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Inhibiting effects of recall*

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Evidence is reviewed indicating that output interference–the deleterious effects of recall of some information on information recalled later–occurs both in primary and secondary memory. It appears that output interference provides at least a partial account for the disparity between information available in memory and its accessibility at recall. It is argued that consideration of output interference may provide a helpful perspective in resolving problems in the study of episodic and semantic memory, including the negative effects of part-list cueing and the tip-of-the-tongue phenomenon.

One of the primary problems in the study of memory is the discovery of why so little of available, stored information can be actively retrieved (Tulving & Pearlstone, 1966). One facet of this problem–the reasons for the effectiveness of retrieval cues–has been explored in some detail (see Tulving & Thomson, 1973, for a recent review). However, the basic reasons for the disparity between availability and accessibility of mnemonic information have not been elucidated. The evidence reviewed here suggests that one reason for the inaccessibility of otherwise available information is that the act of recalling some information produces decrements in the recall of other similar information at a later time. This phenomenon–the deleterious effects of earlier upon later recalls–may be termed output interference (Tulving & Arbuckle, 1963).

The present paper evaluates evidence for output interference in several different episodic memory paradigms (Tulving, 1972). The crux of the distinction between episodic and semantic memory is whether or not temporal factors surrounding the conditions of presentation of the material are stored and retrieved. Recall of the temporal context of the learning situation is considered crucial to successful performance in tasks involving memory for discrete episodes, but relatively unimportant in recall of more or less permanently memorized information involving semantic relations (e.g., naming the 50 states of the U.S.). Since memory tasks usually studied by psychologists–such as free recall, serial, and paired-associate learning–are tasks involving episodic memory, output interference in certain versions of these tasks is of primary concern here.

THE TEMPORAL COURSE OF RECALL

In attempting recall of a specified set of items without regard to their order, Ss typically emit items very rapidly at first and show a decreased responding with time. Bousfield and Sedgewick (1944) found a negatively accelerated function between cumulative number of responses and recall time when they required Ss to recall as many instances as possible from well-learned conceptual categories such as birds, makes of cars, and European cities. Aaronson and Markowitz (1968) found the same type of negatively accelerated function in the free recall of short lists of words.

The usual interpretation of this finding is that the first rapid burst of items is due to the great strength of these items, and that thereafter only much weaker items remain to be recalled (see Bousfield & Sedgewick, 1944, p. 158). A slightly different interpretation (called the threshold model by Aaronson & Markowitz, 1968) is that the more items that have surpassed the recall threshold and have thus been recalled, the slower the remaining items are recalled, assuming that rate of recall varies directly with the number of items to be recalled. The first of these two interpretations seems to be completely circular, at least in its present form, for "strength" is synonymous with "order of recall" when the items being compared are all actually recalled. The second seems somewhat more plausible, except that in Bousfield and Sedgewick's (1944) study, the recall of relatively few instances from a potentially great number produced rather marked decreases in later recall. That is, the depletion of the pool of potential responses by the recall of only a few appeared to produce greater decrements in responding than might reasonably be expected. However, this criticism cannot be given much importance, since there is no good way of measuring the size of a category and no sure way of knowing what a reasonable rate of recall is for any particular category size. At any rate, a variety of mathematical models postulating various search rates and mechanisms appear inadequate in accounting for the temporal course of free recall in both episodic (Aaronson & Markowitz, 1968) and semantic (Indow & Togano, 1970) memory tasks.

Another interpretation of the decreasing rate of recall with time is that it is due, at least in part, to output interference. If recall of items early in the output sequence interferes with recall of additional items in some manner, the decreased rate of recall later in the output sequence becomes more understandable. If one

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assumes, along with Rundus (1973) and Roediger (1973), that the act of recall strengthens the representation of an item in memory, this means that on future attempts to retrieve additional items, the ones already recalled will be retrieved again to the exclusion of new items (if there is sampling with replacement). Evidence for just such a process is presented in the next section.

