

Document-ID: 149543

Patron: smith

Note:

NOTICE:

Pages: 11 Printed: 02-11-03 11:20:53

Sender: Ariel/Windows

Texas A&M University Campus Libraries

Courier



ILLiad TN: 149543

Journal Title: Journal of Verbal Learning & Verbal Behavior

Volume: 20

Issue:

Month/Year: 1981

Pages: 110-119

Article Author: Glenberg, A.M., & Smith, S.M.

Article Title: Spacing repetitions and solving problems are not the same

Call #: BF455.A1 J6

Location: evans

Not Wanted Date: 08/07/2003

Status: Faculty

Phone: (979) 845-2509

E-mail: stevesmith@neo.tamu.edu

Name: Steven Smith

Pickup at Evans

Address:

Psychology Department

MS# 4235

College Station, TX 77843

Spacing Repetitions and Solving Problems Are Not the Same

ARTHUR M. GLENBERG

University of Wisconsin

AND

STEVEN M. SMITH

Texas A & M University

Recall of items given spaced repetitions is generally superior to recall of items given immediate repetitions. L. L. Jacoby (*Journal of Verbal Learning and Verbal Behavior*, 1978, 17, 649-667) has proposed that this spacing effect can be accounted for by the distinction between problem solving and remembering. On an immediate repetition any encoding processes and problem-solving operations used on the first presentation can be remembered. On a spaced repetition the operations must be reemployed, thus enhancing the strength of the mnemonic representation of the event. This hypothesis was tested by factorially combining spacing of repetitions, necessity for problem solving at the second presentation, and type of memory test. Requiring problem solving on second presentations did attenuate the spacing effect on a recognition test, but contrary to the hypothesis, no attenuation was found on a recall test.

Jacoby (1978) proposed that repetitions improve memory to the extent that encoding and processing of the repetitions require the use of constructive cognitive operations (i.e., problem solving). When the repetition is such that previous encodings and problem solutions can be simply remembered, the repetition is relatively ineffective for enhancing memory. He also suggested that this distinction underlies the spacing effect, that memory for repeated events is, in general, positively correlated with the spacing of the repetitions of the events (e.g., Hintzman, 1974). According to Jacoby's construction hypothesis, the presentation of a new event requires the construction of a representation of the event. If the event is repeated shortly after the first presentation, then the previously constructed representation can be easily remembered,

eliminating the need for a new application of constructive processes. When the second presentation is delayed, however, the previously constructed encoding may not be easily remembered. In this case the representation of the event must be constructed again. These operations enhance the memorability of the event, and hence the spacing effect is generated. Jacoby does present impressive evidence testifying to the mnemonic effectiveness of problem solving as opposed to simple remembering of previous solutions. Nonetheless, the purpose of this paper is to demonstrate that the spacing effect cannot be explained solely by the distinction between solving and remembering.

In Jacoby's first test of the construction hypothesis, subjects were presented with a list of associatively related pairs of words. When a pair was repeated, the second presentation immediately followed the first, or it was spaced after a lag of 20 items. In the RR condition the subjects simply read the pair aloud at both presentations. In the RC condition subjects read the pair aloud on its

Thanks are due to Larry Jacoby for his helpful discussions of the hypotheses investigated in this report. This research was funded by HEW Grant MH26643. Requests for reprints should be sent to Arthur Glenberg, Department of Psychology, University of Wisconsin, Madison, Wisc. 53706.

first presentation. On the second presentation two or more letters were deleted from the word on the right. At this second presentation the subject was to compare the two words (left-hand word to remember) the right-hand word was read aloud. After presentation of a list of pairs, memory for the pairs was tested by cued recall, the left-hand word being the cue for the right-hand word.

Spacing repetitions improve performance relative to immediate repetitions and importantly, there was a significant interaction between spacing and repetition condition. With immediate repetition performance in the RR and RC conditions was similar. When the repetitions were spaced, recall in the RC condition was much superior to recall in the RR condition. The construction hypothesis explains this at the immediate repetition in the RR condition subjects can simply remember the mutilated word from its recent presentation. The processing is not different from the reading required for immediate repetition in the RR condition hence recall performance is similar in both conditions. At the spaced repetition in the RC condition it is, supposedly, necessary to remember the mutilated word from the first presentation, hence subjects are required to construct the word. Thus, the problem-solving activity is required for the spaced repetition in the RC condition where subjects can simply read the word. This difference in processing is what explains the difference in recall and the spacing effect in the RC condition.

These results provide evidence that problem-solving activities result in more memorable traces than simple repetition. They do not, however, provide support for the hypothesis that spacing effects are due solely to an increase in construction of the second presentation. The spacing of the repetitions increases performance in another way, the results show that subjects engage in an extraordinary problem-solving procedure (i.e., problem solving) at the repetition, performance is improved.

Not the Same

first presentation. On the second presentation two or more letters were deleted from the word on the right. At this second presentation the subject was to construct (or remember) the right-hand word, and read both words aloud. After presentation of a list of pairs, memory for the pairs was tested by cued recall, the left-hand word being the cue for the right-hand word.

