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Selective Reminding for Analysis of Memory and Learning[1]

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A new and more appropriate paradigm for verbal learning is described and illustrated. Reminding a subject only of items not recalled on the immediately preceding trial, instead of presenting all items on each trial, shows retrieval from long-term storage when items are retrieved again without further presentation. This permits simultaneous analysis of long-term storage (LTS), retrieval from long-term storage (LTR), and recall from short-term storage (STR). Evaluating LTR in terms of items consistently retrieved on all subsequent trials (without further presentation) differentiates LTR into random and organized LTR, and also provides a measure of list learning for comparison with item learning. To illustrate the use of selective reminding for investigation of retrieval alone, an example is also presented of reminding only until first recall.

The purpose of this note is to present and illustrate an extremely simple and effective method for the simultaneous analysis of several components of memory and learning in verbal free recall. In essence, selective reminding simply involves the selective presentation on each recall trial of only those items which were not recalled on the immediately preceding trial. Because this permits the subject to demonstrate retrieval from long-term storage (LTS), by recalling an item which was not presented on that trial, it distinguishes between retrieval from long-term storage (LTR) and recall from short-term storage (STR). This method follows from the previous work of Glanzer (1966, 1972), Craik (1968, 1970), Tulving (1962, 1964; Tulving & Colotla, 1970), and Waugh & Norman (1965). If it is assumed that an item remains in LTS once it has been retrieved from LTS, then the cumulative number of items retrieved from LTS at least once provides a minimal estimate of items available in LTS.

The second aim of this note is to illustrate how list learning, as distinct from item learning, may be evaluated in terms of the number of items (or proportion of the list) which is consistently recalled on all subsequent trials. We would all agree that a list has been learned when all of the items in that list can be recalled on every trial; recall of a list means recall of all items in that list (without recall of any items which do not belong to that list). Now consider two subjects, both of whom can recall 15 items from a 20 item list. The first subject can recall 12 items consistently on each trial, plus three other items randomly retrieved from the other eight items in LTS. The second subject can recall six items consistently on each trial, plus nine items randomly retrieved from the other 14 items in LTS. We would also agree that, although both had learned all of the items, the first subject had learned more of the list. While the first subject has learned a 12-item list, the second subject has only learned a 6-item list; the first subject has learned 60% of the 20-word list, while the second subject has learned only 30% of the 20-word list. Consistent retrieval of an item on all subse-

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quent trials would seem to indicate that (information about) that item has been encoded in some kind of organized semantic structure from which it can be retrieved reliably on every trial (because each item has its place in such a structure), or that retrieval of that item has been integrated with the retrieval of other items in an organized retrieval search. Since items which are consistently recalled on all subsequent trials also are items which are consistently recalled together with each other, the collection of such items will constitute that part of the list which has been learned as a list.

With estimates of LTS (which shows item learning), total LTR, and consistent LTR, random retrieval from LTS (random LTR) is given by the difference between total LTR and consistent LTR. Therefore the proportion of LTS retrieved by random and by organized LTR also can be evaluated.

Selective Reminding of Items Not Recalled

Figure 1 shows the learning protocol of a subject who attempted to write all of the items in a 20-item list of animals (in any order) on each trial. On the first trial all 20 items were read aloud to the subject at a 2-sec. rate. After the first trial, only those items which were *not* recalled on the immediately preceding trial were presented again before the next recall. The stipled cells show which items were presented on each trial. The numbers in each