OUTPUT INTERFERENCE IN CUED RECALL

In the typical free recall experiment, by definition, the S controls the order in which items are recalled. In serial recall Ss always recall items in the same prescribed order. In order to study output interference it is necessary to control the order in which Ss recall discrete pieces of information presented at different times. One efficient method of having Ss perform this task is to present along with each piece of to-be-remembered information another bit of information with which Ss can be cued later. Thus, several studies of output interference (e.g., Tulving & Arbuckle, 1963) used the standard procedure of paired-associate learning. Another cueing procedure used in the study of output interference is the presentation of items from conceptual categories, blocked together, with output order governed by the presentation of category names at recall. A third cueing procedure which seems likely to produce output interference is the presentation of part of a list as "cues" for the remainder of the list (Slamecka, 1968, 1969). It will be argued that the process of S studying part-list cues is functionally equivalent to the actual retrieval of those items studied, and that this interferes with the recall of the remainder of the list.

Before considering in some detail results from use of each of these methods, it should be noted that there are earlier studies containing evidence for output interference when output specification was accomplished by instructing Ss either to recall items in certain serial positions before others (Kay & Poulton, 1951) or to recall one type of material before another (e.g., letters before digits) when both were included in the studied list (Brown, 1954). Kay and Poulton (1951) found that recall of the first four elements of an eight-element series was better when their recall preceded rather than followed that of the last four elements. Brown (1954, Experiment II) found that recall of letters or numbers following their presentation in a paired-associate list was better when recall of either type of material preceded rather than followed recall of the other material. A similar result has been reported more recently by Epstein (1969, 1970).

Output Interference in Paired-Associate Recall

The first systematic study of output interference was that of Tulving and Arbuckle (1963). They presented Ss with lists of 10 paired associates in which the digits 1-10 were the stimuli and common words were the responses. Output order was governed by a balanced Latin square so that each item was recalled equally often at each output position and was preceded and followed by each other item an equivalent number of times. The primary finding was that recall of items presented early in the input sequence did not vary with output position, but recall of items presented late in the input sequence became increasingly poorer across the 10 output positions. Output interference was most dramatic for the last two or three items, and there was some evidence that it extended to items in the fifth and sixth input positions. The conclusion which has been drawn from this experiment is that output interference is due only to a loss of information in primary memory (Waugh & Norman, 1965) and that there is no output interference in secondary memory.

Evidence from other paired-associate experiments does little to alter this conclusion. In six experiments reported by Arbuckle (1967) in which list length and rate of presentation were varied, there was marked output interference for the last item presented. With relatively long lists of 9 and 12 items, there was no output interference for items presented in the early and middle serial positions, but for lists of 6 items there appeared to be some output interference over all serial positions. However, with short lists one might expect some contribution of primary memory for items in most serial positions, and thus output interference might still be attributable to losses of primary memory information. Antognini (1972) reported output interference for items appearing in the last five serial positions of lists of six paired associates, and Tulving and Arbuckle (1966) also found output interference with very short lists.

There seems to be no evidence from paired-associate studies that conclusively demonstrates output interference in secondary memory. However, it should be noted that attributing output interference only to primary memory losses when there is evidence for such interference over the last five or six items stretches the usual limit placed on primary memory, which is estimated to be two to four items (Craik, 1968). Nonetheless, it is the case that in studies using long lists there has been no evidence of output interference for items in the first few serial positions.

Output Interference in the Recall of Categories

Another method of controlling Ss' output order is to present them with lists of items blocked according to category (for example, fish, Indian tribes, types of fabric) and later to cue recall of successive categories by presenting category names. The first experiment employing this technique to study output interference was that of Dong (1972). For present purposes, the most important finding of this study was that the first category recalled when cued with its category name was superior to recall of material within successively recalled

categories. However, when items were randomly presented, recall of items in the first category recalled was not greater than recall of items from categories recalled later. Also, even with blocked presentation of category instances output interference was found only between the first category recalled and all categories recalled later; that is, recall of items within categories did not systematically decrease with the output order of the categories. Unfortunately, the results on which these conclusions are based are rather noisy, and thus these conclusions are tentative, at best. Dong (1972, Experiment II) included only 16 Ss in the recall condition of present interest and thus had only 16 observations at each output position. In addition, the output order of the categories was randomly determined rather than counterbalanced. Nonetheless, the finding of better within-category recall of the first category recalled as opposed to later categories indicates an output interference effect in secondary memory, since an interpolated task (30 sec of reading recall instructions) between presentation and recall minimized primary memory effects.

