Invariance of forgetting rate with number of repetitions in verbal short-term recognition memory*

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Ss listened to a list of eight different three-digit numbers, presented at the rate of one three-digit number per second. In many of the lists, one of the three-digit numbers was repeated three times in immediate succession (in a 3-sec period) before going on to the next number. At the end of the list of eight different three-digit numbers, one three-digit number was presented as a recognition test item. The test item could have appeared at any of the eight serial positions or be a new item. Ss were instructed to rehearse only the current item in the list, not previous items. Under these conditions, repetition of an item led to greater degree of learning in short-term memory, but the forgetting rate appeared to be invariant with number of repetitions.

*Support for the experimental facilities (the computer-controlled laboratory at the Center for Cognitive Studies, Harvard University) was provided by a United States Public Health Service research grant, MH-08083-02, from the National Institute of Mental Health to the Center. Analysis was supported by Grants MH-08890-04 and MH-17958-01 from the National Institute of Mental Health to Wayne Wickelgren, by Advanced Research Projects Agency, Department of Defense Contract No. F44620-67-C-0099, to Ray Hyman, and by Grant NB-07454-03 from NIH to Donald A. Norman.

Wickelgren & Norman (1966) found that items presented in the initial positions of a short list of three-digit numbers were learned better in short-term memory than items presented in later positions in the list, but the forgetting rate was the same for items in all serial positions.

In a series of studies on memory for pitch, using the delayed comparison procedure, Wickelgren (1969) found that increasing the study time for a tone increased the degree of learning of that tone in short-term memory but had no effect on the forgetting rate for the short-term memory trace.

In a study which varied rate of presentation, Norman (1966) found that increased rates of presentation (up to 10 digits/second) decreased the initial level of acquisition of the items in short-term memory but that the forgetting rate was not affected by these differences.

The purpose of the present study was to determine whether or not the invariance of the forgetting rate over different levels of acquisition (degrees of learning) in short-term memory holds true when the degree of learning is manipulated by varying the number of repetitions of a verbal item (three-digit number).

PROCEDURE

The Ss heard a 1-sec ready signal, followed after 2 sec by a list of eight different three-digit numbers, followed by a three-digit test number, followed by 4 sec in which Ss were to decide if the test number had appeared earlier in the list on that trial and to state their confidence on a scale from 1 (least) to 4 (most). On some trials each of the items (three-digit numbers) was presented once; on other trials, one of the items in the list was presented two, three, four, or six times in immediate succession. There was never more than one repeated item in a list. All presentations of an item occupied a period of 1 sec. No time elapsed between the end of the decision period for one trial and the ready signal for the next trial.

DESIGN

There were 10 types of lists: 1 type with no repetitions of items, 6 types with one item presented three times (repeated item being in Position 1, 2, . . . , or 6), and 3 types with the item in Position 2 being presented two, four, or six times. For each of these 10 types of lists, there were six conditions where one of the items in the list was tested for recognition (Position 1, 2, . . . , or 6, counting from the beginning of the list), and three (identical) conditions where a new item (not in the list) was tested for recognition. In addition to these $10 \times 9 = 90$ conditions, there were two (identical) conditions where the item in Position 7 was tested and two (identical) conditions where the item in Position 8 (last item) was tested. All four of the latter conditions were in lists with no repeated items. Thus, there were 94 trials/block. Four practice trials preceded each block. After two practice blocks, there were 10 different blocks taken six times each in the experiment, for a total of 62 blocks. Ss did no more than six blocks in any 1 day.

Table 1
Memory Strength (d') Values as a Function of Delay

Delay (Sec)	Serial Position	S SH		S BN		S RE		S SK	
		Number of Presentations							
		1	3	1	3	1	3	1	3
0	8	—		—		—		6.50	
1	7	5.73		2.92		2.84		3.70	
2	6	1.50	5.07	1.79	3.01	1.49	3.02	1.71	2.71
3	5	.99	3.82	1.18	1.74	.95	1.50	.86	1.74
4	4	1.18	1.70	.96	1.65	.77	1.33	.59	1.05
5	3	.98	1.30	.93	1.09	.73	.73	.38	1.11
6	2	.68	1.68	.41	1.24	.79	1.13	.16	.67
7	1	1.33	1.95	.72	1.46	.61	.95	.21	.66

Note—"—" means d' value not determinable but probably high (d' > 4). Blank means condition not run in experiment.