Spacing repetitions improved performance relative to immediate repetitions, and importantly, there was a strong interaction between spacing and processing condition. With immediate repetitions, performance in the RR and RC conditions was similar. When the repetitions were spaced, recall in the RC condition was much superior to recall in the RR condition. The construction hypothesis explains that at the immediate repetition in the RC condition subjects can simply remember the mutilated word from its recent first presentation. The processing is not much different from the reading required at the immediate repetition in the RR condition, and hence recall performance is similar in both conditions. At the spaced repetition in the RC condition it is, supposedly, difficult to remember the mutilated word from its distant first presentation, hence subjects are required to construct the word. Thus, more problem-solving activity is required than at the spaced repetition in the RR condition, where subjects can simply read the words. This difference in processing is used to explain the difference in recall and the large spacing effect in the RC condition.

These results provide evidence that problem-solving activities result in more memorable traces than simply reading. They do not, however, provide support for supposing that spacing effects are due solely to an increase in constructive encoding at the second presentation as the spacing of the repetitions increase. Stated another way, the results show that when subjects engage in an extraordinarily effective study procedure (i.e., problem solving) at the repetition, performance is much bet-

ter than when ordinary study procedures (i.e., reading) are used at the repetition. The results do not demonstrate that, under ordinary list-learning conditions, subjects engage in more constructive activity at a delayed repetition compared to an immediate repetition, nor do the results demonstrate that these putative activities underlie the performance difference typical of the lag effect.

Jacoby's second experiment is more to the point. He crossed degree of spacing with difficulty of the problem solving (number of letters deleted from the right-hand word) in the RC condition. With short spacings, where the previously read solutions can be easily recalled at the repetition, difficulty should have no effect on recall. At longer spacings, where the solution is less likely to be recalled (especially in the hard problem-solving condition where fewer letters are present as retrieval cues), the hard problems should require more constructive activity than the easy problems. Thus recall performance after long spacings should be better with hard problems than with easy problems, and an interaction between spacing and difficulty is predicted. In fact, the interaction was found, but apparently for the wrong reasons. As predicted, problem difficulty did not affect performance at short spacings. At the long spacings, recall after the easy problems was unexpectedly depressed relative to shorter spacings in the easy problem condition. This depression caused the interaction, not the predicted facilitation in the hard problem condition.

Two sets of previous findings also speak against the construction hypothesis. First, the effect of spacing is not always monotonic. When the retention interval is short relative to the spacing intervals, then increasing the spacing first enhances performance; further increases in the spacing, however, lead to a drop in performance. This nonmonotonicity has been found in cued recall (Peterson, Wampler, Kirkpatrick, & Saltzman, 1963), recognition mem-

call of items given
Verbal Behavior,
counted for by the
iate repetition any
presentation can be
thus enhancing the
was tested by facto-
the second presen-
d presentations did
hypothesis, no attenu-

d for a new application
cesses. When the sec-
delayed, however, the
cted encoding may not
ed. In this case the rep-
event must be con-
ese operations enhance
f the event, and hence
generated. Jacoby does
evidence testifying to
ectiveness of problem
to simple remembering
ons. Nonetheless, the
er is to demonstrate that
cannot be explained
nction between solving

test of the construction
s were presented with a
related pairs of words.
peated, the second pre-
ely followed the first, or
a lag of 20 items. In the
subjects simply read the
presentations. In the RC
read the pair aloud on its

ory procedures (Glenberg, 1976), and free recall (Glenberg, 1977, 1979). The construction hypothesis has no obvious mechanism to account for these effects, and hence cannot explain all spacing effects. On the other hand, Hintzman (1974) has proposed that the initial rise in the spacing function is produced by one set of mechanisms, whereas the latter portions of the curve (which may increase or decrease) are produced by different mechanisms. Even allowing this distinction, however, the construction hypothesis runs afoul on a second set of findings.

The second set of findings comes from tests of one of the construction hypothesis's predictions. Suppose that different orienting questions are asked about a stimulus at its separate presentations. If the orienting questions require the analysis of different aspects of the stimulus so that previous analyses cannot be remembered and used at the second presentation, then at least some constructive processing will be required at both presentations regardless of the repetition lag. In this case, the spacing effect should be attenuated (relative to the conditions where the same orienting questions are asked at both presentations), if not eliminated.

This prediction has been tested a number of times. Shaughnessy (1976, Experiment 3) used an incidental learning procedure to present words one, two, or three times. At each presentation the words were rated on a frequency, imagery, or pleasantness scale. Some words were rated on the same scale at each presentation, whereas other words were rated on a different scale at each of their presentations. This latter condition requires construction of a solution (rating on a new scale) at each presentation, regardless of the repetition lag. Contrary to the prediction of the construction hypothesis, the use of the same versus a different rating scale did not interact with the spacing of the repetitions.