More systematic studies of output interference with categorized material have replicated the finding of output interference in secondary memory, and have further established that recall of items within a particular category decreases in an approximately linear fashion with output position of the category (Smith, D'Agostino, & Reid, 1970; Smith, 1971; Roediger, 1973). Smith (1971) found that output interference (a) was greater when Ss were given a relatively long time for recall of each category (60 sec) rather than a relatively short time (30 sec); (b) did not depend on the inclusion of the last category presented in the recall results, and therefore could not be attributable to loss of information from primary memory; (c) was attenuated, though still present, in a recognition test; (d) was not increased when a 30-sec interpolated task was introduced between presentation and recall; and (e) was greater with large rather than small categories.

In summary, there is good evidence for output interference in secondary memory from studies in which categorized lists are presented and recall is cued with category names. If categories are considered as higher-order memory units (Tulving, 1968) and if stimulus-response pairs in paired-associate lists are considered very small higher-order units, the inconsistency between output interference experiments utilizing paired associates and categorized lists may be resolved by arguing, along with Smith (1971), that a necessary condition for output interference is the memorization of material involving fairly large higher-order units. Smith (1971, Experiment IV) found no output interference in the cued recall of categories when only two items in each category had been presented.

An alternative hypothesis, equally consistent with the available evidence, is that output interference is due entirely to the absolute number of items previously recalled. In paired-associate experiments and in other situations encouraging the formation of small higher-order units, fewer items will be recalled before the recall of any particular higher-order unit than when large higher-order units are formed, and thus output interference will be reduced. Evidence consistent with this position has been reported by Roediger (1973). In comparing recall cued with only category names to recall cued with some items from the categories in addition to the category names, greater output interference between categories was found in the latter case. If presenting items as cues is functionally equivalent to Ss' retrieving these items, then more items would have been "retrieved" when item cues were presented along with the category names than when only the category names were presented, and thus one would expect the greater output interference in the former case. In another experiment in which the presentation or nonpresentation of item cues with category names was varied within lists (and thus at any given output position an approximately equivalent number of items had been retrieved regardless of cueing condition), there was no greater output interference when performance under conditions of both category names and item cues was compared to performance with only category name cues. One final bit of evidence is that results from two experiments (Roediger, 1973) have shown that when category size (i.e., number of items presented per category) is varied within lists, there is no greater output interference in recall of large than small categories, as Smith (1971, Experiment IV) has shown with between-list designs. This is consistent with the hypothesis that output interference is determined by the sheer number of items that have been recalled rather than simply the number of items (or size of higher-order units) stored in memory.

Presentation of Part-List Cues

In a series of experiments, Slamecka (1968, 1969) compared recall performance on a recently presented list for Ss who received some of the items from the list as cues with Ss who recalled under conditions of free recall. These part-list cueing experiments were designed to test the notion, derived from a variety of theories, that items are stored in memory in a dependent fashion. If such is the case, then presumably presentation of part of the list as cues for the remainder should augment recall of the remainder as compared to recall of these same items under conditions of free recall. The results of some eight experiments (Slamecka, 1968, 1969) showed that presenting various proportions of a list as "retrieval cues" not only failed to facilitate recall of the remainder of the list, but actually seemed to exert a slight but consistent *inhibiting* effect on recall, as compared to recall under noncued conditions.

It seemed at first that the inhibition found in part-list

cueing experiments was merely an uninteresting methodological artifact. Ss in the conditions receiving part-list retrieval cues were deprived of recall from primary memory (Waugh & Norman, 1965), while control Ss were not. This interpretation was reinforced by two experiments (Slamecka, 1968, Experiments V and VI) which showed that when Ss in both the control and part-list cueing conditions were either allowed to use the "echo box" or not allowed to use it, there was little, if any, inhibition. However, other experiments (Slamecka, 1969; Wood, 1969) showed that even with this artifact controlled, there was inhibition in recall of Ss given part-list cues as compared to control Ss. Slamecka concluded that, "For reasons as yet unknown, it appears that context interferes slightly with the nonassociative retrieval of old items [1969, p. 560]."

