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THE TOTAL TIME HYPOTHESIS IN PAIRED-ASSOCIATE LEARNING: FACT OR ARTIFACT

by

EDWARD J. STUBIN

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1972

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August 22, 1972 May D'Amato
date Chairman of Examining Committee

Aug 28, 1972 Florence L Denmark
date Executive Officer

May D'Amato

Phyllis Greenhouse

Solomon Weinstock
Supervisory Committee

The City University of New York

Abstract

THE TOTAL TIME HYPOTHESIS IN PAIRED-ASSOCIATE LEARNING: FACT OR ARTIFACT

by

Edward J. Stubin

Advisor: Professor May D'Amato

Three experiments were conducted to evaluate the validity of the total time hypothesis in paired-associate learning. The results of Exp. I indicate that in the study-test procedure, the superior performance found with more rapid presentations cannot be entirely accounted for by differential short-term memory benefits. In Exp. II, study time was either entirely allotted to paired-associate learning, or was divided between learning and a nonrelated task. Those Ss having 50% more study time performed no better than Ss having to divide their time between the two tasks. In Exp. III, an attempt was made to equate study time with presentation time through the use of a paced overt rehearsal procedure. Presentation rate significantly affected total learning times as a result of this restriction, while no effects were observed in a typical free rehearsal condition. It was concluded that those limited instances of total time invariance are the result of the covert redistribution of rehearsal time, and are not due to a reciprocal relationship between rehearsal time per trial and the number of trials.

Acknowledgement

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I am grateful to my father, Morton Stubin, for his understanding and encouragement.

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Introduction

The total time hypothesis (TTH) states that regardless of how learning time is distributed, the amount of material learned during a fixed amount of time will remain constant. Bugelski (1962) established the existence of this relationship in paired-associate learning. In this study, all Ss were required to learn the same eight pairs of nonsense syllables to a criterion of two successive anticipations. The presentation of each pair consisted of a 2-second stimulus exposure followed by either a 2-, 4-, 6-, 8- or 15-second stimulus-response exposure. With the addition of 2 seconds prior to the appearance of the next stimulus item, the total presentation times for the resulting five experimental groups were 6, 8, 10, 12 and 19 seconds. A trial consisted of the presentation of all eight pairs of nonsense syllables. Total learning times were calculated by multiplying presentation times by the mean number of trials per item to reach criterion. For all five groups studied, these products did not differ significantly. Bugelski (1962) concluded that "Within the limits, then, of the intervals and conditions used, the conclusion appears reasonable

that presentation time multiplied by trials amounts to a constant value, T_p X T = k (p. 410)."

Bugelski and Rickwood (1963) conducted a study in which Ss controlled their own stimulus-response presentation times. Although only this one experimental group was run, the mean total learning time, 65.5 seconds, did not differ significantly from scores obtained earlier by Bugelski (1962). The finding that 8.1 trials were required to reach criterion led the authors to conclude that Ss allowed themselves approximately five seconds per response on the average.

Bugelski's (1962) statement of the TTH was preceded by Hovland's (1949) work on rote learning theory. Although this work was originally concerned with the effects of massed versus distributed practice on paired-associate learning, its findings have been interpreted as offering support of the TTH. In this study, stimulus and stimulus-response presentations were exposed for 1:1 or 2:2-seconds. The mean number of trials to criterion with the 1:1-second rate was 27.5 and 15.0 for the 2:2-second group. The trials X times products, 51.0 and 59.8 seconds, were approximately the same for both groups.

Goss, Morgan and Golan (1959) have obtained evidence which supports the TTH, although their work was not directly concerned with this matter. This experiment involved an examination of the effects of various response occurrence percentages on paired-associate learning. Of relevance to the TTH are the results regarding 100% occurrence of response members. A comparison of 2:2- and 3:3-second rates reveals that while the number of trials to reach criterion were different, 24.8 versus 16.4, the per item total times were almost identical, 99.2 versus 98.4 seconds.

A study by Baumeister and Hawkins (1966) obtained results which the authors interpreted as support of the TTH. Strictly adhering to Bugelski's (1962) procedure, this experiment was concerned with the effects of explicit versus blank stimulus-response presentations. For all groups the stimulus was exposed for 2 seconds, while stimulus-response durations and intertrial intervals were concomitantly varied so that for three of the five conditions studied, total time remained constant at 19 seconds. Group 1, which had a 2-second stimulus-response exposure and a 15-second intertrial interval, required 12.2 trials to reach criterion. Group 2, which had a

7-second stimulus-response exposure and a 10-second intertrial interval, required 10.9 trials. Group 3, in which the time allotment was 15 and 2 seconds, required 9.2 trials. None of the differences was statistically significant at the .05 confidence level. The authors concluded that within the explored limits, total time was more important than explicit stimulus-response time.

Additional support for the TTH is contained in a series of experiments by Postman and Goggin (1966), dealing with the effects of whole versus part learning in paired-associate learning. It was found that in spite of the substantial variations in list difficulty, the difference in total learning time between the whole and part conditions remained at or near zero.

A study by Brewer (1967) examined the effects of presentation rate and restricted rehearsal on total learning time. Adhering to Bugelski's (1962) procedure, Brewer (1967) combined stimulus-response exposures of 2, 4 and 6 seconds with a 2-second stimulus exposure and a 2-second interitem interval to yield presentation rates of 6, 8 and 10 seconds per pair. In an attempt to control rehearsal, Ss were required to overtly repeat the presented

pair either 2, 4 or 6 times, depending upon the particular rate at which items were shown to them. There were no restrictions as to the pace of the overt repetitions; Ss were only instructed to make the required number of repetitions whether or not the pair had been correctly anticipated. Performance under overt rehearsal was compared to three groups given the same presentation rates, but not restricted in their rehearsal. It was found that neither presentation rate or rehearsal restriction affected total learning time.

In a recent study by Mueller and Slaymaker (1970), stimulus and stimulus-response durations were simultaneously increased or decreased in a factorial design, so that total learning time remained the same over 10 trials for all four conditions. Stimulus and stimulus response durations varied between .5 and 2.5 seconds, with both increases and decreases made in .5-second steps. Regardless of the exposure manipulation, performance was the same among all four conditions, confirming the TTH.

Of the previously cited studies which have supported the TTH, except for Postman and Goggin (1966),

all have employed the anticipation method. In this procedure, Ss are presented with a stimulus item and must correctly anticipate the response member of that pair prior to the exposure of both members, e.g., Bugelski (1962). An alternative procedure involves the alternation of study trials with test trials. In the typical study-test procedure, the entire list is presented for study one pair at a time; each study trial is then followed by a test trial in which each stimulus item is presented individually.