Maskarinec and Thompson (1976, Experiment 2) also used an incidental procedure to present words three times. Either

the same type of orienting question (demanding analysis of syntactic, rhyme, or meaning features) was required at each presentation, or a different type of orienting question was asked at each presentation. Again, the predicted interaction between spacing and same or different orienting activity failed to materialize. Bird, Nicholson, and Ringer (1978) used an intentional learning procedure with the addition of orienting activities. Repeated words were judged as high or low on the same scale (active-passive or pleasantness in Experiment 1, active-passive or number of letters in Experiment 2) at each presentation, or different scales were used at the two presentations. Neither experiment produced an interaction between spacing and same or different orienting activities.

Jacoby (Note 1) has suggested two ways in which the results of these experiments can be reconciled with the construction hypothesis. First, in all of the experiments the repetitions were in the same modality as the initial presentations. On an immediate repetition, encoding the item within the same modality may be trivial since it engages some of the same processes as the just preceding presentation, irrespective of additional operations required by the orienting tasks. A spaced repetition may require a complete reencoding, however. This reencoding, or reconstruction, enhances later recall and generates the spacing effect.

Hintzman, Block, and Summers (1973) reported a study where spacing, modality of the first presentation, and modality of the second presentation were factorially combined. Contrary to the construction hypothesis, they found that same or different modality did not strongly interact with the spacing effect. This study may be criticized by proponents of the construction hypothesis, however, because the orienting activities at the two presentations were not controlled.

Second, Jacoby (Note 1) suggested that in previous experiments the critical conditions, although requiring nominally different orienting activities, may have induced the

use of the same cognitive process. For example, presentation of the repeated item is imageable, and asking a question if the item is larger than instances of nominally different activities. They may, however, be substantially similar cognitive processes. For example, constructing a visual image in this case, constructive activity is avoided at the repetition by the outcome of the preceding repetition is rendered ineffective. Whereas this effect is nullified. Whereas this well taken, it is unlikely that previously reviewed experiments on orienting tasks that overlapped content required to save the hypothesis.

In summary, the construction hypothesis does not fare well under scrutiny. Nonetheless, because experiments were specifically designed to test the hypothesis, all of them can be criticized on one point: the same modality of presentation for repeated presentations in the orienting task condition) or the orienting activities were not controlled when the repetitions occurred in different modalities). These problems are the two experiments in this study.

EXPERIMENT 1

In this experiment, an incidental procedure was used. Words were presented either immediately or after a delay in the remember (R) condition. In the orienting activity condition, the orienting activity was required at each presentation. According to the construction hypothesis, when the repetition lag is zero, subjects should be able to "remember" the previous encoding response. When the repetition lag is one, subjects should experience a delay in remembering the previous response, and they should experience an increase in response time or error rate in some additional

orienting question (de- of syntactic, rhyme, or was required at each pre- ferent type of orienting d at each presentation. ed interaction between or different orienting ac- rialize. Bird, Nicholson,) used an intentional e with the addition of Repeated words were low on the same scale pleasantness in Experi- sive or number of letters at each presentation, or re used at the two pre- r experiment produced een spacing and same or activities.

has suggested two ways ts of these experiments with the construction hy- ll of the experiments the the same modality as the s. On an immediate rep- e item within the same trivial since it engages rocesses as the just pre- n, irrespective of addi- equired by the orienting repetition may require a g, however. This reen- struction, enhances later s the spacing effect.

, and Summers (1973) ere spacing, modality of on, and modality of the n were factorially com- the construction hypothe- at same or different mo- ngly interact with the study may be criticized e construction hypothe- ause the orienting ac- presentations were not

(Note 1) suggested that nents the critical condi- rring nominally different may have induced the

use of the same cognitive processes on each presentation of the repeated items. For ex- ample, asking on a first presentation if the item is imageable, and asking on the repeti- tion if the item is larger than a horse, are instances of nominally different orienting activities. They may, however, induce sub- stantially similar cognitive processes, for example, constructing a visual image. In this case, constructive activity can be avoided at the repetition by remembering the outcome of the preceding processing, the repetition is rendered ineffective, and the prediction of an attenuated spacing ef- fect is nullified. Whereas this argument is well taken, it is unlikely that all of the previously reviewed experiments used orienting tasks that overlapped to the ex- tent required to save the hypothesis.

In summary, the construction hypothesis does not fare well under experimental scrutiny. Nonetheless, because none of the experiments were specifically designed to test the hypothesis, all of the experiments can be criticized on one point (e.g., the same modality of presentation was used at repeated presentations in the different orienting task condition) or another (e.g., the orienting activities were uncontrolled when the repetitions occurred in different modalities). These problems are avoided in the two experiments in this report.

EXPERIMENT 1

In this experiment, an incidental learning procedure was used. Words were repeated either immediately or after a short delay. In the remember (R) condition the repetition was in the same modality, and the same orienting activity was required at both pre- sentations. According to the construction hypothesis, when the repetition is immedi- ate, subjects should be able to simply "re- member" the previous encoding and re- sponse. When the repetition is spaced, subjects should experience some difficulty remembering the previous encoding and response, and they should be forced to engage in some additional, constructive

processing to encode the repetition and generate a response. This extraordinary pro- cessing given the spaced repetition enhances its memory strength relative to that of the massed repetition, and thereby produces the spacing effect.

