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Abstract

An experiment was run using a within Ss design to evaluate the effect of information delay in a continuous paired-associates learning task. The delay interval between offset of the stimulus and onset of information feedback ranged from zero to twelve seconds. The basic independent variables involved manipulating the form of activity required of S during the delay interval, and the type of information feedback provided. Under one set of conditions learning showed a marked decrement with an increase in the delay period. However, for other conditions no effect was observed, and for yet others learning improved with increasing delay intervals. Thus within a single experiment it was possible to isolate some of the variables that determine the effect reinforcement delay has on learning. The results were shown to be predictable from current theories of human learning.

Information Delay in Human Learning*

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One of the most carefully studied variables in the psychology of learning is the delay interval between the occurrence of a response and its subsequent reinforcement. In animal studies the reinforcing event may be the delivery of a food pellet or the avoidance of electric shock, whereas in human studies reinforcement is usually equated with the presentation of information feedback. A survey of the literature on delay of reinforcement in animal learning provides quite consistent evidence that learning is impaired as the delay interval is increased. It is largely on the basis of such evidence that many textbooks in psychology and education emphasize the pedagogical value of immediate feedback. However, a survey of the literature on human learning does not yield such an orderly picture (Bilodeau, 1966). Although some studies find that delay of knowledge retards learning in human subjects (Greenspoon and Foreman, 1956; Saltzman, 1951), others indicate that it has no effect (Bilodeau and Ryan, 1960; Bourne, 1966; Hockman and Lipsitt, 1961). There is even some evidence suggesting that delaying information feedback may facilitate learning (Buchwald, 1967; Kintsch, 1964). The purpose of this study is to further explore the effects of information

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delay with the hope of isolating some of the variables that give rise to such a diverse pattern of results.

The learning task in this experiment is a modification of the typical paired-associate list learning procedure. The modification makes it possible to study learning by individual subjects under conditions that are uniform and stable over 15 or more experimental sessions each lasting for approximately one hour. The task employs a long series of discrete trials, each initiated with a test, and then terminated with a study of a paired-associate item. New items are continually being introduced and old ones deleted throughout the course of the experiment; a new item may appear at any point in the trial sequence, receive a fixed number of presentations distributed over a subset of trials, then be dropped and replaced by yet another item. In this way the list-structure features of the typical paired-associate experiment are eliminated, thereby making the difficulty of the task and the S's level of performance roughly the same over the entire course of the experiment.

Each trial of the experiment begins with the onset of a stimulus to which S must respond as rapidly as possible. The stimulus then goes off and t seconds later the reinforcing event occurs. There are three independent variables in the present study. One is the time delay t between the offset of the stimulus and onset of the reinforcing event. The second involves the type of activity S engages in during the delay interval t; in one condition S is free to do as he pleases, whereas in the other he is required to count backwards by threes, thus eliminating rehearsal and possibly causing the stimulus to be forgotten before the onset of the reinforcing event. The third variable involves the nature of the reinforcing event. In one condition only the correct response is displayed during the study phase of the trial, thereby requiring S to remember the stimulus over the delay period in order to associate it with the correct response; in the other condition the stimulus reappears along with the correct response at the time of study.

METHOD

The experiment was run under computer control. Each S was seated at a cathode-ray-tube (CRT) display terminal; immediately below the lower edge of the CRT was a bank of eight response keys, labeled in consecutive order from 2-9. Stimulus and reinforcing events were displayed on the CRT; S made his response by depressing the appropriate key. The stimuli were consonant trigrams (e.g., XJR) generated randomly with the restriction that the three letters be different. Once a given stimulus had been presented for its specified number of trials it was not used again for that S. Responses were the numbers from 2 to 9 and were assigned randomly to stimuli; thus the guessing probability associated with a correct response was 1/8. The Ss were 15 female college students who received $2.00 per experimental session. Each S participated in approximately 15 sessions.

Experimental sessions involved a series of 200 trials. The sequence of events characterizing a trial was as follows: (i) The word test appeared on the CRT and below it a stimulus trigram. The S was instructed to respond as rapidly as possible with the response that had been previously associated with the stimulus, and to guess if she was uncertain or if it was the item's first presentation. (ii) After S made her response, the screen was blanked out for t seconds. (iii) At the end of t seconds, the reinforcement phase of the trial was initiated; for 4 seconds the word study appeared on the screen and immediately below it the numeral designated as the correct response. (iv) After the offset of the reinforcing event, the CRT went blank for 2 seconds before the next trial began.

