compound stimulus terms were three four-letter nouns and each response term was another four-letter noun. On the terminal test for stimulus selection, each of the four elements was presented singly and the *S* was required to reproduce the remaining three elements. The main finding of interest for present purposes was that a given stimulus element elicited other stimulus components with some substantial probability (which increased as a function of degree of learning) only when the response term was recalled. When the response term was not recalled, the probability of additional stimulus elements being reproduced was essentially zero. In other respects, the

usual results of stimulus selection studies were duplicated, e.g., the effectiveness of the components varied with ordinal position. The dependence of component reproduction on response recall led Wichawut and Martin to the conclusion that (a) stimulus components do not become associated with each other, and (b) in the presence of a given stimulus component the retrievability of additional ones is mediated by the common response term.

We have two comments on these findings and interpretations. First, the inference that the reproduction of components is mediated by the response term is not entailed by the conditional probabilities. There is a simpler explanation. As the facts of selection show, the *Ss* attended to some elements but not to others. If a *S* had attended to a particular element, A_1 , then he was able to recall the response and also to reproduce other elements. The latter fact means, descriptively at least, that an association had been formed between elements. If a *S* had failed to attend to an element, he could not give either the response or other elements. It is not apparent why a process of mediation via the common response has to be invoked at all. Conditional probability does not imply causation.

Our second comment concerns the generality of the findings of Wichawut and Martin. The implication is that there is no incidental learning of associations involving nonselected elements. Such complete absence of incidental learning after many exposures to a set of materials is a rather rare phenomenon. It appeared likely that this state of affairs was peculiar to the arrangement used by Wichawut and Martin in which the stimulus components were distinctive meaningful units and also belonged to exactly the same class of verbal items as the response. Under these circumstances, the *Ss* may have learned selectively shortened serial chains anchored to the terminal unit (the response). The situation might well be different when stimuli are less segmented and well differentiated from the responses. In light of these considerations, a reanalysis of the results of a study by Postman and Greenbloom (1967) was undertaken. In that experiment, the stimuli were trigrams and the responses were digits. The design included two levels of trigram pronunciability, with response recall higher for the easy than for the hard list. To maximize the sensitivity of the tests, the reanalysis was limited to the hard lists which also produced more single-letter cue selection than did the easy ones. The probabilities of stimulus-element reproduction conditional on recall or nonrecall of the response were determined for the 18 single-letter components of the stimuli in a list (three positions in each of six trigrams). The analysis thus parallels that of Wichawut and Martin, except that the responses were not presented as cues.

As Table 1 shows, the probability of element reproduction in the absence of response recall was clearly greater than zero. Thus, the contingency observed by Wichawut and Martin for strings of words

does not hold for trigram stimuli paired with digit responses. The probabilities of recall of elements and of response covaried as expected. Another feature worth noting is that the degree of covariation was less when the first letter rather than the second or third was used as a test cue. There are probably two factors responsible for this pattern of conditional probabilities: (a) Selection was more likely to remain strictly limited to the salient first letter than to the other two; hence, failures to reproduce other letters along with the response were most common when the first letter was selected; and (b) component associations reflect normal habits of processing verbal units in serial order; consequently, the remaining elements were more likely to be elicited even in the absence of response recall (indicating nonselection as a functional cue) by the first letter than by the other two letters. In any event, the results of this analysis cast doubt on the generality of the findings of Wichawut and Martin. It is, therefore, premature to incorporate a general principle of stimulus-component independence into a theory of transfer and interference.