SUBJECTS

The Ss were four Harvard undergraduates who volunteered and were paid for their services.

RESULTS AND DISCUSSION

Memory operating characteristics were plotted on normal-normal coordinates for each serial position (delay condition) vs the new item condition, for each type of list. Assuming that new items have zero mean strength, memory strength (d') values were estimated for all delays of testing old items in all types of lists for both repeated and nonrepeated items. The memory strength (d') values were the x-intercepts of the least-squares fits to the memory operating characteristics. The assumptions and methods of strength analysis (Thurstonian scaling, statistical decision theory) as applied to recognition memory are described in Wickelgren & Norman (1966) and Wickelgren (1968).

The memory strength (d') estimates for all delays of testing items presented three times are presented in Table 1 along with the average of the d' estimates for all delays of testing items presented only once. The latter averages were gotten by including all tests of once-presented items in all list types, including lists which had repeated items, but only including tests of once-presented items that were presented *after* the repeated item. Including tests of once-presented items that had occurred *before* the repeated item would have required some estimate of the different interfering effects of repeated vs nonrepeated items, and no such estimate can be made from the present study.

Clearly, items presented three times are remembered better than items presented only once. There is also virtually no overlap in the d' scores for the unaveraged data for each S. Items presented 2, 4, or 6 times and tested at delays of 6 sec had d' values consistent on the average with a monotonic increase in memory performance with increasing number of presentations, but there were too few data to conclude anything regarding the form of this function. However, does this difference in short-term memory performance result simply from a difference in degree of learning (acquisition), or is the short-term forgetting rate slower as well for more frequently presented material?

Strength retention functions for short-term memory appear to be exponential in form (e.g., Wickelgren & Norman, 1966; Wickelgren, 1970). Strength retention functions for the present study are also well fitted by an exponential decay function of the form, $d' = ae^{-bt}$, where a is the degree of learning in short-term memory, b is the forgetting rate, and t is the delay in seconds (items) between the end of learning and the start of the retention test. As can be seen in Table 1, there is a slight primacy effect, largely confined to the first item. This appears in all studies where the first item is tested and is clearly a property of the first item in the list, not a property of the delay (7 sec in this study). Thus, the primacy effect is due to the greater degree of learning of the first item in a list, not to a violation of the exponential decay assumption, as has been shown directly by Wickelgren & Norman (1966).

The latter study indicated that the degree of learning of items in other serial positions of a list of three-digit numbers was approximately constant. Making this assumption, we can fit exponential decay curves separately to the d' values for one and three presentations for Serial Positions 2-8 for each S to determine if the forgetting rates (b values) are different. The a and b parameter estimates obtained by a least-squares fit on a semilog plot ($\log d' = \log a - b \log t$) are shown in Table 2 along with the results of a t test comparing the regression coefficients (b values) for one and three presentations for each S. Because we expected no difference in forgetting rates, we desired to use the most powerful test of this hypothesis. Thus, all the unaveraged d' values were used for the once-presented data, rather than just the average d' values presented in Table 1. Indeterminate d' values were omitted and d's less than .1 were treated as .1 in this analysis.

The differences in forgetting rates (b values) for one and three presentations were not significant for any S, were very small for three of the four Ss, and were split 2-2 on the direction of the difference. Thus, the present results support the hypothesis that the forgetting rate in short-term memory is invariant with number of presentations, though the degree of learning in short-term memory can be substantially increased by increasing the number of presentations.

Table 2
Acquisition and Forgetting-Rate (b) Parameters as a Function of Number of Presentations

S	Number of Presentations	a	b	$t(b_1 \text{ vs } b_3)$	df	p
SH	1	2.29	.21			
	3	8.76	.33	−.87	34	n.s.
BN	1	3.20	.31			
	3	4.01	.22	.70	34	n.s.
RE	1	2.25	.26			
	3	4.04	.27	−.07	34	n.s.
SK	1	4.94	.55			
	3	4.75	.32	1.29	35	n.s.

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