The study used a within-Ss design and the independent variables were as follows: (i) The delay interval t was either 0, 3, 6 or 12 seconds. (ii) During the delay interval, S was either free to do as she pleased or was required to count backwards by threes. For trials on which S was required to count backwards, a randomly selected three-digit number appeared on the CRT at the start of the delay period designating the point from which the count was to commence. The count and no-count procedures will be denoted C and $\overline{C}$. (iii) The reinforcing event also was of two types. In one condition only the correct response was displayed on the CRT during the study phase of the trial; in the other condition, the stimulus was reproduced along with the correct response during the study period. These two conditions will be denoted O (information outcome only) and SO (stimulus plus information outcome). With four values of t, two intervening activities and two reinforcing procedures, there are 16 basic item types. However, with t = 0 the C and $\overline{C}$ distinction is not meaningful and therefore the actual number of conditions is 14. Each stimulus-response item was presented for a series of trials using one of these 14 procedures.

An experimental session began by having the computer generate a pool of 16 stimuli that S had not previously seen, and assigning responses to them at random. Further, for each stimulus-response pair a number from three to seven was randomly selected to determine the number of trials that item would be presented before it was discarded and replaced by a new item. The experimental session was then initiated and run off, using the following algorithm: (i) On each trial an item was randomly selected from the pool of 16, eliminating as possible candidates any item that had been presented during the last 10 trials. (ii) After the item was presented, a check was made to determine if it had received its pre-allotted number of presentations. If not, it was returned to the pool for presentation on a later trial. If it had, then it was discarded and replaced by a new stimulus-response pair which was randomly assigned to one of the 14 experimental conditions and given a number specifying its allotted number of presentations. (iii) Steps 1 and 2 were repeated until 200 trials had been run. Note that the scheme for sampling from the active pool of items guaranteed that an item was not presented until at least 10 other items have intervened, thus eliminating memory effects due to short inter-item presentations.

RESULTS AND DISCUSSION

For each experimental condition, we have computed the probability of a correct response on the n^{th} presentation of an item, which will be denoted as p_n. The basic dependent variable to be considered here is the mean value of the probability of a correct response on trials 2 through 7; i.e., $\overline{p} = (p_2 + p_3 + \ldots + p_7)/6$. The value of p_1 is not included in the average since performance on the first presentation is strictly a function of guessing. Figure 1 presents $\overline{p}$ as a function of the delay period $\underline{t}$ for each of the experimental treatments. There is