Critique of Martin's Position

We return now to an overall consideration of Martin's proposals. In his account, the explanation of the phenomena of retroaction and proaction takes its point of departure from the principle of encoding variability. Martin's (1968) original formulation of this principle is modified inasmuch as changes in stimulus encoding are, in agreement with Greeno et al (1971), explicitly tied to changes in the characteristics of the successive responses. With the aid of the assumption of a feature-sampling bias carrying over from interpolated learning to the test of retention, the retroactive losses in the recall of the first list can be understood; persistence of earlier encodings produces PI. While this hypothesis may be reasonable, there has been little or no support for the assumed occurrence of encoding variability in several recent experiments. Perhaps the most persuasive data against the hypothesis were reported by Goggin and Martin (1970). Other studies yielding essentially negative results are those of Williams and Underwood (1970), Weaver, McCann, and Wehr (1970), and Postman and Stark (1971). A shift in the feature-sampling distribution may be expected on a priori grounds, but the evidence is that the encoding of the nominal stimuli typically does not change between first- and second-list learning. These findings, which negate the assumption that identical nominal stimuli have a high probability of being recoded in the transfer phase, should not be confused with results showing a shift in stimulus selection when an entirely new element is first introduced during second-list learning, i.e., the stimuli are A in the first list and AX in the second list (Houston, 1967a; Merryman & Merryman, 1971). The latter findings are essentially irrelevant to the problem at issue, which is to account

for retroaction when the nominal stimuli remain unchanged.

Martin expresses some reservations about the experimental tests of recoding that have been carried out, calling attention to the risk of identifying "obvious, external, experimenter-defined stimulus attributes with the learner's subtle, internal, subjectively defined functional encodings [1971, p. 330]." When that is done, one may conclude erroneously that the encoding adopted during first-list learning was retained in its original form in the transfer phase. Martin may be correct in his concern that the tests of recoding used so far have lacked sensitivity. However, the concept of recoding has explanatory value only to the extent that it can be translated into experimental operations if the entire question is not to be begged. So far, the attempts to produce changes in encoding under controlled conditions have yielded largely negative results. These findings must stand until and unless other methods are developed and compel new inferences.

There is an internal contradiction, or at least an inconsistency, in Martin's attempt to reconcile the apparent independence of retrieval of first- and second-list responses on MMFR tests and the evidence for clustering by stimuli in the free recall of responses. To account for the latter, Martin invokes the similarity of the two functional encodings of a given nominal stimulus. Specifically, he suggests the operation of a mediational chain $B_1-A_{B_1}-A_{C_1}-C_1$. It is difficult to see why a parallel process does not take place in MMFR. In fact, it remains unclear exactly what is meant by the independence of stimulus components if different functional encodings sharing common features elicit each other as they are alleged to do during free recall of the responses. It does not seem possible to insist on strict independence of stimulus components as they function in MMFR and at the same time to link them in an implicit mediational chain under conditions of free recall.

We have indicated some of the difficulties encountered in the application of Martin's theoretical schema to empirical findings which the author regards as crucial for his own position as well as those of others. There is in addition a more general systematic objection to Martin's analysis of the process of interference. The entire argument is developed with reference to the A-B, A-C paradigm of negative transfer. This paradigm has, to be sure, served as the point of departure in classical treatments of interference. It is a fact, however, that substantial amounts of retroaction have been observed under conditions in which the nominal stimuli in the successive tasks are unrelated, e.g., the A-B, C-D and A-B, C-B paradigms. These findings have made it necessary to recognize the existence of components of interference that are not tied to the characteristics of the stimulus for the forward association, in particular those responsible for the reduced availability of responses and backward associations. A general theory of interference

cannot be considered adequate unless it is applicable to the entire range of paradigms that produce retroaction and proaction. The limited generality of Martin's analysis may be attributed to the fact that he follows Greeno et al (1971) in rejecting, without an adequate substitute, the two-stage conception of associative learning. Thus, no provision is made for the analytic distinction between response learning and associative learning which can be logically extended to the unlearning of the two components. In placing the explanatory burden exclusively on changes in stimulus encoding, Martin appears to have reverted to a single-stage conceptualization of interference, similar to that of Gibson (1940) and Osgood (1949) which preceded the development of a component analysis of transfer.

