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EFFECT OF INCENTIVE ON STORAGE AND RETRIEVAL PROCESSES [1]

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A continuous paired-associate task was used to examine the effect of monetary incentive on response probability when incentive was presented at the time a pair was studied, at the time it was tested, at both times, or at neither time. All paired-associate items were assigned either a high or a low value. The *S* was either cued or not cued with this value at the time he studied the item and again when he was tested. After each test trial, feedback was presented that indicated whether or not the response had been correct and what the value of the item was. The results indicated that presenting the value of an item at the time the item was studied greatly affected the probability of a correct response at test; a study cue of high value led to better performance than a study cue of low value. A similar although smaller effect took place when the value of the item was presented at the time the item was tested; *S*s responded more accurately when told that the item on which they were being tested was a high-value as opposed to a low-value item. These data were considered in terms of the memory model of Atkinson and Shiffrin which postulates differential control processes at the time of initial storage and subsequent retrieval.

The task of *S* in a typical verbal learning experiment may be viewed as the storage of information at the time an item is studied, and retrieval of the information at the time the item is tested. This distinction between storage and retrieval has become important in recent theoretical work that considers the structure and organization of human memory in terms of information-processing notions. One such theory has been proposed (Atkinson & Shiffrin, 1968; Shiffrin & Atkinson, 1969) and successfully applied to many aspects of human learning, including the concepts of reinforcement and reward (Atkinson & Wickens, 1970). This theory makes a distinction between a short-term (or temporary) store and a long-term (or permanent) store. The *S*'s task is viewed as the transfer of information from an initial sensory register through short-term store, to permanent memory, and later the retrieval of this information and the production of a response. Some aspects of the memory system are inflexible and cannot be modified by *S*; these include the various memory stores and their interconnections. On the other hand, the way in which the system is used and the strategies, or control processes, that determine what information is retained, what is transferred, and what is lost will vary with the task and *S*'s motivation. In particular, the reward associated with an item influences *S*'s performance by affecting the control processes used by *S* to store and to retrieve information about that item.

The theory makes relatively straightforward predictions about the effects of reward on the storage of information in a paired-associate task. If a high reward is assigned to a pair at the time it is studied, *S* will devote a large proportion of his limited processing capability to that pair. For example, if *S* is studying pairs by rehearsing several of them at once, high-value items can be entered into the rehearsal set with high probability and maintained there for a large number of trials, while low-reward items may frequently be ignored. Note that this explanation implies that the effect of presenting reward at the time of study will be most pronounced when a single *S* must deal with

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the full range of reward values at the same time. It should, however, be minimal or absent in a between-*S*s design (Harley, 1965a, 1965b). The presence of an incentive effect using a within-*S* design is well documented, both in short-term memory tasks (Kernoff, Weiner, & Morrison, 1966; Tarpy & Glucksberg, 1966; Weiner, 1966, Exp. I–V, X–XV; Weiner & Walker, 1966; Wickens & Simpson, 1968) and in tasks that require the use of more permanent memory (Atkinson & Wickens, 1970; Harley, 1965a, 1968; Hayer & O'Kelly, 1949).

In contrast to the clear effect of reward on storage, there has been no demonstration of an effect of associating reward with an item at the time the item is tested. Studies in which incentive cues have been presented at the time of test have failed to show any effects, either with short-term tasks (Weiner, 1966, Exp. VI–VIII; Wickens & Simpson, 1968) or long-term tasks (Wasserman, Weiner, & Houston, 1968; Weiner, 1966, Exp. IX). Under the appropriate conditions however, the aforementioned theory predicts that it is possible to influence *S*'s choice of retrieval control process through the use of reward, and thereby to produce an incentive effect. The most obvious way in which this effect could be mediated is through the depth of *S*'s search of memory, which this effect could be mediated is likely to locate the correct response, if the item is given a high value at the time of test. This effect should manifest itself primarily when long-term memory must be searched, since the retrieval of information from short-term storage appears to be immediate and complete (Atkinson & Shiffrin, 1968). In view of this analysis, it is not surprising that the experiments previously cited have failed to find retrieval effects, since their designs have either concentrated on short-term retention or have employed a between-*S*s design.