In the construct (C) condition, the repe- tion was in a modality different from that of the first presentation, and a different orienting activity was used at both presen- tations. In this condition, encoding the stimulus and generating a response requires constructive processing, regardless of the spacing interval. The memory strengths of repeated items should be equivalent, and the spacing effect should be attenuated or eliminated.

An important point is that the expected interaction between processing mode (R vs C) and spacing (immediate vs spaced) is ex- plained by the effect of various encoding and storage processes on memory strength. Retrieval processes used on the retention test are not considered. Therefore, the in- teraction should be observed on all mea- sures of memory strength; specifically it should be observed on both recall and rec- ognition tests. This prediction of the con- struction hypothesis is tested in Experi- ment 1.

This experiment also tests Component- Levels theory (Glenberg, 1979) which con- siders both study and test processes in ex- plaining the spacing effect. In addition, the data generated in the experiment can be used to perform a general test of context- matching theories of spacing effects pro- posed by Ross and Landauer (1978). These aspects of the results are pursued in the General Discussion.

Method

Subjects. The 24 subjects were students enrolled in an introductory psychology course during the summer session. They were awarded course credit for their par- ticipation.

Materials and design. A total of 115

single-syllable, three-, four-, and five-letter, common nouns was used. Each noun represented an easily imageable object. Five words were used in a practice list. Thirty-two of the words were used as distractors on the recognition test. The others were presented to the subjects on the experimental list. This list began with a 7-event primacy buffer filled with three once-presented and two repeated words. The list ended with a similarly constructed recency buffer. The middle of the list contained eight 12-event blocks. Each block consisted of two words given immediate repetitions, two words given spaced repetitions (at lags of 3–5 with a mean of 4), and four once-presented filler items. Each block had a unique assignment of repetition conditions to serial positions. Within each block half of the events were presented aurally and half visually. One of the words given an immediate repetition was in condition R, and had both of its presentations in the same modality (equally often visual or auditory). The other immediately repeated word was in condition C, and had its presentations in different modalities (equally often visual–auditory and auditory–visual). This arrangement also held for the words given spaced repetitions.

There were four different assignments of specific words to conditions. These assignments ensured that each word was used equally often in the four conditions defined by the factorial combination of spacing of repetitions and mode of processing (R or C).

At each presentation the subject judged if the object represented by the presented word was larger or smaller than a standard, or if the object was more or less pleasant than a standard (the words were selected to avoid large discrepancies from the standard on either dimension). In either case subjects responded with a "+" or "-." Additionally, each subject used two standards, although both standards were used equally often in the size and pleasantness comparisons. Within each block half of the events were judged on each of the dimensions with

both standards being used equally often. Words in condition R were compared to the same standard, on the same dimension, at each presentation. Words in condition C were compared to different standards, on different dimensions at their presentations. Two sets of standards (lamp, boot and chair, dog) were used in the experiment.

The events within an experimental session were controlled by a previously recorded stereo tape. One channel of the tape was used to advance a slide projector every 5 seconds. The first of each pair of slides visually presented the serial position of the event. This number also appeared in one quadrant of the subject's response sheet (which was used on all 110 trials). The quadrant containing the number indicated whether the word in that serial position was to be presented visually or aurally, the dimension on which to compare the word to the standard, and the appropriate standard. The second of each pair of slides either presented a single word in capital letters, or it was blank. When the second slide was blank the word was aurally presented from the second channel of the stereo tape.

The purpose of this design was to ensure that the presentations of the words repeated in condition R were very similar (in presentation modality, dimension of comparison, standard of comparison, and quadrant of the response sheet in which the response was recorded). Thus, according to the construction hypothesis the encoding of the second presentation on an immediate repetition is made trivial. On the other hand, the presentations of the words repeated in condition C are very different (in presentation modality, dimension of comparison, standard of comparison, and quadrant of the response sheet). Therefore, regardless of the repetition spacing, the second presentation requires cognitive processes different from those of the first presentation. The processing of the second presentation cannot be made trivial by the first presentation.

Procedure. Subjects were run in groups of one to six. Upon entering the laboratory

they were first asked to read sent form. They were then to experiment examined the w people judge various quali They were not told of the until after the list was presre of the presentation pro parison tasks, and respon: detailed. An eight-item pr then presented. The list wa once-presented and repeate sampled from the condition: ment. The comparison task were those used in the expe

Following the practice list instruction, the experimenter presented. There were two show presentation of the list in o slide trays. Immediately fo the response sheets were c sheets of paper were distrib subjects were asked for writte the words. Five minutes w free recall. Next, the reca collected and the recognitio tributed. This test consisted containing the 32 critical r intermixed with the 32 di subjects were instructed to c words that they believed to sented. This test was self-p

Results and Discussion

The probability of a sta error was set at .05 for all a

Recall. The proportions main conditions are presen Statistical analyses were pe number of words recalled. the spacing of the repetition a ing mode are significant, F $MS_e = 1.13$, and $F(1,16) = 7$ respectively. The two va interact, $F(1,16) = .38$, MS

These results replicate B Maskarinec and Thomps Shaughnessy (1976): The orienting activity does not a the spacing effect in free re

g used equally often. R were compared to the he same dimension, at Words in condition C different standards, on at their presentations. ards (lamp, boot and ed in the experiment.