Name M.A. Date 3-5-73

Age 45 Sex F

WRITTEN – REMIND ALL OMISSIONS

FOUR – FOOTED ANIMALS

	1	2	3	4	5	6	7	8	9	10	11	12
1. DOG	1	6	6	11	1	1	1	1	1	1	1	1
2. FOX	8	7	7	12		15	2	2	2	2	2	2
3. HORSE		11	11	13	10	5	7	10	3	5	19	7
4. BUFFALO			1	17	14	14	10		4	6	12	
5. LION				2	3	8	15	3	14	17	3	5
6. RHINOCEROS	6	12	8	10	7	12	4	16	6	12	7	13
7. ELEPHANT	7	8	9	8	11	13	18	8	11	9	9	15
8. ANTELOPE			2	18	5	7	11	11	5	7	14	16
9. BEAR			5	16		13	13	12	18	8	13	17
10. LAMB		3		4	4	9	14	4	13	18	4	6
11. RAT	5		5	9	9	11	3	17	7	11	8	12
12. RACCOON		2	10	15	8		6	15	12	10	6	11
13. SHEEP	10	11		3	16	10		5	15	19	18	3
14. LLAMA			12	14		4	8	9	16	14	10	18
15. GOAT		3				6	16	13		3		4
16. CHEETAH	4		4	7	15	3	12	14	8	13	11	19
17. SQUIRREL	3	9			13		9		9	16	16	9
18. BEAVER	2	10			6			7	17		5	14
19. DONKEY				6	2	2	5	18	19	4	17	8
20. TURTLE	1			5	12		17	6	10	15	15	10
Σ RECALL	10	12	12	18	16	16	18	18	19	19	19	19
LTR	7	10	12	17	16	16	18	18	19	19	19	19
STR	3	2	0	1	0	0	0	0	0	0	0	0
LTS	7	10	15	19	19	20	20	20	20	20	20	20
LIST LEARNING	3	4	7	10	10	13	15	16	17	17	18	18
RANDOM LTR	4	6	5	7	6	3	3	2	2	2	1	1

FIG. 1. Written free recall when reminded only of items not recalled on the immediately preceding trial. Stipled cells show items presented on each trial.

column represent the relative order of recall of those items which were retrieved on each trial. Entries in cells without stipling show retrieval from LTS without presentation on that trial. Long-term storage, shown by the heavy underline, occurs on the trial before an item is first retrieved without presentation. Consistent retrieval of an item on all subsequent trials is indicated by the triangles. It is apparent that the need for reminders decreases across trials, as more items are retrieved from LTS without any further presentation. There are more recall failures before than after the trial on LTR on every subsequent trial, the difference between this curve and the curve for total LTR shows the (decrease in) random LTR over trials. The relative contributions of consistent and random retrieval from LTS, as well as the total proportion of LTS retrieved, are shown in Figure 2 (right).

Investigation of Retrieval by Selective Reminding

Other kinds of selective reminding are obviously possible. The extreme case of selective

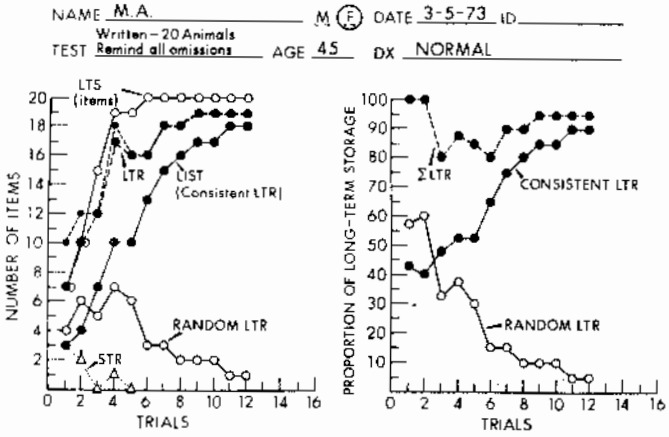

FIG. 2. Components of memory and learning shown by selective reminding of items not recalled on the preceding trial. Dotted line in left panel shows total recall. Retrieval from long-term storage is shown in the right panel.

which LTS occurs. Items from the end of the list required more reminders and were not retrieved consistently without further presentation until later than items from the beginning of the list.

Figure 2 (left) shows the relatively rapid increase in LTS of (information about) items (LTS), the much slower list learning, the total retrieval from long-term storage (LTR) and the very small recall from short-term storage (STR), as well as the total number of items recalled on each trial (dotted line). Since the list learning curve includes all of those items which are consistently retrieved by organized reminding, when all items are presented only once before multiple retrieval trials without further presentation of any items, can be used to evaluate encoding and to determine whether failure to recall an item before its initial recall represents encoding failure or retrieval failure. Selective reminding of an item only until it has been recalled just once, or until it has been retrieved once from LTS (as shown by retrieval without further presentation), can be used to investigate retrieval and to determine whether failure to recall an item after it has once been recalled (from LTS) signifies loss (of information) from LTS or retrieval failure. Thus,

selective reminding may be used to disentangle encoding and retrieval, and to determine how presentation of an item may affect different components of memory and learning.