The present experiment employed a continuous paired-associate task in which a fixed set of stimuli was paired with a changing set of responses, *S* being asked to recall the response most recently associated with a particular stimulus. This choice of paradigm was dictated by several considerations. As previously indicated, the effects of reward were expected to differ in short- and long-term memory. The continuous paradigm used here is one in which the importance of the distinction between short- and long-term memory has been established (Atkinson & Shiffrin, 1968). Thus there was no need to provide an independent demonstration of this distinction in the present experiment, and conclusions about processing in the two types of memory store can be drawn more directly. The use of a paradigm in which items received little study and were subjected to a large amount of interference—effectively an A-B, A-Br paradigm—was also important. It was expected that the effects of incentive would be mediated by changes in storage and retrieval strategy, some of which could be rather subtle in nature. These changes in control processes should have, proportionally, a much larger effect on material having a weak representation in memory. The paradigm used here provides just such material.

The actual incentive was provided by assigning to each new stimulus–response pair one of three reward values. This value was presented to *S* about half the time when the item was studied, and, independently, about half the time when it was tested. This produced a within-*S*s manipulation of incentive and made it possible to demonstrate its effects separately on both the storage and the retrieval of information.

Method

Subjects.—Eight male and eight female high school juniors and seniors, recruited from the Stanford area, served in the experiment. All participated in seven experimental sessions and received a minimum of $1.75 per session. None had any previous experience in verbal learning or memory experiments.

Apparatus.—The experiment was controlled by a program running on a modified PDP-1d computer. The program operated on a time-sharing basis to drive eight KSR-33 teletypes that were situated in a single, windowless, soundproof room. Each *S* sat at a teletype equipped with a standard keyboard and a continuous roll of paper, masked in such a way that a horizontal strip about 2 cm. wide was all that could be seen at a given time.

Procedure.—Each *S* served in one session per day, which took approximately 60 min. A within-

*S*s design was used; experimental conditions within each session were selected randomly, and this selection process was identical for every *S*-session. The stimuli consisted of highly pronounceable CVC trigrams. At the start of each *S*-session, 9 trigrams were chosen randomly from a set of 300. These 9 stimuli were then used throughout that particular *S*-session. The responses were the 26 letters of the alphabet.

The task involved a modification of the typical paired-associate procedure which made it possible to study the memory processes under conditions that were quite uniform and stable throughout the experiment; the task was continuous and each *S* was run for seven daily sessions. In essence, the task involved having *S* keep track of the randomly changing response members of the nine different stimuli. Each trial of the experiment was divided into a test period and a study period. During the test phase, a stimulus was randomly selected from the set of nine stimuli, and *S* tried to recall the response *last* associated with that stimulus. Following the test, the study phase of the trial occurred. Here, the stimulus used in the test phase of the trial was re-paired with a new response for study. Thus every trial was composed of a test and study phase on the same stimulus. Following each trial, a new stimulus was chosen randomly from the set of stimuli and the next trial began. The instructions to *S* required that on a test he was to give the response that was paired with the stimulus the last time it was presented for study. An item (stimulus–response pair) was always assigned one of three values: 11, 22, or 99. This value was either given or not given at the time the item was studied. Again, at the time the item was tested, the value was either given or not given. Thus there were two types of study cue (SC), two types of test cue (TC), and three values, which produced $2 \times 2 \times 3 = 12$ experimental conditions. Each time a new item was formed, it was placed into one of these conditions according to the probability distribution shown in Table 1.