an experimental ses- d by a previously re- One channel of the tape a slide projector every of each pair of slides e serial position of the also appeared in one ject's response sheet n all 110 trials). The the number indicated that serial position was ally or aurally, the di- o compare the word to e appropriate standard. u pair of slides either rd in capital letters, or the second slide was aurally presented from of the stereo tape.

is design was to ensure of the words repeated very similar (in pre- dimension of compari- son, and quadrant in which the response according to the con- the encoding of the on an immediate repe- On the other hand, the words repeated in con- erent (in presentation of comparison, stan- and quadrant of the re- fore, regardless of the e second presentation ocesses different from entation. The process- esentation cannot be rst presentation.

s were run in groups ntering the laboratory

they were first asked to read and sign a consent form. They were then told that the experiment examined the ways in which people judge various qualities of words. They were not told of the memory tests until after the list was presented. The nature of the presentation procedures, comparison tasks, and response mode were detailed. An eight-item practice list was then presented. The list was composed of once-presented and repeated words which sampled from the conditions in the experiment. The comparison tasks and standards were those used in the experimental list.

Following the practice list and further instruction, the experimental list was presented. There were two short breaks in the presentation of the list in order to change slide trays. Immediately following the list the response sheets were collected, blank sheets of paper were distributed, and subjects were asked for written free recall of the words. Five minutes was allowed for free recall. Next, the recall sheets were collected and the recognition test was distributed. This test consisted of a single page containing the 32 critical repeated words intermixed with the 32 distractors. The subjects were instructed to circle exactly 32 words that they believed to have been presented. This test was self-paced.

Results and Discussion

The probability of a statistical type I error was set at .05 for all analyses.

Recall. The proportions recalled in the main conditions are presented in Table 1. Statistical analyses were performed on the number of words recalled. The effects of the spacing of the repetition and the processing mode are significant, $F(1,16) = 8.85$, $MS_e = 1.13$, and $F(1,16) = 7.75$, $MS_e = .98$, respectively. The two variables do not interact, $F(1,16) = .38$, $MS_e = .71$.

These results replicate Bird et al. (1978), Maskarinec and Thompson (1976), and Shaughnessy (1976): The nature of the orienting activity does not affect the size of the spacing effect in free recall. Therefore,

TABLE 1
PROPORTIONS RECALLED ON THE FREE RECALL TEST

Processing condition	Repetition spacing		
	Immediate	Spaced	\bar{X}
R	.17	.26	.21
C	.24	.32	.28
\bar{X}	.21	.29	—

the construction hypothesis does not describe the sole mechanism responsible for spacing effects.

Recognition test. All subjects circled exactly 32 words on the recognition test. Table 2 presents the proportions of old words circled (hit rates) which are also the proportions of new words not circled (correct rejection rates). The proportions of new words circled (false alarm rates), as well as the proportions of old words not circled (miss rates), are given by one minus the corresponding hit rates.

Statistical analyses confirm significant main effects for the spacing of repetitions, $F(1,16) = 4.74$, $MS_e = .64$, and processing mode, $F(1,16) = 8.67$, $MS_e = 1.01$. The interaction of the two is almost significant, $F(1,16) = 3.69$, $MS_e = .64$, $p = .07$. The difference between the immediate and spaced repetitions in condition R (.08) is significant, $t(23) = 3.19$, $SE = .23$, whereas the corresponding (.01) difference in condition C is clearly not significant. This interaction is replicated in Experiment 2.

Although these results were predicted by the construction hypothesis, it has no way to reconcile them with the free recall data. If the processing mode manipulation was

TABLE 2
RECOGNITION HIT RATES (EXPERIMENT 1)

Processing condition	Repetition spacing		
	Immediate	Spaced	\bar{X}
R	.82	.90	.86
C	.93	.94	.93
\bar{X}	.87	.92	—

effective, then according to the construction hypothesis the interaction of spacing and processing mode should have been found in both recall and recognition. If the manipulation failed, then there should have been no interaction on either test. Again, the conclusion is that the construction hypothesis does not provide the sole mechanism behind spacing effects. Note, the results do not deny the importance of the distinction between problem solving and remembering, nor do they imply that the distinction contributes nothing to spacing effects. Simply, the construction hypothesis cannot account for all spacing effects.

There are two possible problems with the data from the recognition test. First, they are confounded by the initial recall. Words previously recalled are given another presentation and another study period. Thus a previous recall may enhance the probability that a word is recognized. This confounding biases against the obtained results, however. Words given spaced repetitions are recalled more often than words given immediate repetitions. Therefore, the previous recall should enhance the probability of recognizing words given spaced repetitions over those given immediate repetitions. Nonetheless, in condition C the effect of spacing was attenuated on the recognition test.

A second possible problem is that the data in condition C may be artificially constrained by a ceiling effect. Restricting the analysis to subjects who contributed two or more misses to condition C, however, does not substantially change the pattern of results. For these subjects, in condition R the hit rates are .82 and .91 for immediate and spaced repetitions, respectively. In condition C the hit rates are .86 and .82 for immediate and spaced repetitions, respectively.