Numerous criticisms have been leveled at Slamecka's experiments, perhaps because they are so inconsistent with conventional wisdom which assumes that interitem dependencies are formed during free recall learning. As Kintsch and Kalk (1972, p. 1) have noted with regard to Slamecka's experiments, "If this finding (that part-list retrieval cues do not aid recall) were anything but a methodological artifact it would have far-reaching consequences." The most important criticism of Slamecka's series of experiments is that when categorized lists were used (1968, Experiment IV), Ss did not receive more categories (higher-order units) than they could have recalled without the use of external retrieval cues. Several Es have shown that when Ss receive either category names or items from the categories as retrieval cues when there are more categories in the list than could have been recalled without the aid of cues, recall is improved over that obtained in free recall conditions (Tulving & Pearlstone, 1966; Hudson & Austin, 1970; Wood, 1969; Lewis, 1971; Luek, McLaughlin, & Cicala, 1971; Kintsch & Kalk, 1972; Slamecka, 1972). The effect is always detected in measures of the number of categories recalled (defined as the recall of any item in the category) rather than in measures of the number of words per category recalled. It has been almost impossible to show that, contrary to the Slamecka result, cueing aids the recall of lists of unrelated words. Allen (1969) and Anderson (1972) showed some small benefits from presenting part-list retrieval cues, but these effects were at best negligible.

Roediger (1973) has recently proposed a two-factor account of the effectiveness of retrieval cues where (a) retrieval cues improve recall as compared to noncued conditions when they allow access to more higher-order units than could be recalled unaided, but (b) cues impair recall to the extent that they provide more information than is necessary to simply gain access to the higher-order unit. The relative effectiveness of retrieval cues in any particular experimental situation should depend on these two factors.

As already mentioned, there is much evidence that recall is improved when retrieval cues allow access to more higher-order units than could be recalled without the aid of cues. The second factor—accounting for how cues actually "damage" recall—is considered analogous to output interference. Rundus (1973) has developed a model which best accounts for such inhibition. He has assumed that there is an hierarchical arrangement of individual elements to a higher-order control element in higher-order units with the strengths of relationship between the individual elements and the control element varying. Recall of an individual element is presumed to increase the strength of that element, and since recall of an element does not eliminate it from those items considered later for recall, items that have already been retrieved tend to be retrieved again to the exclusion of additional items. Since the act of recalling some items impairs recall of other items, this may be considered as a model of output interference in secondary memory.

A test of Rundus's (1973) model is to present varying numbers of items from categories as retrieval cues following the presentation of categorized lists. If presentation of these items as cues is in some sense functionally equivalent to the retrieval of these items by S, then it should be the case that as one increases the number of items in any given category presented as cues, the proportion of additional items recalled should decline. Results from the relevant studies in the literature are shown in Table 1, where the proportion of the remaining items recalled is presented as a function of the number of items presented as retrieval cues. The measure is thus the tendency for Ss to exhaustively recall all the remaining words presented as part of the category. Also presented in Table 1 are indications of whether presentation of the items was randomly ordered or blocked by category instances, the list length, and the number and size of categories in each list. The data support the proposition that probability of recalling additional items from a category declines with the number of instance cues presented. In addition, the decline in the results of Roediger (1973) and Rundus (1973), the only authors to look for such a trend, was statistically reliable. This decline appears in these studies despite the rather wide variation in such factors as presentation rate and the manner in which the retrieval cues were presented. The only exception to this pattern is Lewis's (1971) results using blocked presentation.

It was assumed in construction of Table 1 that when only one item remains to be recalled in a category, its probability of recall reflects the probability of recalling material within the category rather than the probability of recalling the category itself. Thus, in Slamecka (1968, Experiment IV), for example, when five of the six items in a category were presented for recall, the assumption was made that the recall of the category was perfect, and the fact that Ss recalled the missing item 40% of the time indicated the recall probability of information within the category. Slamecka (1972, Experiment I) made the opposite assumption; that is, that the recall

Table 1
Summary of Part-List Cueing Experiments With Categorized Lists Showing Proportion Recalled of Remaining Items Within a Category as a Function of the Number of Category Instances Cues

Study	Experiment Number	Mode of Presentation	List Length	Number of Categories	Category Size	0	1	2	3	4	5
Slamecka (1968)	IV	Random	30	5	6	.65	.51		.47		.40
Hudson and Austin (1970)	I	Random	30	10	3	.86	.85				
	II	Random	30	10	3	.77	.74				
Lewis (1971)	I	Blocked	42	6	7	.63	.68				
		Random	42	6	7	.52	.48				
Slamecka (1972)	I	Blocked	20	4	5	.75	.70			.63	
		Blocked	40	8	5	.66	.64			.57	
		Blocked	60	12	5	.62	.62			.53	
	II	Blocked	72	18	4	.79	.79		.67		
Rundus (1973)	I	Random	40	4	10	.37	.36	.34	.29	.28	
	II	Random	40	4	10		.35			.30	
Roediger (1973)	II	Blocked	88	4	4	.71	.68	.71	.62		
				4	5	.66	.66	.62	.61		
				4	6	.66	.63		.59		.53
				4	7	.61	.61		.53		.50

probability in this situation indicates category recall and that recall of material within the category was perfect. Although technically consistent with Cohen's (1963) definition of category recall, this assumption seems illogical, since it leads to the conclusion that in Slamecka's experiment (1972, Experiment I) category recall with only one cue per category was about .94, while category recall with four cues per category was .58.