Newman (1964), employing a study-test procedure, factorially varied pairing time, 2 or 4 seconds, with test time, 2 or 4 seconds. With total time equated, the number of items recalled at different test trials was approximately equal in certain instances. The mean number of items correctly recalled by Ss in Group 22 (2-second pairing time, 2-second test time) was 3.00 after 336 seconds of training. After the same total time, Ss in Group 42 recalled 3.05 items. The mean number of items correctly recalled by Ss in Group 24 was 3.25 after 368 seconds of training. The corresponding figure for Group 44 was 4.10 items after 364 seconds.

In both of these comparisons, the differences between means were not statistically significant, thereby confirming the TTH.

Using a more ambitious version of the self-pacing technique established by Bugelski and Rickwood (1963), Zacks (1969) has obtained findings which were interpreted as supporting the TTH. Unlike the original experiment, a study-test procedure was employed in place of the anticipation method. The Ss either were allowed to study each pair as long as they wished or were presented with the pairs at a 2-second rate. The conditions were factorially varied with a fixed study-test trial order and a condition in which Ss were given the freedom to choose when they would be tested. It was concluded that these variations did not affect the total learning time to reach criterion.

Reviewing this area, Cooper and Pantle (1967) cite nine studies which they claim support and three studies which qualify the TTH in paired-associate learning. They suggest that the process underlying learning time invariance may simply be the repetition of representational responses (RR), a RR in paired-

associate learning being defined as "the perception of Response A contiguous with Stimulus A (p. 226)." Since equal amounts of total exposure time allow for equal numbers of RRs, learning would be equivalent regardless of the distribution of repetitions. However, Cooper and Pantle (1967) point out that a distinction must be made between rehearsal time which is potentially available (nominal), and the time during which rehearsal actually occurs (effective). If effective learning time were actually less than the nominal time indicated, there would be a corresponding decrease in the opportunity for the production of RRs. Exposure durations of .5 seconds, although perhaps having 20 presentations and therefore a total time of 10 seconds, may be so rapid as to prevent the evocation of RRs, while extremely prolonged exposures may result in boredom or lack of attention in which case S would not use the entire stimulus-response presentation for rehearsal. Cooper and Pantle (1967) conclude that in order for the TTH to hold, task requirements must not exceed simple rehearsal, i.e., repeated RR evocation, and RR-defined effective time must be related in a positive linear

manner to nominal time.

In summary, most of the evidence in favor of the TTH has been obtained from studies which have used list lengths of eight or fewer items (Goss, Morgan and Golin, 1959; Bugelski, 1962; Bugelski and Rickwood, 1963; Newman, 1964; Baumeister and Hawkins, 1966; Brewer, 1967; Zacks, 1969) and/or a narrow range of presentation rates (Hovland, 1949; Goss, Morgan and Golin, 1959; Newman, 1964; Brewer, 1967; Mueller and Slaymaker, 1970). However, in spite of this positive evidence, a number of studies can also be cited which question the TTH.

Johnson (1964), using a study-test procedure, factorially varied total time, 10,20, 40 and 80 seconds, and number of exposures, 1, 5, 10 and 20. The resulting presentation rates varied from .5 to 80 seconds. Frequency of exposure was found to have a significant affect on the number of correctly recalled responses. For the materials and method used, a 2- to 4-second presentation rate seemed optimal. Although Johnson's (1964) findings question the TTH, this evidence has been used by Cooper and Pantle (1967) to limit the generality of this position.

Extremely rapid exposures are held to prevent proper rehearsal, while full use is not made of the longer exposures. Cooper and Pantle (1967) have questioned Johnson's (1964) results due to his failure to include the 4-second intertrial interval in the learning time calculations. For example, Ss in the one 20-second exposure group had only 20 seconds learning time per item, while Ss with twenty 1-second exposures had 20 seconds + 20(4 seconds)/8 items = 30 seconds total learning time per item.

The work of Carroll and Burke (1965) is particularly important since it examined the effects of a number of critical variables. In this study, presentation rate (1.5:1.5, 2:2 and 4:4 seconds), list length (4, 8, 12 and 20 pairs), three levels of meaningfulness, two levels of S ability and two equivalent forms were factorially varied. The amount of time required to learn each pair to a correct anticipation was compared among conditions. All main effects except list form were significant. Of particular interest was the interaction between list length and presentaton rate. As the number of pairs increased, the positive relationship between

presentation rate and performance became more pronounced. These findings indicate that the extent of the TTH may be more limited than has been suggested by Cooper and Pantle (1967).

A study by Heimer (1968) also indicates that the generality of the TTH may be restricted to those experiments which have used a narrow range of presentation rates. While closely adhering to Bugelski's (1962) original procedure, Heimer (1968) increased stimulus-response exposure times beyond the durations traditionally examined. As exposure times increased, 9, 19, 30 and 60 seconds, so did the total time which was required to learn the associations, 58.78, 108.46, 146.56 and 268.75 seconds, respectively. Of particular interest was the finding that comparisons of groups whose presentation times differed by 11 seconds or less failed to reveal any significant differences in total learning times, whereas comparisons of more temporally diverse conditions were statistically significant. Heimer (1968) concluded that Bugelski's (1962) findings may only hold within the range of his presentation continuum.

A recent study by Calfee and Anderson (1971) has

attempted to reconcile the discrepant findings in this area by considering the nature of various stimulus material and their effect on rehearsal. Presentation rates were found to significantly affect performance when trigrams were used as stimuli with digit responses; this effect was more pronounced for materials of high intralist similarity. Optimal performance corresponded with exposure durations between 2 and 4 seconds. However, presentation rates failed to alter total learning times when stimulus materials consisted of digit-trigram pairs. These results further indicate that total time invariance is a task dependent phenomenon.

