The JOURNAL OF EXPERIMENTAL PSYCHOLOGY is published monthly, two volumes per year, by the American Psychological Association, Inc., at Prince and Lemon Sts., Lancaster, Pa. The subscription rate per volume is $8.00, or $16.00 annually. Single copies are $1.50. Subscriptions, orders, address changes, and business communications should be addressed to the American Psychological Association, Inc., 1333 Sixteenth St. N.W., Washington 6, D. C.

This Journal publishes original experimental investigations which are intended to contribute toward the development of psychology as an experimental science. Studies with normal human subjects are favored over studies involving abnormal or animal subjects, except when the latter are specifically oriented toward the extension of behavior theory. Experimental psychometric studies and studies in applied experimental psychology or engineering psychology may be accepted if they have broad implications for experimental and theoretical psychology.

Normally, articles exceeding 20 printed pages cannot be accepted. Within this limit, the piecemeal experiment-by-experiment reporting of psychological research is discouraged, and the reporting of the data and conclusions of substantial segments of research efforts is encouraged. Specifically, an integrated series of studies accomplished simultaneously (e.g., most doctoral dissertations) *must* be presented in a single article. Special provision is made for the publication of Supplementary Reports and Replication Reports in articles of not more than 1.5 printed pages (see Editor's Note, this Journal, 1957, **53**, 1–2).

Address all articles submitted for publication to the Editor, Arthur W. Melton, Department of Psychology, University of Michigan, Ann Arbor, Michigan. **Manuscripts *must* adhere to the conventions concerning reference citations, preparation of tables and figures, manuscript format, etc., as described in the *Publication Manual of the American Psychological Association*.** When in doubt about practices of the Journal, authors should examine a recent issue.

Articles are published in the order of their receipt, except in rare circumstances. Authors are supplied with 50 free offprints without covers. All of the cost of an author's alterations in galley proof is charged to the author. Priority in publication is given to articles whose authors assume the full cost of publication. In 1959 the publication cost is $30 per printed page. Authors of priority publications receive no free offprints.

To save printing costs, supplementary material to articles in this Journal are deposited with the American Documentation Institute. Copies may be obtained by ordering the Document Number given in the footnote reference to ADI. Orders should be sent to ADI Auxiliary Publications Project, Photoduplication Service, Library of Congress, Washington 25, D. C. Orders *must* be accompanied by checks or money orders payable to the Chief, Photoduplication Service, Library of Congress.

Second-class postage paid at Lancaster, Pa.

Send address changes to 1333 Sixteenth St. N.W., Washington 6, D. C. Address changes must reach the Subscription Office by the 10th of the month to take effect the following month. Undelivered copies resulting from address changes will not be replaced; subscribers should notify the post office that they will guarantee second-class forwarding postage. Other claims for undelivered copies must be made within four months of publication.

Journal of
Experimental Psychology

VOL. 58, No. 3 SEPTEMBER, 1959

SHORT-TERM RETENTION OF INDIVIDUAL VERBAL ITEMS [1]

LLOYD R. PETERSON AND MARGARET JEAN PETERSON

Indiana University

It is apparent that the acquisition of verbal habits depends on the effects of a given occasion being carried over into later repetitions of the situation. Nevertheless, textbooks separate acquisition and retention into distinct categories. The limitation of discussions of retention to long-term characteristics is necessary in large part by the scarcity of data on the course of retention over intervals of the order of magnitude of the time elapsing between successive repetitions in an acquisition study. The presence of a retentive function within the acquisition process was postulated by Hull (1940) in his use of the stimulus trace to explain serial phenomena. Again, Underwood (1949) has suggested that forgetting occurs during the acquisition process. But these theoretical considerations have not led to empirical investigation. Hull (1952) quantified the stimulus trace on data concerned with the CS-UCS interval in eyelid conditioning and it is not obvious that the construct so quantified can be readily transferred to verbal learning. One objection is that a verbal stimulus produces a strong predictable response prior to the experimental session and this is not true of the originally neutral stimulus in eyelid conditioning.