The issue of the generality of Martin's thesis has to be pressed further. It is a well-known fact that RI and PI are not limited to paired-associate learning but have also been observed under quite different procedures such as serial and free-recall learning. It is possible to say, of course, that in all such cases there is a change in the sampling of the features of whatever the functional stimuli might be in the successive lists. A sampling bias would then carry over to the test of recall and produce interference. The application of such a hypothesis would, however, soon encounter serious difficulties. Let us mention only two examples. Spatial and ordinal positions have been identified as effective functional stimuli in serial learning; it hardly seems reasonable to assume that such stimuli comprise sufficiently distinctive and independent features to account for substantial amounts of retroaction. In the case of free recall, the identification of the functional stimuli or retrieval cues for individual items constitutes a major theoretical problem. It seems doubtful that interference in free recall can be subsumed under the A-B, A-C schema applied to individual words. Yet RI in free recall is not only quite heavy, but its onset is also very rapid (e.g., Postman & Keppel, 1967; Tulving & Psotka, 1971; Tulving & Thornton, 1959). The problem of generality faced by any interference theory thus clearly reaches beyond the confines of the conventional paired-associate paradigms. At least some of the concepts of existing theories are in principle applicable to the analysis of interference outside the domain of paired-associate learning, e.g., the unlearning of contextual, positional, and spatial associations and the operation of a mechanism of response suppression.

GREENO'S THEORY OF TRANSFER AND INTERFERENCE

Stages of Associative Learning

The point of departure in Greeno et al's (1971) analysis is a new definition of the successive stages of associative learning. In the first stage, a record of the

stimulus-response pair is stored in memory as a unit. In the formation of such a unit, the encoding of the stimulus is influenced significantly by that of the response with which it is paired; conversely, the encoding of the response is influenced by that of the corresponding stimulus. In the second stage, the learner acquires the ability to retrieve the responses when the stimulus terms are presented on test trials. A retrieval plan is developed, the efficiency of which depends primarily on the characteristics of the stimulus terms. Greeno et al propose this schema in lieu of the conventional division of the acquisition process into a response-learning and associative stage (Underwood & Schulz, 1960). The basic evidence presented in support of the revised conceptualization is that the duration of the first stage, as estimated by the application of a mathematical model, is found to be influenced by stimulus as well as response difficulty. Thus, both members of the pair, not just the response, are implicated. This evidence is less than compelling. Since the measure used to index the duration of the first stage is strongly correlated with the number of errors before the first correct response to an item, the outcome is a foregone conclusion. The duration of the first stage cannot but be a function of both stimulus and response difficulty, because both response learning and associative learning must have progressed to an adequate level before the first correct response to a particular stimulus can be given.

The new definition of the stages of associative learning formalizes the assumption that the nature of the response influences the functional encoding of the stimulus, and vice versa. This formulation may have an advantage for certain theoretical purposes, e.g., in relating negative transfer and interference to changes in stimulus encoding. At the same time, however, there is a loss of the explanatory power which has accrued from the systematic analysis of response processes per se (Underwood & Schulz, 1960). Such phenomena as the effects of response familiarization on subsequent associative learning are left unaccounted for. The early demonstration by Underwood, Runquist, and Schulz (1959) that Ss are able to recall responses before they can pair them with the correct stimuli is overlooked. Quite apart from the difficulties which emerge in the analysis of interference processes, on which we have already had occasion to comment in our discussion of Martin's views, the new two-stage formulation also leaves many unfilled gaps in our understanding of the phenomena of acquisition.

Negative Transfer

Within the theoretical framework proposed by Greeno et al, negative transfer is expected to develop in the first instance because of interference with the storage of new pairs. Such interference will develop to the extent that the stimuli, the responses, or both are encoded in the

same way as in the successive lists. Greeno takes it for granted that encodings will, indeed, be carried over from the first to the second task: this is the principle of persistent encoding to be contrasted with Martin's (1968) principle of encoding variability. (There may, of course, be persistence followed by change, but the relationship between these apparently contradictory principles has not been considered explicitly by either author.)

A second source of negative transfer is the disruption of the first-list retrieval plan when old stimuli are paired with new responses. There are two ways in which the retrieval difficulties can be overcome so that the mastery of the transfer task becomes possible: (a) The first-list retrieval system is suppressed, although it remains intact and available for future use. Such suppression of the total retrieval plan is possible when there are distinctive cues to list differentiation and hence to the differentiation of the successive retrieval systems. The presence of new stimuli in the C-B paradigm, and of new responses in the A-C paradigm, presumably serves this function. (b) In the absence of effective cues to list differentiation, the development of a retrieval plan for the transfer task entails the "disorganization or breakdown" of the earlier system. The A-Br paradigm, in which both the stimuli and the responses remain the same, is a case in point. Presumably the suppression of an intact retrieval system and the substitution of a new one can be accomplished more readily and will produce less interference than the breakdown and reorganization of a previous system which has become inappropriate.

