Repetition effects in short-term memory*

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Human short-term memory was studied using repeated presentations of the stimulus materials. A consonant trigram was presented, rehearsal was prevented for a 20-sec interval, and the procedure was then repeated without allowing an attempted recall. A single recall test was given after the interval that followed the last presentation. Number of presentations (one, two, three, and four) was the independent variable. Considerable increases in recall were obtained as number of presentations increased.

Short-term memory has been given definition by a set of procedures devised by Peterson & Peterson (1959). For their longest retention interval (18 sec), the Peterson and Peterson procedure can be diagrammed as:

"CHJ" [Interval_{18}] Recall_1

(Procedure 1)

in which "CHJ" is the consonant trigram presented to the S and the subscript following "Interval" denotes the length of that period (in seconds) during which the S counts backward by threes or fours orally in order to prevent rehearsal.

One method of introducing repetition into the short-term memory situation was used by Hellyer (1962), whose procedure can be diagrammed:

"CHJ, CHJ" [Interval_{18}] Recall_1

(Procedure 2)

Hellyer used 1, 2, 4, or 8 presentations of the trigram before initiating a single retention interval, and his results show a considerable growth of recall scores as a function of number of presentations. However, Hellyer's procedures permit the interpretation that, during the preinterval repetition of the consonant syllable, the trigram may become ensconced in long-term store. The point of the Peterson and Peterson experiment, of course, was that the curve of retention for the trigram in short-term store could be revealed by blocking transfer of the material to long-term store during the retention interval. Nothing is necessarily revealed about short-term memory in a situation where the material is well-practiced before the start of the retention interval.

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Another method of giving repetition exists, however, and it is the object of the present investigation to explore this method. The procedure (for two presentations) may be diagrammed:

"CHJ" [Int._{20}]; "CHJ" [Int._{20}] Recall_1

(Procedure 3)

It is important to notice that Procedure 3 provides for the presentation of the trigram, the presumable decrease of memory for it in time, and then a subsequent repetition of the trigram without giving an intervening opportunity for recall. Obviously, the general procedure can allow for as many repetitions as one may desire. For example, a condition giving four repetitions could be diagrammed:

"CHJ" [Int._{20}]; "CHJ" [Int._{20}];

"CHJ" [Int._{20}]; "CHJ" [Int._{20}] Recall_1

Still considering Procedure 3, if the intervals are sufficiently long so that memory is completely degraded during each interval, one might reasonably expect a Recall_1 score of zero, regardless of the number of repetitions. However, if the recall intervals are short enough to yield a finite probability of recall at the end of each interval (as is undoubtedly the case when 20-sec intervals are used), then one might reasonably expect these probabilities to accumulate over intervals.

More specifically, if proportion of correct recalls at the end of the first interval is taken as Pr_1, then the proportion (Pr_2) at the end of the second interval might be given by: $Pr_2 = Pr_1 + Pr_1(1 - Pr_1)$. More generally, after n presentations:

$$Pr_n = Pr_{n-1} + p(1 - Pr_{n-1}) \quad (1)$$

where Pr = proportion recalled on any trial and p = a constant fraction of the material remaining to be learned. It should be noted that the equation being considered here is chosen for study not because of its great sophistication as an acquisition model, but because it describes an obvious way to interpret data obtained under Procedure 3.

If an empirical curve is obtained whose slope is steeper than the slopes of curves generated by Eq. 1 for plausible values of p, a question must be raised concerning where and how the information that is recalled under such conditions of repeated presentation is stored. If an empirical curve is obtained that differs significantly from *any* curve that can be generated by Eq. 1, the hypothesis that an acquisition model such as the one defined by Eq. 1 can account for the effects of repetition in short-term memory situations must be questioned.

SUBJECTS

The Ss in the experiment were 64 female students enrolled in introductory psychology at the University of Missouri–St. Louis, who participated to fulfill a course requirement. Each S was tested individually. Each S served under all four conditions of the experiment. Order of presentation of conditions and linkage of trigram with condition were counterbalanced in a factorial design that required 16 Ss per replication, and four replications were run.

APPARATUS

The stimulus materials used in the experiment were four consonant trigrams (CKM, PZH, SJW, and XFQ), which had

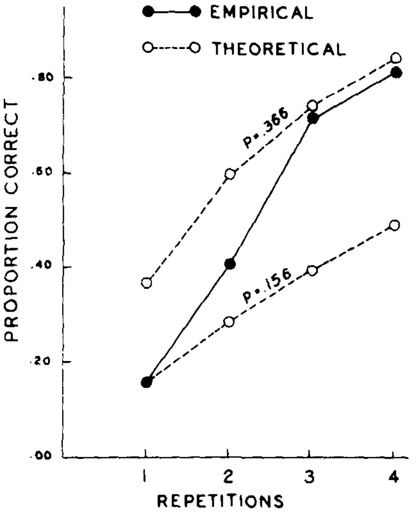

Fig. 1. Proportion of correct recalls as a function of number of repetitions. The dotted curves are theoretical functions generated by Eq. 1. The lower theoretical curve employs the empirically obtained Pr_1 of .156 as p. The upper theoretical curve employs a p value of .366, which yields the maximum slope for any member of the family of curves generated by Eq. 1.