Two studies have shown that the effects of verbal stimulation can decrease over intervals measured in seconds. Pillsbury and Sylvester (1940) found marked decrement with a list of items tested for recall 10 sec. after a single presentation. However, it seems unlikely that this traditional presentation of a list and later testing for recall of the list will be useful in studying intervals near or shorter than the time necessary to present the list. Of more interest is a recent study by Brown (1958) in which among other conditions a single pair of consonants was tested after a 5-sec. interval. Decrement was found at the one recall interval, but no systematic study of the course of retention over a variety of intervals was attempted.

EXPERIMENT I

The present investigation tests recall for individual items after several short intervals. An item is presented and tested without related items inter-

[1] The initial stages of this investigation were facilitated by National Science Foundation Grant G-2596.

vening. The initial study examines the course of retention after one brief presentation of the item.

Method

Subjects.—The *S*s were 24 students from introductory psychology courses at Indiana University. Participation in experiments was a course requirement.

Materials.—The verbal items tested for recall were 48 consonant syllables with Witmer association value no greater than 33% (Hilgard, 1951). Other materials were 48 three-digit numbers obtained from a table of random numbers. One of these was given to *S* after each presentation under instructions to count backward from the number. It was considered that continuous verbal activity during the time between presentation and signal for recall was desirable in order to minimize rehearsal behavior. The materials were selected to be categorically dissimilar and hence involve a minimum of interference.

Procedure.—The *S* was seated at a table with *E* seated facing in the same direction on *S*'s right. A black plywood screen shielded *E* from *S*. On the table in front of *S* were two small lights mounted on a black box. The general procedure was for *E* to spell a consonant syllable and immediately speak a three-digit number. The *S* then counted backward by three or four from this number. On flashing of a signal light *S* attempted to recall the consonant syllable. The *E* spoke in rhythm with a metronome clicking twice per second and *S* was instructed to do likewise. The timing of these events is diagrammed in Fig. 1. As *E* spoke the third digit, he pressed a button activating a Hunter interval timer. At the end of a preset interval the timer activated a red light and an electric clock. The light was the signal for recall. The clock ran until *E* heard *S* speak three letters, when *E* stopped the clock by depressing a key. This time between onset of the light and completion of a response will be referred to as a latency. It is to be distinguished from the interval from completion

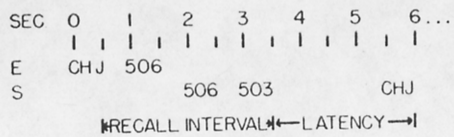

Fig. 1. Sequence of events for a recall interval of 3 sec.

of the syllable by *E* to onset of the light, which will be referred to as the recall interval.

The instructions read to *S* were as follows: "Please sit against the back of your chair so that you are comfortable. You will not be shocked during this experiment. In front of you is a little black box. The top or green light is on now. This green light means that we are ready to begin a trial. I will speak some letters and then a number. You are to repeat the number immediately after I say it and begin counting backwards by 3's (4's) from that number in time with the ticking that you hear. I might say, ABC 309. Then you say, 309, 306, 303, etc., until the bottom or red light comes on. When you see this red light come on, stop counting immediately and say the letters that were given at the beginning of the trial. Remember to keep your eyes on the black box at all times. There will be a short rest period and then the green light will come on again and we will start a new trial." The *E* summarized what he had already said and then gave *S* two practice trials. During this practice *S* was corrected if he hesitated before starting to count, or if he failed to stop counting on signal, or if he in any other way deviated from the instructions.

Each *S* was tested eight times at each of the recall intervals, 3, 6, 9, 12, 15, and 18 sec. A given consonant syllable was used only once with each *S*. Each syllable occurred equally often over the group at each recall interval. A specific recall interval was represented once in each successive block of six presentations. The *S* counted backward by three on half of the trials and by four on the remaining trials. No two successive items contained letters in common. The time between signal for recall and the start of the next presentation was 15 sec.