Stubin, Heimer and Tatz (1970) have indicated that the anticipation method, when employed to study total time, contains at least three methodological confounding errors. In this procedure, Ss in the more rapid exposure conditions receive proportionately less stimulus-response or effective study time since the stimulus exposure and the intertrial interval accounts for a larger percentage of rehearsal time as presentation rates become more rapid. For example, in Bugelski's (1962) study, stimulus-response presentations accounted for only 33% of the total learning time in the 6-second

condition, while this figure was 79% for the 19-second presentation rate. The importance of this factor was demonstrated in an experiment conducted by Nodine (1963). Stimulus and stimulus-response exposures were varied factorially over four values. Although the number of correct responses on four recall-test trials increased as both stimulus and stimulus-response presentation times were lengthened, each doubling of the stimulus-response duration resulted in increments which were approximately twice as large as those produced by each doubling of the stimulus duration. A recalculation of Bugelski's (1962) data based on Nodine's (1963) results, although unorthodox, reveals an interesting set of findings. By assigning the stimulus duration one-half its actual value, the resulting total learning times become 40.8, 52.8, 46.4, 47.0 and 56.1 seconds, respectively. Note that while the difference Bugelski (1962) reported between the most rapid and the slowest rate was 1.0 second, the corresponding difference determined by this recalculation is 15.3 seconds.

A second source of error found in the anticipation method involves the confounding of presentation rate

and testing; specifically, the number of tests varies directly with presentation rate. Both Battig (1965) and Izawa (1969, 1971) have demonstrated that distinctively different processes are involved in the presentation and the testing of items. The final methodological error involves the confounding of dependent and independent variables as a result of multiplying trials to criterion by exposure duration. With the reintroduction of the exposure duration, shorter presentations permit more sensitive inferences about actual learning time. For example, if a particular item requires 5 seconds in order to be learned, the recorded time in a 6-second condition will be incorrect only by 1 second, while this error increases to 14 seconds in a 19-second condition.

Stubin et al. (1970) circumvented these difficulties by employing a variation of the study-test procedure. While the total presentation time of each pair was stringently maintained at either 20 or 40 seconds, per trial exposure duration was set at either 2, 5, 10, 20 or 40 seconds. Following the final stimulus-response presentation, a single test was administered. The dependent variable was the number of items correctly recalled on

this test. Support of the TTH would have required that the number of recalled items did not differ significantly within both the 20- and 40-second conditions. However, two parallel inverted U-shaped functions were obtained; with the 5-second exposure being the most efficient presentation rate in both conditions. These results were substantiated by Johnson's (1964) findings. In view of the fact that most of the evidence of total time invariance had been collected through the use of the anticipation method, the results which were obtained by Stubin et al. (1970), using a procedure which controlled for the confoundings present in the anticipation method, were particularly damaging to the TTH.

In a reply to Stubin et al. (1970), although not refuting the criticisms inherent in the anticipation procedure, Bugelski and McMahon (1971) state that the modified study-test procedure is not without its confounding elements. Essentially, their criticism concerned the fact that the time between the final exposure of an item and the testing of that item varied as a function of the presentation rate. For example, assuming that testing begins immediately after the final

pair has been presented, the mean time between the last presentation of a pair and testing would be 20 seconds in an 8-pair list if the presentation rate were 5 seconds, while in a 40-second condition the corresponding mean time would be 2 minutes and 40 seconds. Bugelski and McMahon (1971) contend that this presentation-test interval difference resulted in the 5-second condition receiving additional short-term memory benefits. Bugelski and McMahon (1971) attempted to control for this discrepancy by increasing the interval prior to testing by 2 minutes and 40 seconds in a 5-second presentation rate condition. This group was compared to two groups which replicated the 5- and 40-second presentation rates of Stubin et al. (1970). Although the mean number of items recalled by the 5-second group decreased from 6.63 to 5.39 due to the testing delay, there was only a slight difference between the regular 5- and 40-second groups, .86 items. The failure to replicate the results of the Stubin et al. (1970) 40-second group unfortunately obscures any interpretations. Note that the criticism of Bugelski and McMahon (1971) would lead to the prediction that Ss in the 40-second group would

have to do significantly worse than Ss in a 5-second group due to the longer presentation-test interval. On an intuitive level their argument is not without validity. However, the failure to replicate Stubin et al. (1970) poses a problem since Bugelski and McMahon's (1971) results do not support their own criticism.

The purpose of Exp. I first was to attempt to replicate part of the results obtained by Stubin et al. (1970). Secondly, the criticism concerning the possibility of differential short-term memory benefits was evaluated by two independent methods. The first of these methods involved extending the interval prior to testing in a manner very similar to that employed by Bugelski and McMahon (1971). This additional delay prior to testing was included for both rapid and slow presentation conditions in order to control for any effects due solely to delayed testing, a precaution which Bugelski and McMahon (1971) failed to consider. The second approach involved equating any short-term benefits by presenting a review trial prior to testing in both rapid and slow presentation conditions. In the first procedure, equalization was achieved by minimizing

possible short-term benefits, while in the second procedure this was accomplished by equally increasing the opportunity for short-term benefits.

EXPERIMENT I

Method

Subjects

The Ss consisted of 120 undergraduates enrolled in introductory psychology courses at Brooklyn College during the 1971 fall semester. All Ss were naive to rote learning experiments. Extra course credit was given for participation. There were approximately an equal number of males and females in each condition, with ages varying between 17 and 26 years.

Apparatus

The stimulus material consisted of the following 8 pairs of nonsense syllables: TOF-LAH; BIH-XIR; KAR-WEH; GAC-QET; DUP-TEZ; FAX-SOQ; CEZ-MUN; GEY-NUR. The association value of these items vary between 47 and 53% (Glaze, 1928). These were the same pairs used by Bugelski (1962) in establishing the TTH, and were also used by Stubin et al. (1970) and by Bugelski and McMahon (1971). The stimulus material was prepared by photographing one-inch white plastic letters against a

black background. The negatives, i.e., black letters on a white background, were then bound into slides.

Presentation was via a Kodak Carousel model 800 slide projector, which was automatically controlled by a Hunter model 124S timer. The accuracy of the apparatus was checked throughout the experiment by independently timing both individual exposures and the total sequence of exposures. Ss sat 8 feet from the white wall on to which the material was projected. The projected letters were two inches in height, and each pair was approximately eight inches in length. In order to insure that learning was not due to memorization of the presentation order, nine different list arrangements, as well as a different test order were employed for each S.

Procedure

Block randomization was used to assign 20 Ss to each of the six experimental groups. All Ss were run individually.

The experimental manipulations took the form of a 3 X 2 factorial design. The first variable in-

volved treatment prior to testing, the second was rate of presentation. The three treatments prior to testing consisted of one of the following: a regular condition (REG) which replicated the procedure followed by Stubin et al. (1970); a delay condition (DEL) involving a 2-minute and 40-second blank interval prior to testing; a review condition (REV) in which a 3-second per pair review trial immediately followed the presentation of the last pair of nonsense syllables. For all six groups the total exposure time per item was 40 seconds. A trial consisted of the consecutive presentation of all eight pairs. There were no interitem or intertrial intervals other than the .5 seconds required for the projector to change slides.