EXPERIMENT 2

This experiment was designed to eliminate both of the possible problems with the recognition data of Experiment 1. The

study procedure was exactly the same in the two experiments. In Experiment 2, however, there was no recall test before the recognition test. In addition, to reduce the possibility of ceiling effects, the recognition test was delayed by 24 hours and the number of distractors was increased from 32 to 64.

Method

Subjects. The 32 subjects were students enrolled in an introductory psychology course. They were awarded course credit for their participation.

Procedure. The subjects were treated exactly as in Experiment 1 up to the end of the presentation sequence. They were then excused and asked to report back the next day for another "task involving words." At that time the subjects were asked to circle exactly 32 words (of the 96) that they believed they studied the previous day.

Results and Discussion

Table 3 presents the proportion of old words circled (hit rates). For each cell, the false alarm rates correspond to half the difference between 1.0 and the hit rate.

Statistical analyses confirm the obvious effects in Table 3. There are main effects for the spacing of repetitions, $F(1,24) = 8.88$, $MS_e = .90$, and processing mode, $F(1,24) = 18.35$, $MS_e = .90$. The interaction of the two is also significant, $F(1,24) = 5.50$, $MS_e = .82$.

These results replicate the results from the recognition test in Experiment 1. Constructive processing attenuates the spacing

effect when memory is tested by a recognition test.

GENERAL DISCUSSION

The construction hypothesis predicts the results of Experiments 1 and 2. Activities that require operations on the second component do not attenuate the spacing effect. The spacing effect was found in Experiment 1 and in at least three of the four reports (Bird, et al., 1976; Thompson, 1976; Shiffrin, 1977). Clearly, then, the size of the spacing effect depends on both the study conditions and the test conditions. The spacing effect predicted by the construction hypothesis is dictated by the construction hypothesis.

Component-Levels (Glenberg, 1979) uses both study and test conditions to predict the size of the spacing effect. According to the theory, the spacing effect typically results in an increase in the number of different components in a multicomponent trace. One type of computational component, representing the word is presented, is assumed to drift or change. If it is assumed to be related to specific encoding tasks, then the spacing components are especially effective on a recall test where the word is given in the test context. Since the spacing effect is given spaced presentations, the match between the word (retrieval cue) and the word is greater for words given spaced presentations. This differential effect of the spacing effect. Since the context in which an item is presented is relatively unaffected by

TABLE 3
RECOGNITION HIT RATES (EXPERIMENT 2)

Processing condition	Repetition spacing		\bar{X}
	Immediate	Spaced	
R	.72	.83	.78
C	.86	.87	.87
\bar{X}	.79	.85	—

was exactly the same in
 nents. In Experiment 2,
 as no recall test before the
 In addition, to reduce the
 ing effects, the recognition
 ed by 24 hours and the
 ctors was increased from

32 subjects were students
 ntroductory psychology
 re awarded course credit
 ation.

ie subjects were treated
 eriment 1 up to the end of
 equence. They were then
 ed to report back the next
 task involving words." At
 jects were asked to circle
 (of the 96) that they be-
 ed the previous day.

Discussion

nts the proportion of old
 rates). For each cell, the
 correspond to half the dif-
 1.0 and the hit rate.

yses confirm the obvious
 3. There are main effects
 of repetitions, $F(1,24) =$
 9 , and processing mode,
 $MS_e = .90$. The interaction
 so significant, $F(1,24) =$

uplicate the results from
 est in Experiment 1. Con-
 ng attenuates the spacing

TABLE 3
 HIT RATES (EXPERIMENT 2)

Repetition spacing		
Immediate	Spaced	\bar{X}
.72	.83	.78
.86	.87	.87
.79	.85	—

effect when memory strength is measured
 by a recognition test.

GENERAL DISCUSSION

The construction hypothesis correctly
 predicts the results of the recognition test:
 Activities that require different encoding
 operations on the second of two presenta-
 tions attenuate the spacing effect. This re-
 sult was found in Experiments 1 and 2. The
 construction hypothesis fails to predict the
 results of the recall test: In this case, ac-
 tivities that require different encoding op-
 erations on the second of two presentations
do not attenuate the spacing effect. This re-
 sult was found in the recall test of Experi-
 ment 1 and in at least three other published
 reports (Bird, et al., 1978; Maskarinec &
 Thompson, 1976; Shaughnessy, 1976).
 Clearly, then, the size of the spacing effect
 depends on both the study conditions (as
 predicted by the construction hypothesis)
 and the test conditions (which is not pre-
 dicted by the construction hypothesis).

Component-Levels theory (Glenberg,
 1979) uses both study and test conditions to
 predict the size of the spacing effect. Ac-
 cording to the theory, spacing repetitions
 typically results in an increase in the stor-
 age of a number of different types of com-
 ponents in a multicomponent memory
 trace. One type of component, the contex-
 tual components, represents the context in
 which the word is presented. This context
 is assumed to drift or change over time, and
 it is assumed to be relatively unaffected by
 specific encoding tasks. These contextual
 components are especially useful on a free
 recall test where the only retrieval cue is
 the test context. Since traces of words
 given spaced presentations include more
 different contextual components than
 traces of words given immediate presenta-
 tions, the match between the test context
 (retrieval cue) and the trace is generally
 greater for words given spaced presenta-
 tions. This differential retrieval produces
 the spacing effect. Since it is assumed that
 the context in which an item is presented is
 relatively unaffected by encoding tasks di-

rected at the individual item, the spacing
 effect is predicted in both conditions R and
 C in free recall.