Results and Discussion

Responses occurring any time during the 15-sec. interval following signal for recall were recorded. In Fig. 2 are plotted the proportions of correct recalls as cumulative functions of latency for each of the recall intervals. Sign tests were used to evaluate differences among the curves (Walker & Lev, 1953). At each latency differences among the 3-, 6-, 9-, and 18-sec. recall interval curves are significant at the .05 level. For latencies of 6 sec. and longer these

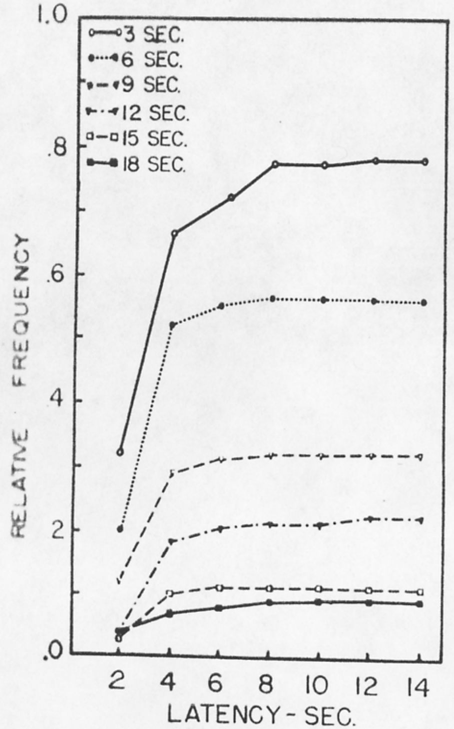

Fig. 2. Correct recalls as cumulative functions of latency.

differences are all significant at the .01 level. Note that the number correct with latency less than 2 sec. does not constitute a majority of the total correct. These responses would not seem appropriately described as identification of the gradually weakening trace of a stimulus. There is a suggestion of an oscillatory characteristic in the events determining them.

The feasibility of an interpretation by a statistical model was explored by fitting to the data the exponential curve of Fig. 3. The empirical points plotted here are proportions of correct responses with latencies shorter than 2.83 sec. Partition of the correct responses on the basis of latency is required by considerations developed in detail by Estes (1950). A given probability of response applies to an interval of time equal in length to the average time required for the response under consideration to occur. The mean latency of correct responses in the present experiment was 2.83 sec. Differences among the proportions of correct responses with latencies shorter than 2.83 sec. were evaluated by sign tests. The difference between the 3- and 18-sec. conditions was found to be significant at the .01 level. All differences among the 3-, 6-, 9-, 12-, and 18-sec. conditions were significant at the .05 level.

The general equation of which the expression for the curve of Fig. 3 is a specific instance is derived from the stimulus fluctuation model developed by Estes (1955). In applying the model to the present experiment it is assumed that the verbal stimulus produces a response in *S* which is conditioned to a set of elements contiguous with the response. The elements thus conditioned are a sample of a larger population of elements into which the conditioned elements disperse as time passes. The proportion of conditioned elements in the sample determining *S*'s behavior thus decreases and with it the probability of the response. Since the fitted curve appears to do justice to the data, the observed decrement could arise from stimulus fluctuation.

The independence of successive presentations might be questioned in the light

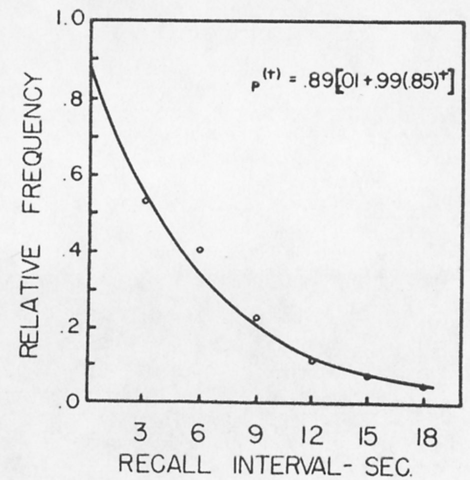

Fig. 3. Correct recalls with latencies below 2.83 sec. as a function of recall interval.