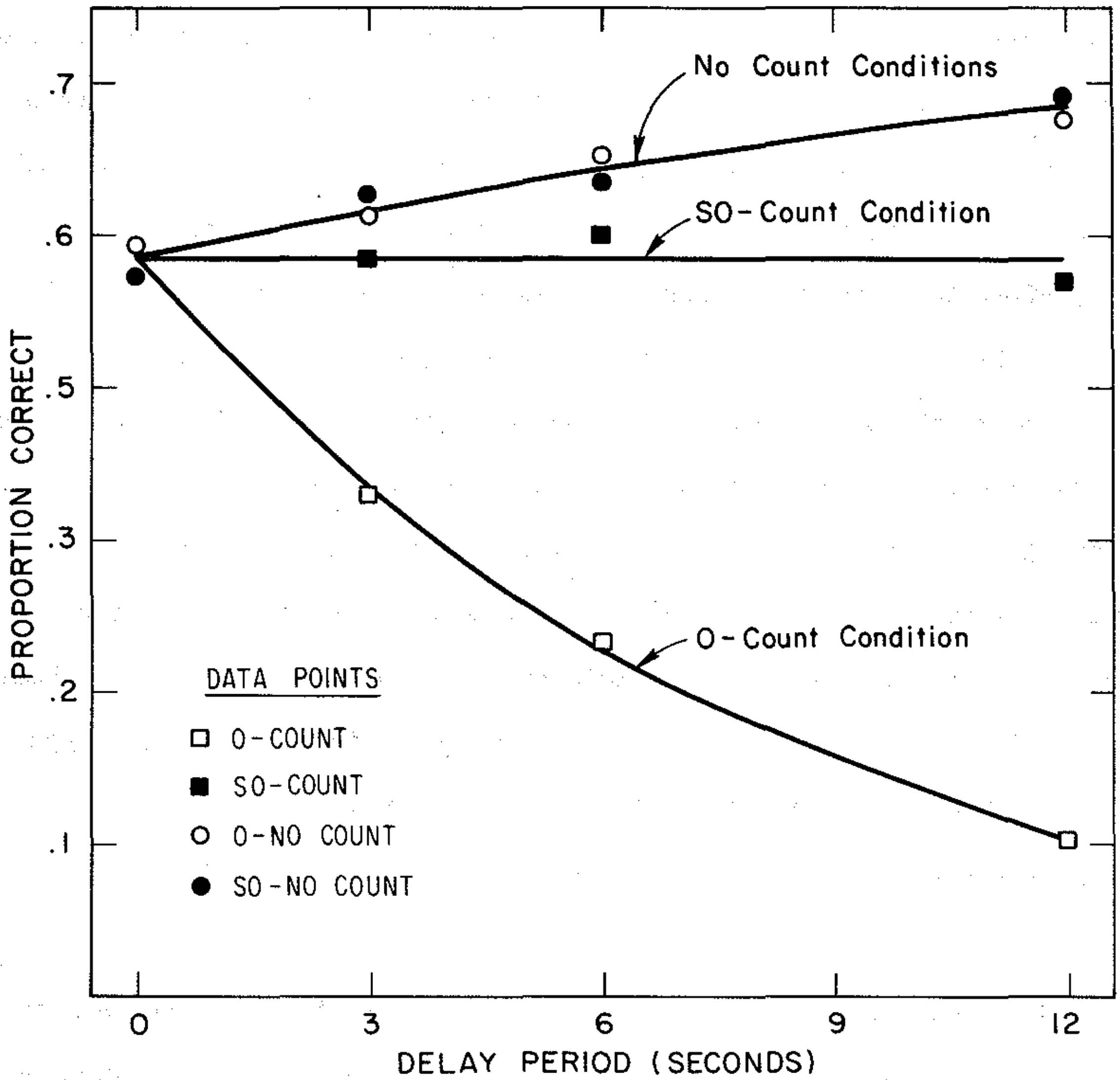

Fig. 1. Relation between $\overline{p}$ and delay period $\underline{t}$. The observed values of $\overline{p}$ are represented as points on the figure, and the theoretical functions are displayed as smooth curves.

no significant difference between the O-$\overline{C}$ and SO-$\overline{C}$ data curves; however, all other comparisons among the four data curves are significant at the .01 level. The value of $\overline{p}$ is a decreasing function of t for the O-C condition, and is in agreement with the proposition that learning is impaired as the delay interval is increased. Note, however, that the effect appears to be completely washed out for the SO-C condition, and here learning is independent of the delay interval. Thus, requiring S to engage in a distracting task during the delay interval can produce either a decrement or no decrement in performance with increasing t, depending on whether or not stimulus information is reproduced at the time of study. The most striking finding, however, is that for both the O-$\overline{C}$ and SO-$\overline{C}$ conditions learning improves as t increases. If S is not distracted by counting during the delay period, then learning is actually facilitated as t increases; further, the increment in performance does not appear to depend on whether stimulus information is or is not reproduced during the study period. What has been demonstrated is that the relation between learning and delay of information can be either positive, negative or nonexistent depending on the nature of the events intervening during the delay period and the type of information presented at the time of study. These findings are not too surprising for each relationship has been demonstrated in one experiment or another. What is important is to be able to replicate the range of effects in the same experimental situation, and thereby specify some of the relevent variables.

Other investigators (Peterson and Peterson, 1959) have demonstrated that the likelihood of recalling a briefly presented consonant trigram decreases exponentially with time if S is required to count backwards by threes during the intervening period. The counting procedure prevents rehearsal, and without rehearsal it appears that the stimulus trace decays with a half life of approximately 10 secs. In view of this result, it can be argued that in the present experiment the counting-backwards procedure increases the likelihood that S will not be able to maintain the stimulus in short-term memory during the delay interval. If this is the case, then learning will be impaired in the O-C condition to the extent that stimulus information is not available during the study period to be associated with the correct response. The loss of stimulus information during the delay interval is not crucial, however, if that information is reactivated at the time of study as was done in the SO-C condition.