Within the REG condition, each pair was presented either for one 40-second exposure or for eight 5-second exposures. Following exposure of the final pair a blank slide was presented for 5 seconds. This slide was in turn followed by a slide containing the word "TEST", which was also presented for 5 seconds. The total interval between rehearsal and testing was 10 seconds.

The procedures within the DEL condition, for both the 5- and 40-second groups, were exactly the same as in the REG condition; the only exception being that the period between the final presentation and the "TEST" slide was 2 minutes and 35 seconds, i.e., the total time prior to testing was now 2 minutes and 40 seconds. There were no task requirements during either of the intervals which separated presentation and testing.

Within the REV condition, exposure times were shortened from 5 to 4.63 seconds and from 40 to 37 seconds. Immediately following the presentation of the last pair, a slide with the word "REVIEW" was presented for 3 seconds. During the review trial, each pair was shown for 3 seconds, thereby increasing the total exposure time in both groups to 40 seconds per pair. The procedure prior to testing was in all other ways identical to the REG condition.

During testing, each stimulus item was presented for 5 seconds. Ss had these 5 seconds in which to verbally respond. Responses either had to be spelled correctly or pronounced correctly in order to be con-

sidered acceptable; no credit was given for a partially correct response, although these responses were recorded.

Following their participation, all Ss were questioned regarding the following: the strategy they employed in learning the material; study time allocation, including both their attention and concentration; the value of the review trial (when applicable); a satisfaction rating on a 1 to 7 scale of the presentation rate.

Instructions

The following instructions were read to all Ss. Instructions used for a particular condition are bracketed.

You are participating in a verbal learning experiment. Your task will be to learn pairs of nonsense syllables so that when you see the first item of a pair, you will be able to report the second. A nonsense syllable is three letters, a consonant, a vowel, and a consonant. These three letters are put together so that you can pronounce them, that is they form a sound, but they have no meaning. The pairs of nonsense syllables that you are to learn will be presented one pair at a time, on that wall. Study these pairs of nonsense syllables so that when only the left-hand or first item is presented, you will be able to report the right-hand or second item. (Before the test, there will be a rapid review presentation of the list. A slide with the word review will signal that the review

session will begin.) Remember, on the test, just the left or first item will be presented and your task will be to report the right-hand or second item that appeared with it. A slide with the word test will signal that the test will begin. For example, if one pair were red-green, you would have to learn this pair so that when red would be presented, you would be able to tell me _____, and so on. (As or Each time) we go through the list, and also for the test, the pairs will appear in different orders. It will therefore be impossible for you to learn any order of second items, that is, the order of the pairs is never the same, you must learn the specific pairs. If you are not certain of the correct response, guess at it. Are there any questions? As you see each pair, say them clearly once. In this way I can make sure you are pronouncing them correctly. Ready....Let's begin.

Following the presentation of the last pair of items, Ss were given the following message: "Testing will begin in a few (minutes or seconds)." Five seconds prior to the presentation of the "TEST" slide, the following reminder was given to all Ss: "Testing will begin. You will be presented with the first item, tell me the second. Guess if you are not certain."

Results and Discussion

Table 1 contains the mean number of items correctly recalled by each of the six groups in Exp. I. A 3 X 2 analysis of variance revealed that the effects of both treatment prior to testing and presentation rate were highly significant, $F(2,114)= 7.54$, $p < .01$, and $F(1,114)= 22.57$, $p < .01$, in determining the number of responses which were correctly recalled. The interaction of these two variables was not significant, $F(2,114)= 2.25$, $p > .10$.

All intergroup comparisons were made using Tukey's (1953) HSD test. Within the 5-second condition, none of the three means differed significantly, $p > .05$. However, there was a significant increase in performance, $p < .05$, in the 40-second condition as a result of the review trial. The difference between the 40-second REG and DEL groups was negligible. Of the three 5- versus 40-second intergroup comparisons, only the difference between the REG groups was significant, $p < .01$.

TABLE 1

MEAN NUMBER OF ITEMS RECALLED AS A FUNCTION OF TREATMENT PRIOR TO TESTING AND OF PRESENTATION RATE

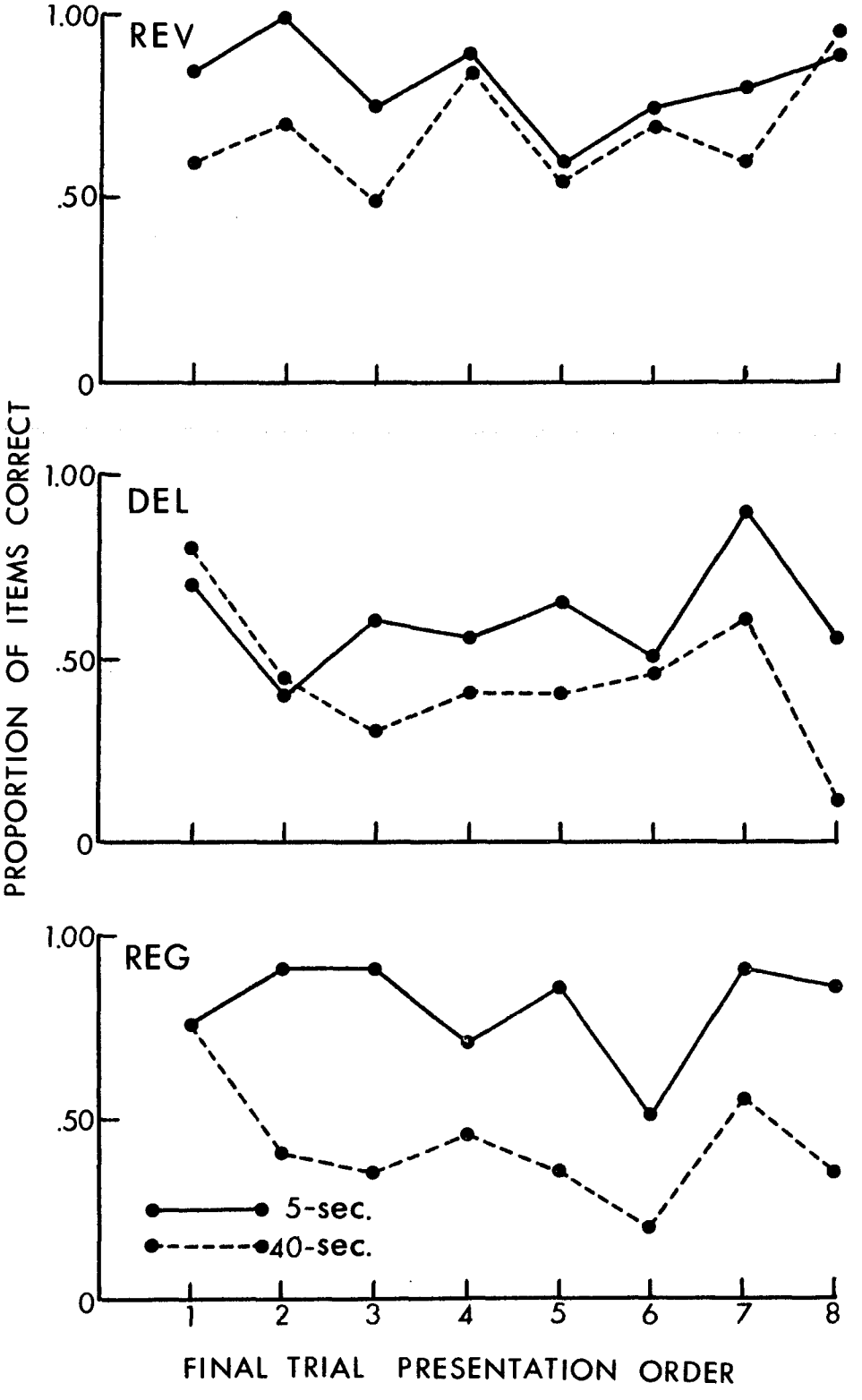
pres. rate		Treatment prior to testing		
		Regular	Delay	Review
5-sec.	mean	6.35	4.90	6.55
	S.D.	1.87	2.43	1.60
40-sec.	mean	3.40	3.50	5.45
	S.D.	2.19	2.04	2.33