of findings that performance deteriorates as a function of previous learning (Underwood, 1957). The presence of proactive interference was tested by noting the correct responses within each successive block of 12 presentations. The short recall intervals were analyzed separately from the long recall intervals in view of the possibility that facilitation might occur with the one and interference with the other. The proportions of correct responses for the combined 3- and 6-sec. recall intervals were in order of occurrence .57, .66, .70, and .74. A sign test showed the difference between the first and last blocks to be significant at the .02 level. The proportions correct for the 15- and 18-sec. recall intervals were .08, .15, .09, and .12. The gain from first to last blocks is not significant in this case. There is no evidence for proactive interference. There is an indication of improvement with practice.

Experiment II

The findings in Exp. I are compatible with the proposition that the aftereffects of a single, brief, verbal stimulation can be interpreted as those of a trial of learning. It would be predicted from such an interpretation that probability of recall at a given recall interval should increase as a function of repetitions of the stimulation. Forgetting should proceed at differential rates for items with differing numbers of repetitions. Although this seems to be a reasonable prediction, there are those who would predict otherwise. Brown (1958), for instance, questions whether repetitions, as such, strengthen the "memory trace." He suggests that the effect of repetitions of a stimulus, or rehearsal, may be merely to postpone the onset of decay of the trace. If time is measured from the moment that the last stimulation ceased, then the forgetting curves should coincide in all cases, no matter how many occurrences of the stimulation have preceded the final occurrence. The second experiment was designed to obtain empirical evidence relevant to this problem.

Method

The *Ss* were 48 students from the source previously described. Half of the *Ss* were instructed to repeat the stimulus aloud in time with the metronome until stopped by *E* giving them a number from which *S* counted backward. The remaining *Ss* were not given instructions concerning use of the interval between *E*'s presentation of the stimulus and his speaking the number from which to count backward. Both the "vocal" group and the "silent" group had equated intervals of time during which rehearsal inevitably occurred in the one case and could occur in the other case. Differences in frequency of recalls between the groups would indicate a failure of the uninstructed *Ss* to rehearse. The zero point marking the beginning of the recall interval for the silent group was set at the point at which *E* spoke the number from which *S* counted backward. This was also true for the vocal group.

The length of the rehearsal period was varied for *Ss* of both groups over three conditions. On a third of the presentations *S* was not given time for any repetitions. This condition was thus comparable to Exp. I save that the only recall intervals used were 3, 9, and 18 sec. On another third of the presentations 1 sec. elapsed during which *S* could repeat the stimulus. On another third of the presentations 3 sec. elapsed, or sufficient time for three repetitions. Consonant syllables were varied as to the rehearsal interval in which they were used, so that each syllable occurred equally often in each condition over the group. However, a given syllable was never presented more than once to any *S*. The *Ss* were assigned in order of appearance to a randomized list of conditions. Six practice presentations were given during which corrections were made of departures from instructions. Other details follow the procedures of Exp. I.

Results and Discussion

Table 1 shows the proportion of items recalled correctly. In the vocal group recall improved with repetition at each of the recall intervals tested.

TABLE 1

Proportions of Items Correctly Recalled in Exp. II

Group	Repetition Time (Sec.)	Recall Interval (Sec.) 3	9	18
Vocal	3	.80	.48	.34
	1	.68	.34	.21
	0	.60	.25	.14
Silent	3	.70	.39	.30
	1	.74	.35	.22
	0	.72	.38	.15

Conditions in the silent group were not consistently ordered. For purposes of statistical analysis the recall intervals were combined within each group. A sign test between numbers correct in the 0- and 3-repetition conditions of the vocal group showed the difference to be significant at the .01 level. The difference between the corresponding conditions of the silent group was not significant at the .05 level. Only under conditions where repetition of the stimulus was controlled by instructions did retention improve.