Figure 3 shows the learning protocol of a subject who attempted to recall all of the items in the list of 20 animals verbally (in any order) on each trial. Verbal recall was used to minimize further item encoding and list learning that might occur during recall. On the first trial all items were read aloud to the subject at a 2-sec rate. After the first trial only those items which had not yet been recalled at all were presented again before the next trial. The stipled cells in each column show which items were presented on each trial. Since all items had been recalled at least once by the third trial, recall after the third trial reflects retrieval alone, without any further presentation. As the heavy underlines show, (information about) each item was encoded in LTS at least by the trial of initial recall (if not before). Of the 34 recall failures, 16 occurred before the initial recall of the 13 items involved. Although retrieval failure after initial recall extended for as many as eight subsequent trials before an item was retrieved from LTS again without further presentation, all 20 items eventually were spontaneously retrieved without further presentation, confirming that such recall failures were due to retrieval failure rather than to loss of (information about) items from LTS. The boxed circles mark the retrieval of an item after previous retrieval failure, and the dots in

Name B.F. Date 11-8-72

Age 23 Sex F

VERBAL-REMIND ONLY UNTIL FIRST RECALL

FOUR—FOOTED ANIMALS

	1	2	3	4	5	6	7	8	9	10	11	12
1. DOG	1	7	5	1	1	1	1	1	1	1	1	1
2. FOX	2	8	6	2	2	2	2	2	2	2	2	2
3. HORSE		1	7	3	3	3	3	3	3	3	3	3
4. BUFFALO		11					16	4	4	5	5	5
5. LION	4	15	15	4	5	5	4	15	11	14	14	15
6. RHINOCEROS		2	16	7	8	12	10	13	16	10	10	11
7. ELEPHANT	3		17	14	12	16	17	14	19	11	11	14
8. ANTELOPE	8	10	8	13	17	11	9	7	17	13	13	13
9. BEAR			1	10	13	14	11	10	6	7	7	8
10. LAMB		4	13	6	7	7	6	17	13	16	16	17
11. RAT	5	12	9	15	15	10	14	12	9	18	18	19
12. RACCOON	6	13	10	16	16	9	15	11	10	19	19	20
13. SHEEP		5	12	17	9	8	7	18	15	17	17	18
14. LLAMA	7	9	11	5	6	6	5	16	14	15	15	16
15. GOAT			2	8	10		18	5	5	4	4	4
16. CHEETAH			3	12	11	15	13	9	8	9	8	10
17. SQUIRREL		14	14						12	6	6	6
18. BEAVER			4	11	14	13	12	8	7	8	9	9
19. DONKEY		3	18	9	4	4	8	6	18	12	12	12
20. TURTLE		6									20	7
Σ RECALL	8	15	18	17	17	16	18	18	19	19	20	20
LTR	7	14	18	17	17	16	18	18	19	19	20	20
STR	1	1	0	0	0	0	0	0	0	0	0	0
LTS	8	16	20	20	20	20	20	20	20	20	20	20
LIST LEARNING	7	12	16	16	16	16	18	18	19	19	20	20
RANDOM LTR	0	2	2	1	1	0	0	0	0	0	0	0

FIG. 3. Verbal free recall without further presentation after first recall. Stipled cells show items presented on each trial. Boxed circles mark recovery after previous recall failure.

the right upper corner of some cells indicate delayed retrieval of such items after further searching during substantial pauses. Retrieval of previously "lost" items occurred late in the recall of items on the trial in which they were recovered and, once recovered, these items were consistently retrieved from LTS thereafter.