It should be noted that the results presented in Table 1 contradict predictions of theories postulating direct associations between items (Deese, 1959; Anderson, 1972). If items were directly interlinked in memory, it should be the case that presentation of some items as cues would increase the likelihood of other items being recalled (see Slamecka, 1972). Despite the use of categorized materials with presumably great preexperimental interitem associative strength, such is not the case.

It remains to be seen whether or not the two-factor hypothesis of the effectiveness of retrieval cues—that they aid recall to the extent that they allow access to more higher-order units than could be recalled unaided but inhibit recall when too much information is supplied—can be applied to part-list cueing experiments with unrelated words as well as those with categorized lists. There is little direct evidence concerning interference in cued recall with unrelated word lists, but in one study (Slamecka, 1968, Experiment II), Ss cued with 5, 15, or 25 unrelated items from a recently presented list of 30 had increasingly poorer recall on the remaining items than the appropriate control comparisons. The superiority of the noncued to cued Ss in proportion recalled was .09, .12, and .20 when cued Ss were given 5, 15, or 25 words, respectively. Since some item cues should have provided access to additional higher-order units and thus benefited recall, in order to account for negative cueing effects it is necessary to assume that the inhibitory factor typically has outweighed the facilitatory factor in cueing experiments with unrelated words.

It should be possible to design experiments with unrelated word lists which could potentially reveal the operation of these two factors just as has been done with categorized word lists. One possibility is the use of Mandler's (1967) technique of having Ss sort unrelated words into categories prior to recall to permit identification of the higher-order units. At recall, one could present either only the names Ss gave their categories or both the names and some items from their categories. Dong and Kintsch (1968) have already shown that presentation of names Ss gave their categories facilitates recall of items as compared to free recall. Presumably presenting instances with the category names would decrease the proportion of remaining items recalled as compared to recall with only the category name.

Optimism that the same results could be produced with unrelated words as with categorized words is based on the traditional assumption that the processes underlying recall of unrelated and categorically related word lists are the same. Postman (1972) has challenged this assumption, partly on the basis of results from part-list cueing experiments, and argued that the nature of the processes underlying recall of these two types of material are probably very different. Although relatively fixed higher-order units may be involved in the memorization of categorized lists, Postman has argued, such is not the case with unrelated words. Rather, in typical multitrial experiments with unrelated word lists, every item is presented in the context of different items on every trial due to randomization procedures, and this

encourages a "network of higher order units, or a complex network of associative groupings" which are "fundamentally different from the formation of cohesive, rigidly ordered chunks [1972, p. 23]." Since this hypothesis assumes interitem associations, it is unclear why it would not predict positive cueing effects when part-list retrieval cues are presented.

RELATED EXPERIMENTS

Several other experiments may be related to the phenomenon of output interference. One very simple–perhaps even descriptive–explanation of output interference is that it is the result of items strong in memory [since recall of an item appears to increase its likelihood of being recalled later (Darley & Murdock, 1971)] blocking or inhibiting recall of weaker items. Since one way to increase the strength of an item in a list is to present the item more than once (Waugh, 1967), one would expect that items presented only once in a list would be more poorly recalled if the list contained other words presented twice than if the list contained only words presented once. An experiment by Tulving and Hastie (1972) has shown that this is in fact the case: recall of once-presented (1X) items is poorer in lists containing twice-presented (2X) items, and furthermore this inferiority in recall of 1X items increased with the density of 2X items in the list. Two control lists, each containing 1X items, were used. In one the Ss received the same number of events (tokens) as Ss in the experimental condition where some items were repeated, but in this case all of the items were different words. In the other control condition Ss received the same number of different words (types) as Ss in the experimental condition, but since there were no repeated items there were fewer tokens. It was, of course, also true that 2X items were better recalled than 1X items. Thus, a reasonable description of these results is that the facilitation in recall of 2X items resulted in inhibition in recall of 1X items, as compared to control conditions. Consistent with an output interference interpretation of these results is the fact that 2X items were recalled reliably earlier in the output sequence than 1X items.