The obtained differences among the zero conditions of Exp. II and the 3-, 9-, and 18-sec. recall intervals of Exp. I require some comment, since procedures were essentially the same. Since these are between-*S* comparisons, some differences would be predicted because of sampling variability. But another factor is probably involved. There were 48 presentations in Exp. I and only 36 in Exp. II. Since recall was found to improve over successive blocks of trials, a superiority in recall for *Ss* of Exp. I is reasonable. In the case of differences between the vocal and silent groups of Exp. II a statistical test is permissable, for *Ss* were assigned randomly to the two groups. Wilcoxon's (1949) test for unpaired replicates, as well as a *t* test, was used. Neither showed significance at the .05 level.

The 1- and 3-repetition conditions of the vocal group afforded an opportunity to obtain a measure of what recall would be at the zero interval in time. It was noted whether a syllable had been correctly repeated by *S*. Proportions correctly repeated were .90 for the 1-repetition condition and .88 for the 3-repetition condition. The chief source of error lay in the confusion of the letters "m" and "n." This source of error is not confounded with the repetition variable, for it is *S* who repeats and thus perpetuates his error. Further, individual items were balanced over the three conditions. There is no suggestion of any difference in responding among the repetition conditions at the beginning of the recall interval. These differences developed during the time that *S* was engaged in counting backward. A differential rate of forgetting seems indisputable.

The factors underlying the improvement in retention with repetition were investigated by means of an analysis of the status of elements within the individual items. The individual consonant syllable, like the nonsense syllable, may be regarded as presenting *S* with a serial learning task. Through repetitions unrelated components may develop serial dependencies until in the manner of familiar words they have become single units. The improved retention might then be attributed to increases in these serial dependencies. The analysis proceeded by ascertaining the dependent probabilities that letters would be correct given the event that the previous letter was correct. These dependent probabilities are listed in Table 2. It is clear that with increasing repetitions the serial dependencies increase. Again combin-

TABLE 2

Dependent Probabilities of a Letter Being Correctly Recalled in the Vocal Group When the Preceding Letter was Correct

Repetition Time (Sec.)	Recall Interval (Sec.)		
	3	9	18
3	.96	.85	.72
1	.90	.72	.57
0	.86	.64	.56

ing recall intervals, a sign test between the zero condition and the three repetition condition is significant at the .01 level.

Learning is seen to take place within the items. But this finding does not eliminate the possibility that another kind of learning is proceeding concurrently. If only the correct occurrences of the first letters of syllables are considered, changes in retention apart from the serial dependencies can be assessed. The proportions of first letters recalled correctly for the 0-, 1-, and 3-repetition conditions were .60, .65, and .72, respectively. A sign test between the 0- and 3-repetition conditions was significant at the .05 level. It may tentatively be concluded that learning of a second kind took place.

The course of short-term verbal retention is seen to be related to learning processes. It would not appear to be strictly accurate to refer to retention after a brief presentation as a stimulus trace. Rather, it would seem appropriate to refer to it as the result of a trial of learning. However, in spite of possible objections to Hull's terminology the present investigation supports his general position that a short-term retentive factor is important for the analysis of verbal learning. The details of the role of retention in the acquisition process remain to be worked out.

Summary

The investigation differed from traditional verbal retention studies in concerning itself with individual items instead of lists. Forgetting over intervals measured in seconds was found. The course of retention after a single presentation was related to a statistical model. Forgetting was found to progress at differential rates dependent on the amount of controlled rehearsal of the stimulus. A portion of the improvement in recall with repetitions was assigned to serial learning within the item, but a second kind of learning was also found. It was concluded that short-term retention is an important, though neglected aspect of the acquisition process.

References

Brown, J. Some tests of the decay theory of immediate memory. *Quart. J. exp. Psychol.*, 1958, **10**, 12–21.

Estes, W. K. Toward a statistical theory of learning. *Psychol. Rev.*, 1950, **57**, 94–107.

Estes, W. K. Statistical theory of spontaneous recovery and regression. *Psychol. Rev.*, 1955, **62**, 145–154.