The question remains as to why performance should increase for the $\overline{C}$ condition. In this condition S experiences no difficulty in maintaining the stimulus information in short-term memory during the delay interval, and consequently the O and SO manipulations should have little effect. However, it can be argued that during the delay period S initiates an analysis of the stimulus abstracting out critical features that may facilitate associating the stimulus with the correct response when it is subsequently presented at the time of study. This effect should increase with t, as was observed for both the SO-$\overline{C}$ and O-$\overline{C}$ conditions. Of course, the size of the effect would be expected to be greatest for stimuli that are not easily codable (as was the case in this experiment) and to be minimal for familiar and highly meaningful stimuli. There is yet another reason for expecting performance to increase with t. A stimulus-response pair is seen several times during the experiment and it may be that after its initial trial, the presentation of the stimulus and the retrieval of relevant response information causes that information to be increased in memory independent of the subsequent reinforcing event. The amount of increase could be expected to depend on _t_. A similar type of effect has been observed in an experiment where the strength of a response was shown to increase over a series of trials, with all reinforcing events omitted after the initial trial (Atkinson and Calfee, 1965).

A quantitative account of the results obtained here follows from theories proposed by Atkinson and Shiffrin (1968) and Estes (1967). Using the former theory it can be shown that

$$p_n = 1 - (1-g)(1-\theta)^{n-1}$$

where g is the guessing rate and is 1/8 in this study and θ is a growth parameter dependent on the particular experimental condition. For the O-C condition, $\theta = \rho^t\gamma$ where ρ^t is the probability of retaining stimulus information in short-term memory for time _t_, and γ specifies the amount of conditioning that will occur during the study period if both the stimulus and response information are in short-term memory. For the SO-C condition, retention over the delay interval is not important since the stimulus is reproduced in short-term memory at the time of study. Hence, the amount of learning will not depend on the delay interval, i.e., $\theta = \gamma$ for all values of _t_. Finally, for both $\overline{C}$ conditions there is no loss of stimulus information over the delay period, but it is assumed that the effective conditioning parameter increases as _S_ has more and more time to process the stimulus array; for this condition $\theta = \gamma + \delta(1-\xi^t)$ where δ represents the maximum increment in the conditioning parameter and ξ determines the rate of approach to the maximum. These equations generate the theoretical functions displayed in Fig. 1 for $\rho = .84$, $\gamma = .21$, $\delta = .25$, and $\xi = .97$.

The major conclusion to be drawn from this study is that the effects of reinforcement delay in human learning are fairly complex and depend on both the form of the reinforcing event and the processes occurring during the delay period. What is particularly interesting is that we not only can affect the degree of relation between learning and reinforcement delay, but can actually change the direction of the relationship by appropriate experimental procedures.

References

Atkinson, R. C., and Calfee, R. C. Mathematical learning theory. In B. B. Wolman (Ed.) Scientific psychology. New York: Basic Books, Inc., 1965. Pp. 254-275.

Atkinson, R. C., and Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence and J. T. Spence (Eds.) The psychology of learning and motivation: Advances in research and theory, Vol. 2. New York: Academic Press, 1968. Pp. 89-195.

Bilodeau, E. A., and Ryan, F. J. A test for interaction of delay of knowledge of results and two types of interpolated activity. J. exp. Psychol., 1960, 59, 414-419.

Bilodeau, I. McD. Information feedback. In E. A. Bilodeau (Ed.) Acquisition of skill. New York: Academic Press, 1966. Pp. 255-296.

Bourne, L. E. Information feedback: Comments on Professor I. McD. Bilodeau's paper. In E. A. Bilodeau (Ed.) Acquisition of skill. New York: Academic Press, 1966. Pp. 297-313.

Buchwald, A. M. Effects of immediate vs. delayed outcomes in associative learning. J. verb. Learn. verb. Behav., 1967, 6, 317-320.

Estes, W. K. Reinforcement in human learning. Technical Report No. 125, Institute for Mathematical Studies in the Social Sciences, Stanford University, Stanford, California, 1967.

Greenspoon, J., and Foreman, S. Effect of delay of knowledge of results on learning a motor task. J. exp. Psychol., 1956, 51, 226-228.

Hockman, C. H., and Lipsitt, L. P. Delay-of-reward gradients in discrimination learning with children for two levels of difficulty. J. Comp. Physiol. Psychol., 1961, 54, 24-27.

Kintsch, W., and McCoy, D. F. Delay of information feedback in paired-associate learning. *J. exp. Psychol.*, 1964, *68*, 372-375.

Peterson, L. R., and Peterson, M. Short-term retention of individual verbal items. *J. exp. Psychol.*, 1959, *58*, 193-198.

Saltzman, I. J. Delay of reward and human verbal learning. *J. exp. Psychol.*, 1951, *41*, 437-439.