As Figure 4 (left) shows, LTR continued to increase without any further presentation, and there was very little random LTR. Figure 4 search in which the retrieval of each item is integrated with the retrieval of the other items. If we imagine a cube with an item placed at each corner, it is easy to appreciate that, although each item has its place in such a rigidly organized structure, when all items are recalled by moving along the edges of the cube to retrieve the item at each corner, the similarity of recall order from trial to trial need not be very great. The measure of consistent LTR suggested here should prove useful, since it is

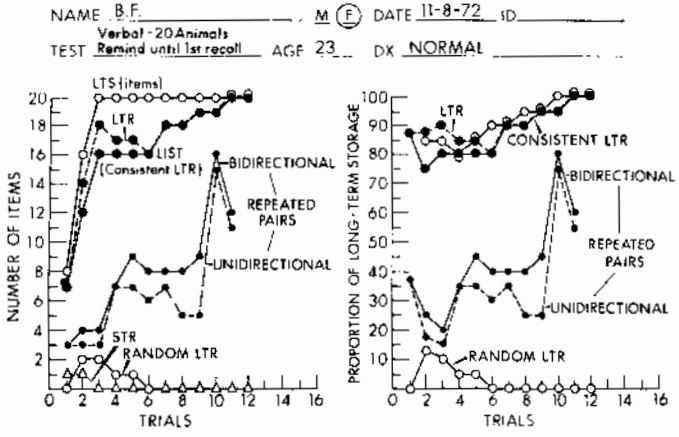

FIG. 4. Left panel: Components of verbal memory and learning without any further presentation after an item was recalled just once, with repeated-pairs measures of subjective organization. Right panel: Retrieval from long-term storage; open circles at top show retrieval after storage (initial recall) of all items.

also shows more standard measures of subjective organization (Tulving, 1962) in terms of unidirectional and bidirectional repeated pairs (Pellegrino, 1971, 1972). It is apparent that there is a great deal of consistent LTR which is not reflected by such a standard measure of subjective organization. Although (subjective) organization may result in similar order of retrieval from trial to trial, it does not follow that organization can (or should) be evaluated only in terms of recall order, or that organization is necessarily minimal when the similarity of recall order from trial to trial is low. All that is required for subjective organization is an organized semantic structure in which each item has its own place relative to the other items or an organized retrieval much easier to use than standard methods of estimating subjective organization, appears to indicate the development of organized retrieval or storage earlier, and also provides an estimate of list learning. This measure of consistent recall can, of course, also be used when studying verbal learning by methods other than selective reminding.

INTERPRETATION OF SELECTIVE REMINDING

The methods for analyzing components of verbal memory and learning described and illustrated here have a considerable range of potential applicability, since selective reminding can be used for paired-associate as well as

for free recall learning, and the measure of list learning (consistent retrieval) applies to serial as well as nonserial learning. I am using these methods to study the development of memory and learning in children, the effect of aging on memory and learning, and impairment of memory and learning in patients with neurological disease, as well as to investigate encoding and retrieval from permanent storage. Although I have used a list of items from the same category here, in order to define a search space in permanent memory for subjects attempting to retrieve items without presentation on every trial, these methods can also be used with other kinds of lists. While other types of scoring certainly are possible, I have described only the simplest kinds of scoring here because they appear to yield very similar results but are much easier to use.

I have interpreted the results obtained by these methods in terms of recall from STS, LTS, retrieval from LTS, and list learning, but it is also possible to view the components of memory and learning described here in other ways (Craik & Lockhart, 1972). The course of such verbal learning can be described simply in terms of empirically observed stages of recall: The trial on which an item is first recalled, the trial after which an item is recalled at least once without any further presentation, and the trial after which an item is consistently recalled on all subsequent trials. It may also be useful to analyze the results of selective reminding in terms of the number of new items gained (but not recalled on the immediately preceding trial), the number of previously recalled items lost without further presentation on that trial, and the number of items retained from one trial to the next (without further presentation), as well as the number of items which are retained for consistent recall on all subsequent trials as illustrated in Figure 5. Selective reminding of only those items not recalled on the immediately preceding trial could thus be used as a method for determining the number of items which can be retained for subsequent recall without further presentation, and the variability of retention at that level.