Hilgard, E. R. Methods and procedures in the study of learning. In S. S. Stevens (Ed.), *Handbook of experimental psychology.* New York: Wiley, 1951.

Hull, C. L., Hovland, C. I., Ross, R. T., Hall, M., Perkins, D. T., & Fitch, F. B. *Mathematico-deductive theory of rote learning: A study in scientific methodology.* New Haven: Yale Univer. Press, 1940.

Hull, C. L. *A behavior system.* New Haven: Yale Univer. Press, 1952.

Pillsbury, W. B., & Sylvester, A. Retroactive and proactive inhibition in immediate memory. *J. exp. Psychol.*, 1940, **27**, 532–545.

Underwood, B. J. *Experimental psychology.* New York: Appleton-Century-Crofts, 1949.

Underwood, B. J. Interference and forgetting. *Psychol. Rev.*, 1957, **64**, 49–60.

Walker, H., & Lev, J. *Statistical inference.* New York: Holt, 1953.

Wilcoxon, F. *Some rapid approximate statistical procedures.* New York: American Cyanamid Co., 1949.

(Received September 26, 1959)

Journal of Experimental Psychology
Vol. 58, No. 3, 1959

VARIATIONS IN CROSS-MASKING WITH FREQUENCY [1]

J. G. INGHAM

Medical Research Council Neuropsychiatric Research Unit, Cardiff, Wales

The general problem of the masking of one pure tone by another was investigated intensively by Wegel and Lane (1924). Later writers have leaned heavily upon this earlier work, which indicated that masking only occurred when the two tones were presented to the same ear. Fletcher, for example, answers with a categorical negative the question: "Does the same interfering effect exist when the two tones are introduced into opposite ears instead of both being introduced into the same ear?" (Fletcher, 1953, p. 157). Wegel and Lane's results did indeed suggest that the small amount of masking apparently observed in the opposite ear could be accounted for by leakage of sound from one ear to the other. Zwislocki (1953) refers to a "physiological component," which does not exceed 5 db, in cross-masking, but does not state the results from which the existence of such a component is inferred. In a previous paper, the writer has shown that the phenomenon of cross-masking does exist, even when the masking tone is not sufficiently intense to cause any appreciable direct stimulation of the opposite ear (Ingham, 1957). It appears likely, therefore, that the phenomenon is one which involves the brain.

That a systematic relationship exists between masking and the frequency separation of the two tones was shown by Wegel and Lane (1924) for monaural masking. The object of the present investigation was to explore cross-masking to see how this effect is related to frequency.

Various hypotheses were put forward as possible explanations of the cross-masking phenomenon (Ingham, 1957). The present experiments were not intended to be critical for any of these but they are relevant. This point will be discussed later.

Experiment I

Method

Design.—Using the same masking tone as before, that is 400 cy./sec., masking was observed on test frequencies of 250, 370, 430, 550, 700, and 1000 cy./sec., presented to one ear. In one session, thresholds for all six test frequencies were measured. In another session, thresholds for only one test frequency were measured, the test frequency being either 250, 430, or 1000 cy./sec. These two procedures were introduced because during preliminary experiments results were obtained which suggested that there might be important differences between them.

The *S*s were paired in order of testing. One member of each pair had the one-frequency session first, followed by the six-frequency session on another day. For the other member of the pair the order was reversed. Orders were allotted at random within each pair. Similarly, within each successive three sets of pairs, the test frequencies 250, 430, and 1000 cy./sec. were allotted at random. The masking tone was always presented to the most sensitive ear, as determined by a preliminary approximate threshold observation for 400 cy./sec. This was done in order to minimize leakage of the masking tone to the opposite ear. Test frequency thresholds for the least sensitive ear were measured, first with the opposite ear unstimulated and secondly with the 400 cy./sec. masking tone, 30 db above threshold, in the opposite ear. Masking was defined as the

[1] The writer wishes to express his appreciation to Derek Richter, Director of Research, and to members of the staff of Whitchurch Hospital and Cardiff Radiotherapy Centre who took part in the experiments.