Unfortunately, more recent experiments by Hastie (1973) have called into question this interpretation of the Tulving and Hastie (1972) experiments. In one experiment Hastie (1973) found that there was inhibition in recall of 1X items only when Ss were instructed, before list presentation, to distinguish between 1X and 2X items during recall. Thus, an explanation of poorer recall of 1X words in lists containing 2Xwords in terms of the additional effort Ss must expend storing information about frequency of item occurrence appears at least as plausible, if not more so, than the output interference interpretation. However, no conclusion on this matter is justified without further research.

Assuming that the act of recall does strengthen the recalled information and makes unrecalled information less accessible, another experiment sheds some light on this process. Bousfield and Rosner (1970) compared recall of lists of unrelated words under standard free recall conditions and under conditions of "uninhibited" recall. In the latter, the Ss were told to report any words that came into their minds during the recall period whether or not they knew the item to be a repetition or other type of error. Although Ss in the uninhibited recall condition produced many more words (tokens) during the recall period, evidently they did not produce any more correct words except on the last of five trials, and then the difference was slight. [Curiously, Bousfield and Rosner (1970) reported results only for Trials 1 and 5. There was no difference in mean words recalled on the first trial and only a slight difference in recall on the fifth trial.] Of present interest is the finding that the great majority of additional words produced by Ss in the uninhibited recall condition were repetitions of items recalled earlier in the recall period. Thus, it does seem that the act of recall makes later recall of the same information more likely, even though it is not the information that the S is attempting to recall. It seems possible that one's inability to rid his mind of items already recalled somehow impairs his ability to retrieve other items, or that items strong in memory inhibit recall of weak items.

Although this review is primarily concerned with output interference in episodic memory, there is some suggestive evidence for a similar phenomenon in semantic memory. For one thing, the negatively accelerated function relating cumulative recall to recall time in free recall holds both for recall of lists and for recall of items from semantic memory in the form of producing items from specified conceptual categories (Bousfield & Sedgewick, 1944). As already suggested, it may be that recall of items early in the output sequence inhibits recall of later items. However, there is a logical problem in arguing that phenomena such as this indicate interference *within* semantic memory. The reason is that once an item is recalled from semantic memory, we typically remember the experience of just having recalled this information, and thus it can be said that this fact is registered in episodic memory. If it then seems that the recall of this information produces a decrement in the later recall of other information from semantic memory, this could be described as inhibition produced either within semantic memory or by interaction of information in episodic and semantic memory. There is little reason at the present time to prefer one description over the other in the experiments discussed here.

One experimental demonstration of an interference effect in semantic memory has been reported by Brown (1968). In one experiment, Brown (1968, Experiment I) presented one group of Ss with 25 randomly selected states and instructed them to study these for 5 min,

while a control group spent the time engaged in light reading. At the end of the 5-min period, all Ss were instructed to recall all 50 states in whatever order they wished. The group which studied the list of states prior to recall remembered more of the states on the list than the control group, as expected. The interesting finding was that the control group recalled more of the nonlist states than the experimental group. Thus, it seemed that the presentation or recall of the list states interfered with the experimental Ss' recall of the nonlist states. Brown replicated this result with English teenagers using the 40 counties of England.

Brown (1968) concluded that these experiments were in accord with the hypothesis that "strong associations block weak ones," and he suggested that one possible explanation of "this blocking is that successive retrievals from memory in free recall are somewhat analogous to sampling with replacement. This will mean that items which have already been retrieved are liable to occur as implicit intrusions while S is attempting to retrieve additional items, especially if the successful retrieval of an item still further increases its strength [1968, p. 42]." This interpretation is, of course, quite similar to Rundus's (1973) model.

Karchmer and Winograd (1971) replicated Brown's (1968) finding and also showed that the group which studied the 25 states prior to recall tended to recall these list states before they recalled other states. In a second experiment Karchmer and Winograd (1971) showed that requiring Ss in the experimental group to recall list states before nonlist states produced even more inhibition in the recall of nonlist states. The superiority of the control to the experimental groups in recall of the nonlist states in the first experiment was only 1.41 out of a possible 25, while in the second experiment it was 3.15. The authors argued that their experiments implicated output interference as responsible for the inhibition effect, but admitted that this statement was really no advance over Brown's tentative explanation.