In contrast to the findings of Bugelski and McMahon (1971), the results of both REG groups almost perfectly replicated the superiority of the 5-second group over the 40-second group which was originally found by Stubin et al. (1970); the differences between experiments were .07 and .05 items, respectively. These findings were impressive since a period of three years separated the two studies, and also in view of the fact that Ss were from different populations.

The effect of the review trial in the 40-second condition, and to some extent the effect of the 2-minute and 40-second testing delay in the 5-second condition, both suggest that a short-term component is involved in the performance increases associated with more rapid presentation rates. However, a number of factors indicate that this differential short-term memory explanation is not sufficient to entirely account for these increases in performance.

Figure 1 illustrates the proportion of correctly recalled items as a function of last trial presentation order, for each of the three treatments prior to testing. Note that in all three comparisons, the inter-

Fig. 1. Proportion of items correct as a function of position of item on final presentation trial, for each treatment prior to testing. Final presentation order of REV condition is based on review trial.


1.00
REV
.50
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1.00
DEL
.50
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REG
.50
0
5-sec.
40-sec.
1
2
3
4
5
6
7
8
PROPORTION OF ITEMS CORRECT
FINAL TRIAL PRESENTATION ORDER

action between serial position and presentation rate appears to be negligible. If the higher performance level found with the 5-second rate (REG condition) was due to the shorter presentation-test interval, there should have been a large difference in the recall scores of items which were presented early in the final trial, with a narrowing of this discrepancy towards the end of the list. Note that these results were not obtained in the REG condition. In fact, if any trends exist in the three sets of relatively parallel functions, they are in the opposite direction; the only exception being the REV condition, where the differential short-term memory explanation should not hold since the presentation-test intervals were equal due to the review trial. These findings question the appropriateness of the long-term versus short-term explanation which has been offered by Bugelski and McMahon (1971). Furthermore, the paired associate learning task which was used does not conform to those experimental manipulations which have been used to demonstrate short-term memory. It would seem that a total of 40 seconds of presentation time is sufficient for an item to be stored in long-term memory.

Finally, the higher performance levels at each of the three 5- versus 40-second comparisons, combined with the absence of any interaction between variables, further indicates that the effects of presentation rate on performance are not entirely short-term in nature.

The effect of the review trial on the 40-second condition was highly surprising. If the differences within the REG condition had been maintained following the review trial, the differential short-term memory explanation would have been rejected. However, interpretations of the obtained results are not this clear. While some portion of the 2.05 increase in the number of items recalled within the 40-second condition appears to be due to short-term memory, it is equally likely that some component of this increase resulted from the correction of long-term rehearsal strategies. For example, the 3-second review exposure would allow Ss the opportunity to realize that the response to the stimulus item DUP was not LAH, but TEZ, or that the "Q" response to FAX was not QET, but SOQ. This hypothesis was supported by the results of a pilot study in which a 2-minute and 40-second delay followed a procedure identical to the

REV 40-second condition. The mean number of responses recalled by Ss in the pilot group was 5.17 (N = 8), a difference of only .28 items from the score obtained under the 10-second testing delay in Exp. I. This suggests that the increase in the 40-second condition resulting from the review trial was relatively permanent.

EXPERIMENT II

The discussion of the results of Exp. I indicates the impossibility of developing a situation in which presentation rates are varied, while short-term memory differences are eliminated. The use of the review trial in Exp. I altered the 40-second condition so that in some respects it contained elements found in more rapid exposure conditions. While Bugelski and McMahon (1971) have criticized the single test study-test procedure used by Stubin et al. (1970), based on differential short-term memory benefits, the former authors have neglected to indicate that the same criticism applies to the anticipation method which was used to establish the TTH. Although the dependent variable in the anticipation method is the number of trials required to reach criterion, the time between stimulus-response exposures and testing varies as a function of presentation rate. For example, if the fourth pair in an 8-pair list is the fifth pair in the next trial, the time between presentation and testing is 36 seconds in a 2:2-second condition (8 pairs X 4 seconds), and

is 136 seconds in a 2:15 condition (8 pairs X 17 seconds). If differential short-term memory benefits exist in the study-test procedure, then they must also be present to some degree in the anticipation method.