In any case, selective reminding should prove useful in the investigation of memory

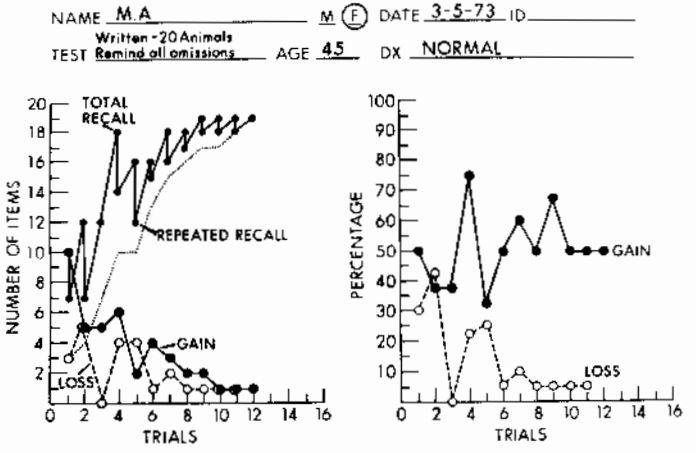

FIG. 5. Overall free recall when reminded only of items not recalled on the immediately preceding trial, in terms of gains and losses from trial to trial for comparison with Figure 2. Vertical lines show losses and diagonal lines show gains, so that upper peaks indicate the total number of items recalled on each trial and the bottom peaks show the number of items carried over for recall on the next trial at least. Dotted line in left panel shows the number of items carried over for consistent retrieval on all subsequent trials. Right panel: Proportion of those items not carried over which were gained on the next trial, and proportion of items recalled on each trial which were not recalled on the next trial.

and learning, and possibly also in other areas of experimental psychology such as cognition and perception, since selective reminding provides the subject with maximal opportunity to show what has been learned, as well as to learn that which has not yet been learned. It is neither necessary nor desirable to present all items before every trial of verbal learning unless the items are to be recalled in some prescribed order. This became clear to me when I thought about how to compare selective reminding with conventional free recall (when all items are presented before each recall trial). It turns out, so far as I can see, that learning by selective reminding can not be compared with learning by conventional free recall, because in conventional free recall there is no way to determine when an item, or when the list or some part of the list, has been learned. All we get from conventional free recall is the total number of items recalled on each trial, and even this is always in response to presentation of the entire list before each recall trial. Even when all items are recalled at the end of free recall learning, recall still occurs only in response to a complete presentation (perhaps as a complex response to a complex stimulus?).

However, in learning by selective reminding, we can determine when an item is learned because we can demonstrate retrieval without further presentation, and at the end of learning by selective retrieval we can show that the list clearly has been learned because it can be retrieved without presentation. In this sense, learning by selective retrieval is clearly "superior" to learning by conventional free recall; at least learning is more clearly demonstrable in selective reminding than in conventional free recall.

Selective reminding and free recall might be compared in terms of later recall without further presentation, but even such a comparison would be confounded by the continual presentation of the entire list during free recall learning. The continuing presentation of all items throughout free recall learning is unfortunate, not only because it (*a*) does not maximize the opportunity to learn items but instead hides items not yet learned among items already learned, and (*b*) does not provide an opportunity to determine that an item has been learned by retrieval without presentation, but also because (*c*) we simply can not determine how presentation of an item affects free recall learning; for example, when does presentation result in initial encoding, in facilitation of retrieval, in prevention of [illegible] in organization of the list? It is obvious that continuing presentation of all items throughout free recall learning must result in further presentation of items which have "already been learned," and that continuing presentation of the list in any order will conflict with the development of subjective organization of retrieval (Mandler & Dean, 1969). In contrast, selective reminding does not result in further presentation of items already learned, and allows the maximum opportunity for subjective organization of the list and its retrieval by minimizing the presentation of items. Therefore, it now seems to me that conventional free recall with continuing presentation of all items throughout learning is a very confusing way to examine learning, while selective reminding appears to provide a reasonable paradigm for nonserial learning.

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