Given these sources of interference, Greeno et al derive certain predictions about the relative difficulty of the two stages of acquisition postulated by them under various conditions of transfer. Consider the C-D, A-C, C-B, and A-Br paradigms. Persistence of encoding is assumed to interfere with the storage of pairs in memory. The magnitude of such interference effects is expected to be of the same order for cases of stimulus and of response identity because the functional encodings of the two terms are interdependent. The first stage should, therefore, be accomplished more rapidly under the C-D than under the A-C or C-B paradigm, with little or no difference between the latter two. As for A-Br, the first stage "might be harder" than in A-C or C-B, but only if the stimulus and response effects on interference with storage are cumulative. Negative transfer in the second stage reflects disruption of the retrieval plan which is tied to the characteristics of the stimuli. The prediction is that the second stage should be easier when the stimuli change, as in C-D and C-B, than when they remain the same, as in A-C and A-Br. Second-stage interference should be heavier in A-Br than in A-C because successive retrieval systems can be differentiated more readily in the latter than in the former case.

If the second stage is viewed as one of associative learning, then there is no disagreement with the rank

Table 2
Mean Number of Errors Before First Correct Response
Under Various Transfer Paradigms

	Paradigm			
	C-D	C-B	A-C	A-Br
I. Postman (1962)				
Low OL	3.64	4.15	5.05	5.22
Medium OL	3.14	3.48	4.92	4.67
High OL	3.12	2.82	3.36	5.23
II. Postman & Warren (1972)				
Condition I	2.66	2.85	3.19	4.32
Condition D	3.20	3.34	3.97	4.11

order of paradigms derived from Greeno's analysis. The predictions regarding the first stage are, however, open to question. Since the duration of the first stage is highly correlated with the number of trials to the first correct response, the conventional position would be that it should reflect both response and associative learning, but with the former carrying greater weight than the latter in the early phase of acquisition. Thus, a difference favoring C-B over A-Br would be expected. Furthermore, with highly meaningful responses the associative component should come to the fore early, and with prior forward associations, a more effective source of interference than backward ones, A-C should be inferior to C-B.

The measures of the two stages which Greeno et al present in support of their predictions (1971, Table 1) were obtained in a number of experiments. The sampling of conditions was quite uneven: only one study comprised all four paradigms of interest, another experiment included three, and the remaining six sets of data were limited to the C-B and A-Br treatments. The prediction with respect to the difference between the latter two was equivocal to begin with; nevertheless, the main emphasis was on this particular comparison. The measures, once more estimated from the parameters of a mathematical model, were interpreted by the authors as showing that C-B is superior to A-Br in the second but not in the first stage of learning. With some exceptions, the differences in the duration of the first stage were small (although they favored C-B in five out of seven cases). In the one experiment in which all four paradigms were included, C-B was superior to both A-C and A-Br, although the apparent differences were small.

Since the measures considered by Greeno et al were fragmentary and based on parameter estimates of unknown validity, we present in Table 2 more direct measures of the index said to be highly correlated with the duration of the first stage, viz, the number of errors before the first correct response to an item. The first set of values comes from an experiment by Postman (1962) in which all four paradigms were used and transfer was measured after three different degrees of first-list learning—to a criterion of 6/10, 10/10, and 10/10 + 50% overlearning. The materials were lists of paired

adjectives. At each level of first-list learning, the mean numbers of errors to the first correct response were clearly lower for C-B than for A-Br and A-C. The differences between the latter two were small, except at the highest level of first-list learning where the interfering associations were heavily overlearned. Thus, the pattern of differences is clearly at variance with that predicted by Greeno et al.

The second set of values comes from a study by Postman and Warren (1972). The materials were again paired adjectives. The first list was learned to a criterion of two successive errorless trials and was followed by the transfer list after either 1.5 or 20 min (Conditions I and D). There was a tendency for acquisition to be slower when the second list was learned after a delay rather than immediately. Under both conditions, the differences among paradigms showed the same pattern as in the earlier study: the mean number of errors before the first correct response was smaller for C-B than for A-C and A-Br. The scores were once more higher for A-Br than for A-C, although that difference was minimized after a delay.