A session started when *S* struck a code key on his teletype. Nine initial study trials served to pair the nine stimuli with randomly chosen initial responses and then the test–study trials which constituted the rest of the session began. A test–study trial consisted of the following sequence of events: (*a*) An item to be tested was chosen randomly from the set of nine and typed out. If the experimental condition to which the item was assigned required that no TC be given, then "( )" was typed preceding the stimulus. If a TC was to be given, then the value of the item preceded the stimulus; e.g., "(99)" cued *S* that the item was worth 99 points. (*b*) The *S* responded by striking one of the alphabetic keys on the teletype. The task was self-paced; unlimited time was permitted for responding. Immediately following the response, feedback was typed out telling how many points had been won or lost on the trial. For example, "+11" would signify that *S* had been correct on an 11-point item and thus had gained 11 points, while "−22" would inform *S* that he had been incorrect on a 22-point item and had lost 22 points for that trial. Note that on items that had received neither an SC nor a TC, the feedback was the only indication to *S* of the item's value. (*c*) A line feed and a carriage return caused the typed line to disappear behind the mask. (*d*) The stimulus just tested was then re-paired with another response chosen randomly from the 25 letters that had not just been paired with the stimulus. The new item was then assigned to an experimental condition chosen randomly according to the probabilities shown in Table 1. The word "STUDY" was then typed out, followed by the new pairing and preceded by "( )" if no SC was to be given. Otherwise, "STUDY" was preceded by the value of the new item. Thus a study trial might look like "(22) STUDY DAX-P." The *S* was given 2 sec. to study this new information, at which time another line feed and carriage return caused all typed material to disappear. This ended the trial, and a new trial would begin immediately with the random choice of a stimulus to be tested.

TABLE 1

PROBABILITY OF AN ITEM BEING ASSIGNED TO EACH CONDITION

Cues given	Value of item (points)		
	11	22	99
SC and TC	.107	.107	.053
SC	.107	.107	.053
TC	.107	.107	.053
None	.080	.080	.040

Note.—SC = study cue, TC = test cue.

On each trial, *S* either gained or lost 11, 22, or 99 points. After 300 trials, the algebraic sum of *S*'s scores was computed and printed out. At the start of each session, *S*s were instructed to try to maximize this sum and were paid according to its magnitude. The payment received for a session was $3.50 × (*T*/9,200), where *T* was *S*'s total for the session and 9,200 was approximately the highest possible score for a session. (The actual highest possible score varied somewhat due to the probabilistic nature of assigning values.) The *S*s always received a minimum of $1.75 for a session.

RESULTS

It has been found in previous studies using a continuous task paradigm that a slight warm-up takes place at the beginning of each session (e.g., Atkinson, Brelsford, & Shiffrin, 1967). For this reason, the first 25 trials of each *S*-session were excluded from data analysis. In addition, the first two sessions were regarded as practice during which S was adapting to the task and the equipment, and the data from these sessions were also excluded.

Data from conditions in which the 11-point items were used did not differ significantly from data for the corresponding 22-point conditions. Because of this, no distinction has been made between these items in any of the following analyses; both types are referred to as low-value items. Correspondingly, 99-point items are referred to as high-value items. Items are therefore classified by three independent binary variables: the value of the item was either high or low, an SC was either given or not given, and a TC was either given or not given. Although this design gives rise to $2 \times 2 \times 2 = 8$ conditions, it should be noted that when neither an SC nor a TC was given, the value of the item should not affect S's performance since S was unaware of the value until after he had responded and feedback had been given. Generally then, only seven conditions are considered.

Table 2 presents the probability of a correct response and the latency of correct and error responses as a function of condition. The conditions are labeled in terms of value and the presence or absence of an SC and a TC. For example, HH refers to high-value items for which both an SC and a TC were presented, while BL (blank–low) refers to low-value items for which a TC but no SC was presented.