An alternative method exists which circumvents the relationship between presentation rate and study-test intervals, which is inherent in both the anticipation and study-test procedures. This method, which is a variation of the study-test procedure, involves the varying of intrapair exposure time within a given presentation rate. If, for example, the presentation rate were 30 seconds per pair, some portion of this single 30-second exposure may be assigned to a different, but neutral task, e.g., counting backwards. This additional task could occupy the first or second 10 seconds of presentation time. Total time comparisons are then made on the basis of the proportion of presentation time spent on paired-associate learning. However, as long as the final portion of an intrapair exposure is devoted to paired-associate learning, the time between the final exposure and testing will be equal. Therefore, the type of differential short-term

memory benefits discussed by Bugelski and McMahon (1971) would be eliminated. An additional feature of this design is that it equates motivational factors since the intrapair interval is the same for all conditions. If total time is critical, the number of correctly recalled items should vary directly as a function of learning time.

The purpose of Exp. II was to examine the validity of the TTH through the use of the procedure just outlined. In the first experimental group, each pair of nonsense syllables was presented once for 40 seconds. Within the remaining two conditions, either the first or middle third (13.33 seconds) of each presentation was allotted to performance on a neutral distractor task (DT). Support of the TTH would rely on the finding that Ss in the first group, having 50% more study time than Ss in both DT conditions, would perform at a significantly higher level than those in the remaining two groups. However, it was hypothesized that total learning time would not be as effective as the distribution of rehearsal time in determining the number of items correctly recalled. Specifically, it

was predicted that there would be no adverse effects on performance when the DT was located in the middle of the presentations. This was based on the hypothesis that increased exposure time is of no additional value once study time has reached some critical value. However, a decrease in performance was expected when the DT was placed between successive pairs, since this manipulation would interfere with Ss' ability to rehearse the previous item.

Method

Subjects

Sixty undergraduates enrolled in introductory psychology courses at Brooklyn College during the 1972 spring semester served as Ss. All were naive to rote learning experiments. Extra course credit was given for participation. There were approximately an equal number of males and females in each condition, with ages varying between 17 and 28 years.

Apparatus

All Ss were presented with the same 8 pairs of nonsense syllables described in Exp. I. Three-digit number slides were prepared in a manner identical to that of the nonsense syllable slides. Presentation and timing equipment, and related procedural details were the same as in the first experiment. A Lafayette model F-953 transistorized metronome was used to pace Ss' performance during the neutral distractor task.

Procedure

Block randomization was used to assign 20 Ss to each of the three experimental groups. All Ss were run individually.

Table 2 is a schematized representation of the experimental manipulations in the second study. The P represents a stimulus-response exposure, with the particular pairs being subscripted. The DT, if included, was positioned either within the presentation of each pair, or between successive pairs. Note that there is only one presentation trial prior to testing. For each pair, exposure time was divided into three 13.33-second periods. In the rehearsal-rehearsal-rehearsal (RRR) condition each pair was presented for a total of 40 seconds. A new slide of the same pair was presented every 13.33 seconds, in order to control for any effects due only to the changing of slides. In the rehearsal-distractor task-rehearsal (RDR) condition, the total exposure time for each pair of items was 26.67 seconds. A 13.33-second rehearsal period both preceded and followed involvement in the DT. In the distractor task-rehearsal-rehearsal (DRR) condition

TABLE 2

SCHEMATIC REPRESENTATION OF DESIGN II

Condition	Distribution of rehearsal time	
RRR	$P_1,P_1,P_1;P_2,P_2,P_2;.....P_8,P_8,P_8;$	Test
RDR	$P_1,DT,P_1;P_2,DT,P_2;.....P_8,DT,P_8;$	Test
DRR	$DT,P_1,P_1;DT,P_2,P_2;.....DT,P_8,P_8;$	Test

P = paired-associate learning
(pair number subscripted)

DT = distractor task

per item exposure time was also 26.67 seconds; however, the 13.33-second DT preceded the two concurrent stimulus-response exposure periods. The DT involved counting backwards by threes to the beat of a metronome. Participation was signalled by the presentation of a 3-digit number slide. This slide was the starting point for the backwards counting. The counting pace, as set by the metronome, was a response every 1.5 seconds. Ss were given practice on this task during the instructional period.

Testing took place 25 seconds after the presentation of the final pair. The Ss were not required to perform any task during this interval. Testing procedures and criteria were identical to those in Exp. I.

Following their participation, Ss were questioned regarding their allocation of study time, and whether or not they had rehearsed the paired-associates during the DT.

Instructions

The following instructions were read to all Ss. Instructions used for a particular condition are bracketed.

(You are taking part in a verbal learning experiment...)

or

(In this experiment, I am studying how people perform when they are asked to work on two different tasks on an alternating basis. During the verbal learning task, which I will explain in a moment, three-digit numbers will be shown on that wall. While one of these numbers is being presented, your task is to count backwards by threes, to the beat of this metronome. For example, if the number on the wall were 112, you would have to say: 112, 109, 106, 103, etc. Let's try a few for practice. If you make an error on one number, don't get nervous. Go on from that point and do the best you can. The second task is a verbal learning task...)

...which involves learning pairs of nonsense syllables so that when you see the first item of a pair of nonsense syllables, you will be able to report the second item of that pair. A nonsense syllable is three letters, a consonant, a vowel and a consonant, which are put together to form a sound, that is, you can pronounce them, but they have no meaning. You are to learn pairs of these nonsense syllables so that when you see the first nonsense syllable of a pair on the test, you will be able to report the second nonsense syllable of that pair. Let me give you an example using the colors red-green instead of nonsense syllables. The one pair red-green would be shown on the wall. You are to study the pair so that on the test, when red is presented by itself, you can tell me _____. On the test, the left-hand or first item, for example, red will be presented and you will have to tell me the right-hand or second item, for example green. It will always be this one way, from right to left, and never the other way around. The order of the eight pairs of nonsense syllables during the study period, and the order during testing when just the first item is presented, will be different. So it will be impossible to learn the order of the second nonsense syllables; you must learn the specific pairs. Guess if you are not certain of the correct response.

(It is important that you divide your time between

counting backwards and learning the pairs of nonsense syllables according to what is on the wall. That is, don't study nonsense syllables while numbers are shown and don't study numbers when nonsense syllables are shown; but work at what is currently on the wall. I have found that this will give you the best possible performance on both tasks since you won't be confusing yourself.)

Pronounce each pair once, in this way I can help you if there are any problems in pronounciation. Are there any questions? Okay let's begin.

Results and Discussion

The results of Exp. II are summarized in Table 3. The most striking finding was that contradictory to the TTH, the RRR condition, in spite of having 50% more study time, failed to reach the performance level of the RDR condition. While the overall difference among groups was statistically significant, $F(2,57) = 3.52$, $p < .05$, only the RDR versus DRR comparison was significant at the .05 confidence level, using Tukey's HSD test.