Some caution should be used in interpreting these experiments by Brown (1968) and Karchmer and Winograd (1971) as cases as output interference in semantic memory. It seems possible that it could be merely due to an artifact of how long Ss in the experimental and control group spend in attempting recall of nonlist material. Since Ss in the experimental group, which receives material to study prior to the recall period, usually attempt to recall this material before they attempt recall of the other material, it is no surprise that they do not recall as much nonlist material in the first minute or so of the recall period as Ss who are instructed to recall all the material in any order without the Ss themselves giving some of the material priority. What is crucial is whether or not the experimental group ever catches up to performance of the control group on the nonlist material. Although both Brown (1968) and Karchmer and Winograd (1971) reported that cumulative recall functions for both experimental and control groups were approximately parallel (with the control group consistently superior), it is not clear whether or not the functions ever reached asymptote. Asymptotic levels of recall are crucial in establishing the validity of the finding of inhibition in recall of nonlist material due to the output order considerations just discussed. In addition, in several experiments by the author the inhibition effect in recall of nonlist material was negligible, at best. It appears that more research is needed involving greater periods of recall time and perhaps large, nonexhaustive categories (such as birds) to establish the validity of the inhibition effect in semantic memory with the Brown (1968) paradigm.

If such an output interference phenomenon is established in semantic memory, it may help account for the puzzling tip-of-the-tongue phenomenon reported by Brown and McNeill (1966). When these authors gave Ss definitions of low-frequency words and asked them to produce the words, in a small percentage of cases when Ss were unable to produce the correct word they nonetheless felt that it was on the "tips of their tongues" and were able to produce a variety of information about the target word, including synonyms, homonyms, the number of syllables in the word, etc. Brown and McNeill (1966) argued that Ss used all this information concerning the target word to eventually locate it in a search through the semantic memory network. However, this interpretation leaves an important question unanswered: With all this information accessible, why is S blocked from recalling the target word in the first place? One speculative response to this question is that the recall of all this extra information by Ss in the tip-of-the-tongue state, rather than aiding recall of the target word, in fact inhibits recall due to output interference.

OUTPUT INTERFERENCE AND RETROACTIVE INHIBITION

The concepts of input and output interference (Tulving & Arbuckle, 1963) can be viewed as an alternative conceptualization to traditional interference theory in accounting for paired-associate recall. Rather than considering the acquisition and retention of entire lists and the interfering effects of other lists, Tulving and Arbuckle (1963) considered retention of a single pair (since under normal conditions each pair is learned, in the sense of being perfectly recallable, as it is presented) as a function of interpolation of other input and output events between presentation and recall of the single pair. Nonetheless, the concepts of output interference and retroactive inhibition (RI) appear at least formally similar. Although output interference is defined as the decrement in recall due to retrieval of other events before the event of interest, while RI is defined as performance decrements due to the storage and retrieval of intervening events, it is also the case that the retrieval

of events in the case of output interference can alter their stored representation. Indeed, as has been argued by Rundus (1973) and Roediger (1973), recall of an event enhances probability of later recall (Darley & Murdock, 1971) and thus may be said to augment the stored representation of that event. Therefore, RI and output interference appear to share the common feature of referring to decrements in recall of some target event(s) as a function of storage of some intervening events.

Despite this formal similarity between RI and output interference, it appears unlikely, at least at present, that theories of RI can be extended to account for output interference, or vice versa. Nonetheless, it should be noted that certain aspects of both situations appear to be captured by the descriptive term "response competition."

CONCLUSIONS

The evidence reviewed here indicates that output interference occurs both in primary and secondary memory, and, in addition, there is suggestive evidence that output interference also occurs in recall of relatively permanent, long-term information from semantic memory. No claim is being made here, of course, that output interference is the entire, or even most important, source of forgetting. Murdock (1963) has shown that even when only one item is tested following presentation of a paired-associate list, recall is far from perfect. From an evolutionary perspective, however, it appears rather curious that there is any evidence at all for output interference, since it seems maladaptive for the very act of recall to produce forgetting of information that needs to be recalled later. Nonetheless, it does appear that output interference accounts in part for the inaccessibility of information available in memory and that consideration of this fact may elucidate otherwise puzzling phenomena in the study of memory.

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