It is evident from the first row of Table 2 that the type of reinforcement given at the time of study is an important determinant of response probability: Ss did better in the HH and HB conditions than in the LL and LB conditions, and those conditions in which no SC was given (BH, BB, and BL) have intermediate response probabilities. Reinforcement given at the time of test had a similar although smaller effect. Items which had been given a high SC (HH and HB conditions) showed a drop in probability correct when no TC had been given, although no such TC effect occurred when the item had been given a low SC (the LL and LB conditions were the same). When no information about the value of an item was given at the time of study, the response probability for that item increased if a high TC, as opposed to a low TC, was given (BH was superior to BL). Lack of TC (BB condition) led to intermediate performance.

The last two rows of Table 2 present the response latency, conditionalized on a correct response (L_c) or an error (L_e). In all conditions the latency of an error was longer than that of a correct response. Both L_c and L_e show pronounced effects of the high-reward conditions. When an error was made, latency was about 6.0 sec. except when the item was designated as being of high value at the time of test; for the HH and BH conditions L_e was about 7.6 sec. and 8.2 sec., respectively. When a correct response was made, latency was about 3.4 sec. in all conditions except HB (2.8 sec.) and BH (4.2 sec.).

In order to evaluate statistically the effects of incentive, SC, and TC on response probability and latency, three analyses of variance (ANOVAs) were performed, using response probability, L_c, and L_e as the dependent measures. For each analysis and each condition, a single value of the dependent variable was computed for each of the 16 Ss. The BB condition was divided into high- and low-value items to obtain a com-

TABLE 2

Probability of a Correct Response and Latency of Correct and Error Responses as a Function of Incentive Condition

Item	Incentive condition						
	HH	HB	BH	BB	BL	LB	LL
Probability correct	.68	.62	.52	.49	.48	.47	.47
Latency of correct response (sec.)	3.4	2.8	4.2	3.5	3.4	3.3	3.5
Latency of error (sec.)	7.6	6.0	8.2	6.0	5.8	5.9	6.0

Note.—H = high, B = blank, L = low (see text for further explanation).

pletely factorial, Value × SC × TC × *S*s, design. The *F* values for the three ANOVAs are shown in Table 3. It can be seen that the response probability shows highly significant effects of value and of SC. In addition, there is a large SC × Value interaction and a smaller but significant TC × Value interaction. These interactions are important, since they provide evidence for a differential effect of incentive, both at time of study and at time of retrieval.

The ANOVA for L_e shows large effects of value, of TC, and of a TC × Value interaction. As indicated in Table 1, the latency was considerably longer when *S* was cued with a high value at the time of test than in any other condition, resulting in both the main effects and the TC × Value interaction. The fact that no terms involving SC are significant suggests that when *S* did not know the response to a stimulus, he was also unaware of the value that the item had been given when it was studied.

TABLE 3

F RATIOS FOR ANALYSIS OF VARIANCE

Source	Response probability	Response latency	
		Correct	Error
Value (A)	42.62**	1.90	24.93**
SC (B)	17.91**	18.17**	1.45
TC (C)	4.46	16.84**	28.18**
A × B	38.95**	10.60**	.54
A × C	5.13*	16.30**	44.77**
B × C	.24	.34	.24
A × B × C	.02	4.75*	2.52

Note.—SC = study cue; TC = test cue.
* $p < .05$.
** $p < .01$.

The analysis of L_c shows highly significant effects of both SC and TC and of the SC × Value and TC × Value interactions. These reflect the fact that correct responses in the HB condition were given more rapidly than average, while responses in the BH condition were slower. There is also a marginally significant SC × TC × Value