The effectiveness of the DT was confirmed by the postexperimental interview. No S in either DT condition reported being able to study the paired-associates while counting backwards.

The results of Exp. II suggest that once a presentation interval has reached some critical duration, further exposure no longer effectively contributes to learning. The decrease in performance in the DRR as compared to the RDR condition, indicates that the allocation of study time is more important than the total time which is available for rehearsal. This

TABLE 3

MEAN NUMBER OF CORRECTLY RECALLED RESPONSES WITHIN EACH OF THE THREE CONDITIONS IN EXPERIMENT II.

	Condition		
	RRR	RDR	DRR
MEAN	3.35	3.80	2.35
S.D.	1.87	2.04	1.30

R = Rehearsal Period (13.3 sec)

D = Distractor Task (13.3 sec)

argument will be extended in the final discussion.

EXPERIMENT III

The source of major difficulty in studying total learning time involves the assumption that study time and exposure duration are equal. This assumption has been questioned only in situations where extremely rapid or prolonged presentations may have resulted in differences in perceptual or motivational factors. Extremely rapid rates may interfere with S's ability to accurately read and/or rehearse the stimulus material, while extended presentations may result in boredom and lack of attention. Although qualifications of the TTH based on these factors have been stated, Bugelski (1970) and Cooper and Pantle (1967), there have not been any attempts at controlling these variables.

Exp. III was intended as a test of the TTH which would control rehearsal so that allocation of study time would more closely correspond with presentation rate manipulations. Rehearsal was restricted to the material currently being presented by requiring Ss to repeat that particular pair, once per second, for the duration of that exposure. While this repetition

rate is rapid enough to restrict rehearsal, it does not interfere with the correct pronounciation of items. Although this paced overt rehearsal was not expected to entirely determine S's allocation of available study time, it was felt that this procedure would allow for a more accurate correspondence between presentation rates and rehearsal. Performance under this manipulation was studied over three presentation rates, and was compared with that of three additional groups upon which there were no rehearsal restrictions.

It should be noted that Brewer (1967), as previously cited, failed to obtain differences in total learning time using an overt rehearsal procedure. However, certain methodological shortcomings in Brewer's (1967) study resulted in inadequate control over rehearsal. While Ss had to overtly repeat each pair, they were allowed to make the required number of repetitions as rapidly as they wished, and were thereby not restricted during the remainder of that exposure. Additional uncontrolled rehearsal time was contained in the 2-second interitem intervals, during which time no task requirements were made of Ss.

During a 6-second stimulus-response presentation, for example, Ss could easily have made the required six repetitions in less than three seconds, leaving over five seconds of stimulus-response time and interitem interval time for unrestricted rehearsal. It was for this reason that overt rehearsal was paced in Exp. III. The present study differs from Brewer's (1967) experiment in two other important respects. First, in order to maximize control over rehearsal, there were no interitem intervals. Secondly, a larger range of presentation rates was used to test the TTH.

Interestingly, most of the evidence supporting the TTH has been obtained from studies which have employed an anticipation procedure, e.g., Bugelski (1962), Hovland (1949), Goss, Morgan and Golan (1959), while studies using the study-test method usually have failed to confirm this position, e.g., Johnson (1964), Carroll and Burke (1965), Stubin et al. (1970). In order to understand those instances of total time invariance, it was necessary to incorporate the procedure with which this phenomenon has been obtained. While presentation rates were not expected

to affect total learning time under the usual free rehearsal conditions, it was predicted that this relationship would break down under restricted rehearsal, i.e., total time invariance was not expected to hold when presentation rates and rehearsal time distribution were brought more in line. It was also expected that the use of the anticipation procedure would reveal other aspects of this method which are responsible for those findings supporting the TTH.

Method

Subjects

Ninety undergraduates enrolled in introductory psychology courses at Brooklyn College during the 1972 spring semester served as Ss. All were naive to rote learning experiments. Extra credit was given to Ss for their participation. There were approximately an equal number of males and females in each condition, with ages varying between 17 and 28 years. Two Ss, each from different groups, were discarded; one for failure to understand the instructions, the other for lack of cooperation.

Apparatus

Stimulus materials and equipment were the same as those used in Exps. I and II. The only exception was that four Hunter decade interval timers, connected in series, were used for timing purposes.

Procedure

Block randomization was used to assign 15 Ss to each of the six experimental groups. All Ss were

run individually.

A typical paired-associate anticipation paradigm was used in this experiment. The stimulus item was presented for 2 seconds, followed by a stimulus-response exposure of either 2, 5 or 15 seconds. Including the time required for slide changing, the total exposure time per pair was 5, 8 or 18 seconds. In the Free condition, Ss were given no additional restrictions as to the allocation of study time. While in the Paced condition, Ss overtly repeated the pair which was currently being presented, once per second, to the beat of a metronome. During the instructional period, Ss in the Paced groups were given practice on overt rehearsal. These manipulations combined to form a 3 X 2 factorial design.

Responses had to be either pronounced or spelled correctly in order to be considered acceptable. Criterion was two consecutively correct anticipations of each pair. As in Bugelski's (1962) procedure, learned pairs were not removed; instead, a mean was calculated which was based on the number of trials required to learn each of the individual pairs. Note

that this mean was based on the number of trials up to but not including the criterion trials.

Following their participation, all Ss were questioned regarding the following: the strategy they employed in learning the material; whether or not they had studied items other than the pair which was shown, and if so, how many pairs. In addition, Ss within the Paced condition were carefully questioned as to the effectiveness of this manipulation, and as to whether or not satiation effects had interfered with their performance.

Instructions

The following instructions were read to all Ss. Additional specific instructions given to Free and Paced groups are indicated.

You are participating in a verbal learning experiment. Your task will be to learn pairs of nonsense syllables so that when you see the first item of a pair, you will be able to report the second item of the pair. A nonsense syllable is three letters, a consonant, a vowel and a consonant, which are put together to form a sound, but which have no meaning. That is, you can pronounce these nonsense syllables, but they have no meaning.

You are to study these pairs of nonsense syllables so that when you see the first or left-hand item by itself, you will be able to report the second or right-hand item that went along with it. Let me give

you an example using the colors red-green instead of nonsense syllables. First you will be presented with red, up on that wall. The first time through the list it will be impossible for you to know the other item that goes with red. However, the very next slide will contain the item that goes with red, for example, red-green. Study this pair, so that the next time we go through the list, and red is presented by iteself, you will be able to tell me the item that went along with red or _____. If you haven't learned the correct response keep studying the pair so that you will get it correct the next time through the list. Now, I will always present the left-hand or first item, for example, red, and you will always have to give me the right-hand or second item, in this example, green. It will always be this one way, and never the other way around. Each time we go through the list of eight pairs, the pairs will be in a different order; so it will be impossible for you to learn the order of the second items. You must learn each of the pairs.