Table 1
Weighting of Theoretical Proportions by Trials

Trials	Coefficients	Proportions on Trials	Weighted Proportions
1	(−3)	$Pr_1 = p$	$-3p$
2	(−1)	$Pr_2 = 2p - p^2$	$-2p + p^2$
3	(+1)	$Pr_3 = 3p - 3p^2 + p^3$	$+3p - 3p^2 + p^3$
4	(+3)	$Pr_4 = 4p - 6p^2 + 4p^3 - p^4$	$+12p - 18p^2 + 12p^3 - 3p^4$
		General Slope Score =	$+10p - 20p^2 + 13p^3 - 3p^4$

been selected for homogeneity of association value (0%-25%) from lists presented by Hilgard (1951). Pilot work had established that these trigrams also possessed high intelligibility under conditions of auditory presentation. The general procedure of Peterson and Peterson was followed, except that all of the experimental events were presented to the Ss by means of a carefully constructed tape recording. This meant that all signals to the Ss had to be auditory, so a chime was substituted for the light that Peterson and Peterson had used as a signal for recall.

PROCEDURE

Extensive preexperimental training was given in the interval-filling activity (counting backward by threes at a rate of 60 3-digit numbers/minute), and two practice short-term memory trials were given before the start of the experiment proper. With the exceptions noted above, the procedures of Peterson and Peterson were followed. All responses made by the S during the 20-sec recall periods were recorded by the E, but scoring was done in an all-or-none fashion, following the procedure of Peterson and Peterson.

RESULTS

The basic empirical findings are shown in Fig. 1, which also shows two theoretical curves. As number of presentations increased from one to two to three to four, number of Ss recalling correctly after the last presentation were 10, 26, 46, and 52, respectively.

A theoretical curve of special interest is the curve (lower dashed curve in Fig. 1) generated by Eq. 1 when the observed proportion of correct recalls after one repetition (Pr_1 = .156) is used for the value of p. A slope analysis devised by Turnage (1969) was used to test the significance of the difference between the linear trends of the empirical curve and this theoretical curve. Individual slope scores were calculated for all Ss by weighting their dichotomous scores on all four trials by the linear coefficients for orthogonal polynomials, an S's slope score being the sum of the weighted scores across trials. Slope scores here can take on values between −4 and +4, inclusive, and the observed range was from −3 to +4, inclusive. The mean slope score for the empirical data was 2.281. The .99 confidence interval for that mean is 1.712-2.851. The fact that the mean slope score of the empirical curve is significantly different from zero implies that improvement occurred as a function of repetition. The slope score of the theoretical curve described above was found by weighting the theoretical proportion for each trial by the appropriate linear coefficient and summing these weighted proportions across trials. This theoretical score of 1.122 falls outside the .99 confidence limit for the empirical slope scores.

DISCUSSION

Since the learning criterion was a stringent one (completely correct recall), it could be argued that the empirical value of Pr_1 underestimates the true value of p, with the result that the theoretical curve under consideration is spurious. If the Ss had learned more on the first trial than their performances under a stringent criterion indicate, then the theoretical curve would underestimate performance to the extent that the proportion of trigrams recalled on Trial 1 underestimates the fraction actually learned. However, we can show that *no* value of p in Eq. 1 could have generated the empirical curve.

Values of 0 and 1.00 for the parameter, p, define the limiting members of the family of theoretical curves that can be generated by Eq. 1. Both are straight lines of zero slope, the first coinciding with the abscissa and indicating no learning at all, the second having a value of 1.00 everywhere and indicating perfect one-trial learning. Intermediate values of p generate intermediate curves having positive slopes with linear components greater than zero. The general equation for the linear slope score of any member of this family of curves can be found by weighting the theoretical proportion for each trial by the appropriate linear coefficient, as shown in Table 1. The maximum value of the slope score of any member of the family of curves can be found by setting the first derivative with respect to p equal to zero, solving the resulting cubic equation for p, and then entering that value of p in the general equation. A p value of .366 generates the curve with the maximum slope for this family of curves (see upper dashed curve in Fig. 1), and this curve, in turn, yields a slope score of 1.564, which falls outside the .99 confidence limits of the mean empirical slope score. This finding means that the linear slope of the empirical curve is steeper than the linear slope of *any* member of the family of theoretical curves defined by Eq. 1.

Nelson & Batchelder (1969) have shown that repeating an incorrectly recalled trigram causes performance increments similar to the ones obtained here, but only if there was a partial recall of the trigram on the first recall test. It will be recognized that no such analysis could be made in the present experiment, because there was only one recall test. However, our finding that no p value could generate our empirical curve would seem to indicate that overt (or even covert) partial recall is not the essential precondition for all increments of this type.

In conclusion, the results of the present study imply that retention in short-term memory is considerably greater than has been supposed on the basis of previous studies using measures of memory taken after a single retention interval. That is, increments not revealed after a single interval nevertheless accumulate over repeated trials, yielding performances on later trials that cannot be predicted on the basis of first-trial performance using Eq. 1. Indeed, no value of p in Eq. 1 will generate a performance curve whose slope is compatible with the slope of the obtained curve.

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