Descriptive components, another type of
 component, encode the characteristics of
 the stimuli (e.g., sound, articulation,
 meaning, visual image) that allow them to
 be identified and discriminated from one
 another. The specific descriptive compo-
 nents encoded depend on both the encoding
 task and the context in which the stimulus
 is presented. These components are espe-
 cially useful on a recognition test where de-
 scriptive components encoded from copy
 cues can match those included in the trace
 and thereby retrieve the traces.

In condition R, the presentation modality
 and the encoding dimensions are the same
 at both presentations. Nonetheless, the
 context surrounding the presentations
 change from the first to the second presen-
 tation, and this contextual change is larger
 for the items given spaced presentations
 than the items given immediate presenta-
 tions. Since contextual changes are as-
 sumed to produce variability in the encod-
 ing of descriptive components (Bower,
 1972; Estes, 1955; Martin, 1968), a greater
 variety of descriptive components are in-
 cluded in the traces of words given spaced
 presentations than immediate presenta-
 tions. Hence in condition R, a spacing ef-
 fect is predicted for the recognition test.

Since words repeated in condition C are
 encoded from two different modalities,
 along two different semantic dimensions,
 traces of these words contain many de-
 scriptive components regardless of the
 spacing. Therefore, when the retrieval cue
 consists of descriptive components (en-
 coded from the recognition copy cue), the
 spacing effect is predicted to be attenuated.

Although on the surface Component-
 Levels theory can account for both the rec-
 ognition and free recall results, it fails a test
 proposed by Ross and Landauer (1978).
 They reason that if increasing the spacing
 between presentations of a repeated word
 increases the total number of contextual
 components stored in that word's repre-

sentation, then increasing the spacing between pairs of once-presented words should, likewise, increase the total number of contextual components stored in their two separate representations. Similarly, the degree to which the test context matches the components stored in the representation of the repeated word is the same as the degree to which the test context matches the contextual components in one or the other of the representations of the once-presented words. Therefore, if the free recall spacing effect is due to context matching, recall of at least one (one, the other, or both) of the paired once-presented words should also generate a spacing effect.

Two tests of this prediction were conducted using the free recall data from Experiment 1. For the first test, 16 pairs of once-presented words were formed. Eight of the pairs (immediate) were formed to have the minimum spacing between the two words in each pair (average = .125). Eight of the pairs (spaced) were formed to have the maximum spacing between the two words in each pair (average = 45.6). Recall was scored to obtain an OR-score, the proportion of times subjects recall one, the other, or both members of a pair. For the immediate pairs the OR-score is .29; for the spaced pairs the OR-score is .29. Clearly, there is no spacing effect.

For the second test the 16 pairs were constructed with these constraints: (a) four pairs were formed from the eight once-presented words in each set of two adjacent blocks (see the methods section of Experiment 1); (b) each pair contained one word presented visually and one word presented aurally; (c) two of the four pairs (immediate) were selected to minimize the spacing within each pair (average = .625) and two pairs (spaced) were chosen to maximize the spacing within each pair (average = 13.4). The OR-score for the immediate pairs is .29, and for the spaced pairs it is .28. Again, there is no spacing effect.

These data are similar to those reported by Ross and Landauer (1978), but they contrast strongly with data reported by

Glenberg and Lehmann (in press). In Glenberg and Lehmann's data, the OR-scores mirrored recall of repeated words both when the repeated words generated a positive spacing effect, and when the repeated words generated a negative spacing effect (words repeated with a short spacing were recalled better than words repeated with a long spacing). As in the present Experiment 1, Glenberg and Lehmann used an incidental learning procedure with semantic orienting tasks followed by a free recall test. A major difference between the experiments is that Glenberg and Lehmann presented words on one list and then repeated them in another list. Spacing was manipulated by varying the time between the lists. An interpretation of the different OR-score results is, therefore, that context matching provides an adequate explanation of free recall spacing effects when the spacing intervals are manipulated between lists. When the spacing interval is manipulated within a list (as in Experiment 1, and Ross and Landauer) context matching does not play a major role in producing the spacing effect.

In summary, the contrast between the results found on the recognition and recall tests clearly indicates that the conditions of study and the conditions of testing interact to determine the spacing effect. Component-Levels theory (Glenberg, 1979) incorporates assumptions about study and test processes, so it can encompass the differences between the results from the recognition and recall tests. The OR-score analysis indicates, however, that its context-matching explanation of the free recall data from Experiment 1 is probably incorrect. Jacoby's (1978) construction hypothesis focuses solely on study processes. Therefore, it cannot provide a complete explanation of spacing effects.