The scores shown in Table 2 yield the same alignment of paradigms as do the overall measures of transfer performance. That was to be expected on the basis of the conventional two-stage formulation, since response learning and associative learning jointly determine the occurrence of the first correct response to a specific stimulus. In accounting for whatever discrepancies there appear to be between the findings of Greeno et al and ours, we must for the present limit ourselves to the comment that our measures were determined from the actual experimental observations, whereas theirs were parameter estimates.

The one-to-one correspondence between the indexes of the first stage and total transfer performance invites an additional comment on the conceptualization of Greeno et al. Their basic distinction is between a storage and a retrieval stage. This distinction suffers from an inevitable ambiguity when it is applied to experimental observations. Whether or not an item has been stored can be determined only by means of a test of retrieval. Hence, any measure of the storage stage, whether indexed directly by the first correct response or estimated indirectly, can be obtained only when the second stage, in which the S presumably learns to retrieve the items, is already under way. Thus, we conclude that the analysis of negative transfer offered by Greeno et al remains open to question on logical, pragmatic, and empirical grounds.

Retroactive Inhibition

Greeno et al attribute RI to the reduced retrievability of first-list items. While the stored representations of the original units presumably remain intact, the adoption of a new retrieval plan in the transfer phase interferes with the S's ability to use the stimuli as cues in the recall of

the first list. Recovery from RI, e.g., during successive tests, is more likely when the original retrieval plan is suppressed but intact, as in A-C, than when it is reorganized, as in A-Br (cf. James, 1968). An important feature of this analysis is that the interference with recall is assumed to operate "at the level of several items or the whole list, rather than at the level of individual items [1971, p. 339]." Consequently, the independent retrieval phenomenon is seen as consistent with the theory and incompatible with a mechanism of associative unlearning. We have already tried to show in our discussion of Martin's position why this inference is not acceptable.

It remains for us to comment on the interpretation of RI as due to the suppression or degradation of a retrieval plan brought about primarily by a change in stimulus terms. It is not clear to us what exactly is meant by a retrieval plan for a list as a whole in the context of paired-associate learning. The retrieval plan is assumed to evolve "mainly because of the relationships that the subject discovers among the stimuli or stimulus-response pairs in the list [p. 334]." But how does the discovery of such relationships generate a plan for the retrieval of specific responses? When a list is segmented into discrete pairs, with responses to be given to stimuli in an unpredictable order, the idea of a retrieval plan for the list as a whole would appear to be a contradiction in terms. It is possible to conceive of a system of encoding the stimuli that would minimize interpair interference, but such a mode of attack on the learning task would normally be considered under the heading of stimulus differentiation. Furthermore, the development of such encoding devices would presumably be part of the storage process which is assigned to the first, rather than the second, stage of learning. Certainly the retrieval plan cannot refer to the acquisition of a repertoire of responses, since the concept of a response-learning stage is explicitly rejected. In short, in the absence of any further specification or elaboration, the reference to a retrieval plan for an entire list of arbitrarily paired units is elusive. To say, therefore, that RI reflects the suppression or disruption of such a plan does not carry any concrete implications. The assertion reduces to the tautology that interference with recall reflects interference with retrieval. All this is not to deny that RI may be produced by the loss of retrieval cues, but this hypothesis has to be translated into experimental operations appropriate for a given learning situation before it can be evaluated (e.g., Tulving & Psotka, 1971).

The question of generality raised by Martin's analysis applies also to the position of Greeno et al, although the latter do consider the implications of the proposed mechanisms for paradigms other than A-B, A-C. Interference with storage is expected whenever there is an overlap of either stimulus or response elements. Thus, the occurrence of negative transfer under the A-B, C-B arrangement could be accommodated. However, retroactive effects are predicted only when there is a

disruption of the retrieval plan which is tied primarily to stimulus overlap between the successive tasks. Thus, little if any RI is expected under the C-D and C-B paradigms. As we have already noted, however, these expectations are contrary to fact. Again, this theoretical account provides no purchase on the explanation of RI in other than paired-associate situations, such as serial learning and free recall. Furthermore, no explicit consideration has been given to the mechanisms of PI.