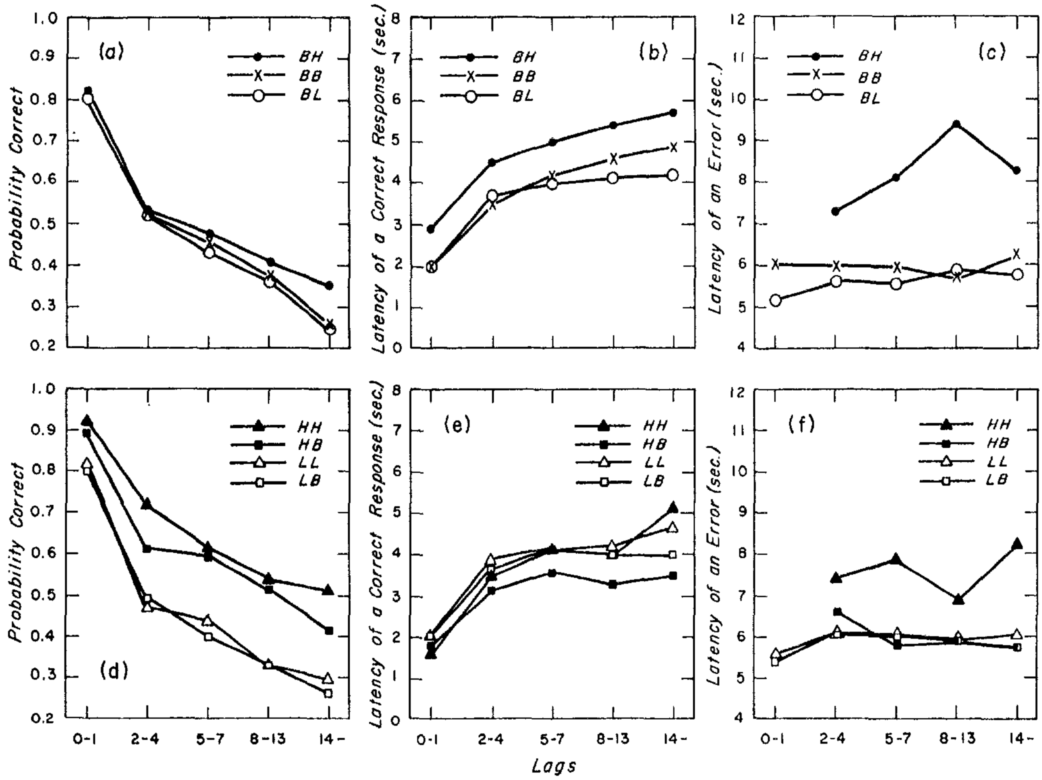

FIG. 1. Probability of a correct response and latency of correct and error responses as functions of lag and condition.

interaction, probably resulting from a combination of these two causes.

To obtain an indication of the relative importance of short- and long-term memory processes in these incentive effects, the data were subdivided according to *lag,* which is defined as the number of test–study trials that intervened between the time a particular item was studied and the time it was tested. Note that lag, as used here, is not a measure of temporal delay, but represents largely the amount of interfering material that was presented between study and test. When items are tested at short lags, short-term processes, such as rehearsal, will be most important, while at longer lags with more intervening material, the information will probably have been forced out of any short-term processing schemes and long-term processes will be used. Figure 1 shows response probability, L_c, and L_e, as functions of lag for each of the seven experimental conditions. The lags have been lumped into groups of 0–1, 2–4, 5–7, 8–13, and greater than 13 so that each group contains about a fifth of the observations. Each set of seven conditions has been divided, for purposes of clarity, into those in which an SC was not given (Fig. 1a, 1b, 1c) and those in which an SC was given (Fig. 1d, 1e, 1f). In the HH, HB, and BH conditions, there were fewer than 50 errors at Lag 0–1. In view of this paucity of data, the 0–1 points have been omitted from the L_e curves for these conditions.