REFERENCES

- BIRD, C. P., NICHOLSON, A. J., & RINGER, S. Resistance of the spacing effect to variations in encoding. *American Journal of Psychology*, 1978, 91, 713-721.
- BOWER, G. H. Stimulus sampling theory of encoding

variability. In A. W. Melton & *Coding processes in human memory*, D.C.: Winston, 1972.

- ESTES, W. K. Statistical theory of series and regression. *Psychology*, 62, 145-154.
- GLENBERG, A. M. Monotonic and effects in paired-associate and ory paradigms. *Journal of Verbal Behavior*, 1976, 15, 1-10.
- GLENBERG, A. M. Influences of retri the spacing effect in free recall. *Experimental Psychology: Human Memory*, 1977, 3, 282-294.
- GLENBERG, A. M. Component-level effects of spacing of repetitions on nition. *Memory & Cognition*, 1979, 7, 1-10.
- GLENBERG, A. M., & LEHMANN, J. T. Repeated words over a week. *Memory*, 1978, 6, 1-10.
- HINTZMAN, D. L. Theoretical in spacing effect. In R. L. Solso *cognitive psychology: The Learning and Memory*, Hillsdale, N.J.: Erlbaum, 1974, 1-10.
- HINTZMAN, D. L., BLOCK, R. A., & LEHMANN, J. T. Modality tags and memory for of the spacing effect. *Journal of Verbal Behavior*, 1973, 12, 1-10.
- JACOBY, L. L. On interpreting the e Solving a problem versus reme

ann (in press). In Glen-
s data, the OR-scores
repeated words both
words generated a posi-
and when the repeated
negative spacing effect
h a short spacing were
words repeated with a
the present Experiment
mann used an incident-
dure with semantic
owed by a free recall
ence between the ex-
lenberg and Lehmann
one list and then re-
ther list. Spacing was
ing the time between
etation of the different
therefore, that context
adequate explanation
ing effects when the
manipulated between
ing interval is manipu-
in Experiment 1, and
context matching does
ple in producing the

ontrast between the re-
ognition and recall
that the conditions of
ons of testing interact
ing effect. Component-
berg, 1979) incorpo-
out study and test pro-
compass the differences
from the recognition
OR-score analysis in-
t its context-matching
e recall data from Ex-
ty incorrect. Jacoby's
hypothesis focuses
cesses. Therefore, it
mplete explanation of

REFERENCES

A. J., & RINGER, S. Resis-
fect to variations in encod-
of Psychology, 1978, 91,
ampling theory of encoding

- variability. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory*. Washington, D.C.: Winston, 1972.
- ESTES, W. K. Statistical theory of spontaneous recovery and regression. *Psychological Review*, 1955, 62, 145-154.
- GLENBERG, A. M. Monotonic and nonmonotonic lag effects in paired-associate and recognition memory paradigms. *Journal of Verbal Learning and Verbal Behavior*, 1976, 15, 1-16.
- GLENBERG, A. M. Influences of retrieval processes on the spacing effect in free recall. *Journal of Experimental Psychology: Human Learning and Memory*, 1977, 3, 282-294.
- GLENBERG, A. M. Component-levels theory of the effects of spacing of repetitions on recall and recognition. *Memory & Cognition*, 1979, 7, 95-112.
- GLENBERG, A. M., & LEHMANN, T. S. Spacing repetitions over a week. *Memory & Cognition*, in press.
- HINTZMAN, D. L. Theoretical implications of the spacing effect. In R. L. Solso (Ed.), *Theories in cognitive psychology: The Loyola Symposium*. Hillsdale, N.J.: Erlbaum, 1974.
- HINTZMAN, D. L., BLOCK, R. A., & SUMMERS, J. J. Modality tags and memory for repetitions: Locus of the spacing effect. *Journal of Verbal Learning and Verbal Behavior*, 1973, 12, 229-238.
- JACOBY, L. L. On interpreting the effects of repetition: Solving a problem versus remembering a solution. *Journal of Verbal Learning and Verbal Behavior*, 1978, 17, 649-667.
- MARTIN, E. Stimulus meaningfulness and paired-associate transfer: An encoding variability hypothesis. *Psychological Review*, 1968, 75, 421-441.
- MASKARINEC, A. S., & THOMPSON, C. P. The within-list distributed practice effect: Tests of the varied context and varied encoding hypotheses. *Memory & Cognition*, 1976, 4, 741-746.
- PETERSON, L. R., WAMPLER, R., KIRKPATRICK, M., & SALTZMAN, D. Effects of spacing presentations on retention of a paired-associate over short intervals. *Journal of Experimental Psychology*, 1963, 66, 206-209.
- ROSS, B. H., & LANDAUER, T. K. Memory for at least one of two items: Test and failure of several theories of spacing effects. *Journal of Verbal Learning and Verbal Behavior*, 1978, 17, 669-680.
- SHAUGHNESSY, J. J. Persistence of the spacing effect in free recall under varying incidental learning conditions. *Memory & Cognition*, 1976, 4, 369-377.

REFERENCE NOTE

- JACOBY, L. Personal communication, May 4, 1979.

(Received June 4, 1980)