EVALUATION OF RECENT CRITIQUES OF INTERFERENCE THEORY

We will now summarize our evaluation of the recent arguments of Martin and Greeno et al for a new conceptualization of the interrelated processes of negative transfer, retroaction, and proaction.

(1) The rejection of the principle of associative unlearning is based on a mistaken interpretation of the relationship between negative transfer and unlearning. It has not been, and need not be, assumed that the unlearning of old associations has to "clear the way" for the learning of new ones. Hence, the independent retrieval phenomenon, quite apart from the objections to the measurement procedures by which it has been established, has no critical bearing on the hypothesis of associative unlearning.

(2) The hypothesis of response suppression has been rejected in toto on insufficient grounds. The question of whether or not a mechanism of response selection contributes to RI cannot be answered by such measures as indexes of response clustering in free recall. The evidence pointing to item-specific associative losses, e.g., under conditions of mixed-list interpolation and under the A-Br paradigm, does not in and of itself invalidate the hypothesis. The question at issue has been, and remains, a quantitative one: what proportion of RI under given conditions of learning and testing can be attributed to response selection?

(3) While the emphasis placed by both Greeno et al and Martin on the characteristics of both stimulus and response encoding is timely and useful, too much of an explanatory burden is placed on these processes. This conclusion is based on two major considerations. First, because of the overriding importance attached to the temporal course of stimulus encoding during successive tasks, the analyses focus narrowly on conditions of stimulus identity which do not by any means exhaust the range of paradigms under which retroactive and proactive effects are observed. Second, the central assumptions about either the variability (Martin) or persistence (Greeno et al) of stimulus encoding across tasks are essentially ad hoc and either have not been tested or have for the most part failed to be supported where relevant empirical evidence is available. The concept of subjective encoding inherently carries a risk of question-begging invocation and should therefore be used cautiously in theory development.

(4) The analyses of Greeno et al and Martin are beset by an internal contradiction with respect to the contrast between generalized and item-specific interference. The central emphasis on the encoding of individual pairs carries a *prima facie* implication that interference effects should be item-specific. This implication is made explicit by Martin, who predicts the loss of an item on the test of recall if the relevant features of a particular stimulus fail to be sampled. However, in order to postdict the phenomenon of retroaction, he must appeal to a mechanism that operates on the list as a whole, viz, the persistence of a sampling bias in favor of the features selected during the transfer phase. Since the basic mechanism responsible for retroaction is taken to operate on the entire list, item specificity loses its systematic meaning. Whenever a process comes into play at the list level, it will produce effects on specific items. There is no way of predicting, however, which items will be vulnerable and which items will be immune to generalized interference.

Similar considerations apply to Greeno's analysis. Again, the source of interference is at the list level, but now it is the retrieval plan rather than the aggregate of stimulus features that is suppressed, and the specific encodings of individual stimuli and responses have no determinate consequences for recall performance. In sum, Martin has substituted stimulus-feature suppression, and Greeno has substituted retrieval-plan suppression, for response suppression. It is fair to ask whether either of the new formulations is at the present time anchored more securely to experimental evidence than the principle of response-set interference. The data we have reviewed do not seem to compel an answer in the affirmative. The latter can, moreover, claim some advantage because of its continuity with a large body of facts implying the operation of response-related processes in acquisition and recall. Whichever variant of list suppression one favors, the available findings do not make it possible to rule out altogether item-specific unlearning in the sense of extinction of individual associations.

We see no reasons at this time to abandon abruptly the concept of associative unlearning or to jettison response-set interference as a possible contributor to retroaction and perhaps proaction. On the other hand, we do not wish to reject out of hand all the interesting speculations offered by Greeno et al and Martin. They have called attention to the possible importance of changing encoding processes in determining the course of transfer and interference at recall. Other investigators have focused on the same issue in different contexts (e.g., Tulving & Psotka, 1971; Wood, 1971). The introduction of such ideas into the analysis of transfer and interference is very much in the spirit of the times, but it does not call for the dismantling of the entire conceptual framework which has evolved over the years out of classical interference theory. We see this conceptual framework as in continuing need of critical

reexamination; but if this enterprise is to be successful, the most urgent task is the resolution of the many inconsistencies and apparent contradictions in the rapidly growing body of experimental findings.

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