Figure 1a shows the probability of a correct response as a function of lag for Cond. BH, BB, and BL. Because no SC was given, differences in these three conditions reflect differences in retrieval processes alone. The superiority of the BH condition over the BB and BL conditions increases with lag, suggesting that differences in retrieval processes for different incentives may be due to effects taking place in long-term memory. When a correct response is made, latency increases as a function of lag for all conditions (Fig. 1b, 1c). This finding is fairly stable, occurring for almost every *S* in every condition. The increase in L_c implies that the material *S* must search to retrieve the correct response contains some temporal information; when the lag is large, a longer and more elaborate search must be made than when the lag is small. In contrast, when an error is made, latency is almost independent of lag. Apparently, when the correct response cannot be retrieved, *S* also has no information about the age of the item. This contention is supported in a study by Brelsford, Freund, and Rundus (1967) which showed that, in a task similar to this one, *S* could give no information about the lag of an item when he could not recall the correct response. It is also quite consistent with the observation that L_e is independent of SC.

Discussion

This experiment has clearly demonstrated that performance can be improved by associating a large reward with correct responses on paired-associate items, either at the time the pair is studied or at the time it is tested. The analysis of variance (see Table 3) indicates that study or test cueing of the item's value affects the probability of a correct response, the latency of correct responses, and the latency of errors. In addition to demonstrating such incentive effects, the directions and magnitudes of these differences provide support for the model of reinforcement considered by Atkinson and Wickens (1970).

The control processes that are available to *S* at the time of study are more powerful than are the control processes available at the time of retrieval. An extreme study strategy, e.g., would be to maintain all high-point items by rehearsal until they are tested, while at the same time ignoring low-point items. This strategy would lead to perfect performance on items which had received a high SC and close to chance performance on items which had not. On the other hand, the primary way in which *S* can improve performance at the time of test is by spending more time searching his memory for the response. Although *S* was allowed unrestricted response time, the general form of the task discouraged any extremely wide variation: *S* was required to work at the task until 300 trials had been completed and, in addition, undue attention devoted to a search of memory probably interfered with any items that *S* was currently rehearsing in his short-term memory. Thus, the theory predicts that differential incentive should affect performance most when it is given at the time of study. This prediction is supported by the data presented in Table 2.

The effects of an SC are reflected not only in the response probability, but also in the latency. When no TC was given, correct responses were more rapid when the item had been studied with a high value than when it had been studied with a low or missing value (in Table 2, cf. Cond. HB with BB and LB). Apparently, the representation of the item deposited in memory at the time of study was best when the item was known to be of high value, and this representation was more easily retrieved when the item was tested.

When a TC was given, its effects were quite different from the study effects previously discussed. When *no* SC was given (see Fig. 1a) there was no effect of reward on response probability at lags less than about 4. At lags of 5–7, a difference appears between the BH and the other two conditions, and this difference increases with the lag. No such difference appears, however, when the item was labeled high when studied, perhaps because *S* was often able to remember the item's value even when no TC was given. The superior performance on high items at long lags is consistent with the retrieval processes previously discussed. Items tested at a short lag have a relatively high probability of being in short-term store when they can be retrieved perfectly regardless of the reward assigned to them. At longer lags, however, there is little likelihood of short-term retention and the items must be retrieved from long-term store. When this is the case, *S* can make a more extensive search for high-point items than for low ones.

The experiment that has been presented in this paper has demonstrated that cueing *S* to an incentive can lead to changes in his performance, both when the cueing takes place at the time when the item is studied and when it takes place at the time when the item is tested. The existence of reinforcement effects when the cue is placed in the former position has been fairly well documented by other workers, but this is, to the present authors' knowledge, the first report of a clear effect of incentive cueing on the retrieval of information. Beyond simply demonstrating these effects, however, the data give support to a general theoretical formulation of human memory and reinforcement. The effect of the rewards is reflected in the differential use of strategies or control processes used by *S* to store and to retrieve information. When a high-value item is under consideration, a greater amount of *S*'s limited information-processing capacity is devoted to it than when low-valued items are considered. The result of this shift in *S*'s attention is to make the highly rewarded items more completely stored and more likely to be retrieved.

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