If you are not certain of the correct response, take a guess at it. We will continue until you get all items in the list correct, twice consecutively. For this reason, once you get a pair correct don't think you no longer have to know that pair. Again you must get the entire list of pairs correct, twice consecutively.

Remember, tell me the second item when the first is shown.

Free:

As you see each pair, say them out loud once so that I can make sure you are pronouncing them correctly.

Do you have any questions?

Let's begin.

Paced:

As you see each pair, I want you to rehearse that pair by repeating the nonsense syllables out loud, once each time the metronome clicks. So for example, if the pair on the screen were red-green, you would rehearse: red-green...red-green...red-green, etc. Why don't you practice, using red-green. Good, try

it again, using blue-yellow.

Be sure you repeat the pair whether or not you supply the correct response. That is, whether you are right or wrong, I still want you to continue to study the pair being shown, by rehearsing them out loud to the beat of the metronome. If you are not keeping pace with the metronome, I'll remind you.

Do you have any questions?

Let's begin.

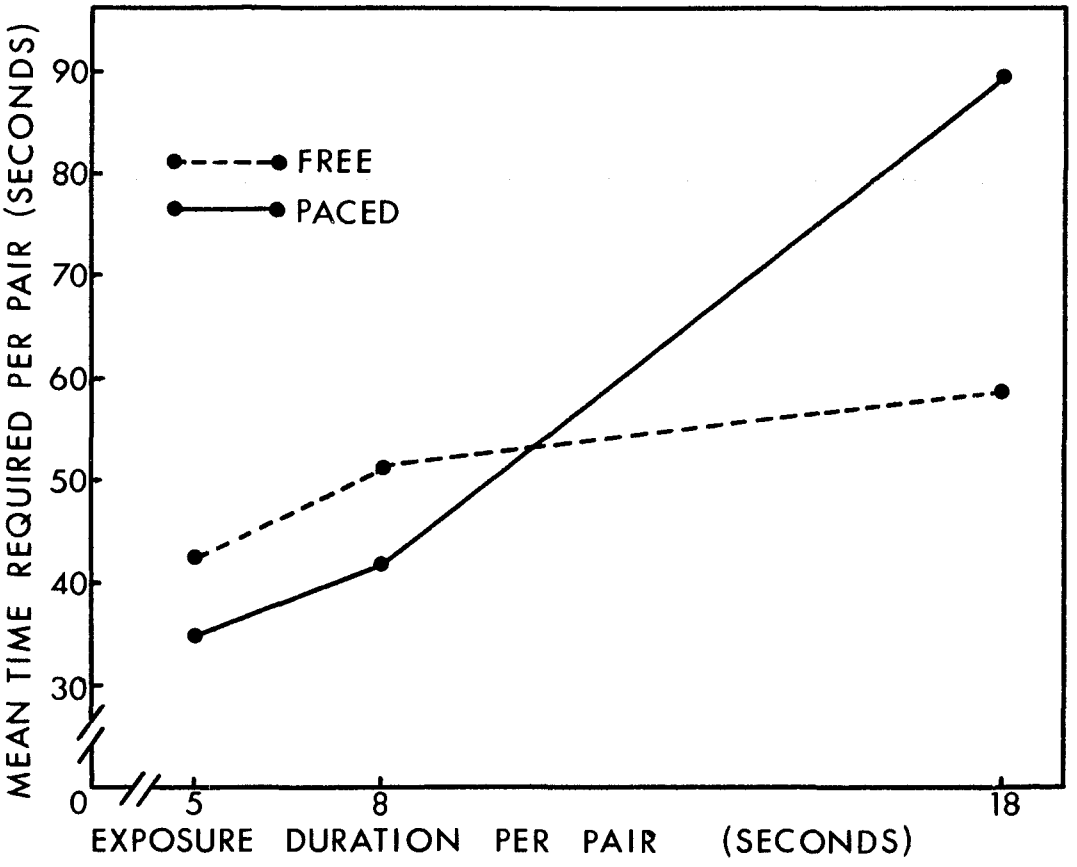
Results and Discussion

The results of Exp. III are illustrated in Fig. 2. A 3 X 2 analysis of variance found that presentation rates were significant, $F(2,84) = 20.86$, $p < .01$, in determining the total time necessary to reach criterion. While the effect of rehearsal method was not statistically significant, $F(1,84) = .87$, $p > .05$, the interaction between the treatments was highly significant, $F(2,84) = 7.76$, $p < .01$.

A one-way analysis of variance confirmed the prediction that total time invariance would be obtained within the Free condition, $F(2,42) = 1.99$, $p > .05$. In addition, each of the three intergroup comparisons, using Tukey's HSD test, failed to reveal a significant difference in performance at the .05 level of confidence.

Within the Paced condition, Ss having an 18-second presentation rate performed significantly poorer than Ss in both the 8-, $p < .01$, and 5-second groups, $p < .01$. The difference between the 8- and 5-second groups was not significant, $p > .05$. Of

Fig. 2. Mean number of seconds required per pair as a function of exposure duration, for Paced and Free rehearsal.


MEAN TIME REQUIRED PER PAIR (SECONDS)
90
80
70
60
50
40
30
0
5
8
18
FREE
PACED
EXPOSURE DURATION PER PAIR (SECONDS)

the three Free versus Paced comparisons, only the difference at 18 seconds proved to be significant, $p < .01$.

A close examination of the learning times within the Free condition reveals an anomaly. While none of the differences among these groups was statistically significant, the difference in total learning time between the 5- and 18-second groups amounted to an increase of 38%. A similiar discrepancy can be found in the original Bugelski (1962) study, in which differences of up to 25% were not statistically significant. An examination of the variances of these groups offers an explanation for the failure to find statistically significant differences. While the group means within the Free condition ranged from 42.54 to 58.65 seconds, the mean of the group standard deviations was 22.32. The corresponding values in Bugelski's (1962) study were 56.1 to 70.1 for the group means, with a mean standard deviation of 25.1. The failure of such marked differences in learning times to reach statistical significance was due to the large variability of scores. A major source of this variability is appar-

ently the differences among Ss with respect to their ability to perform in a paired-associate learning task. An additional component of these large variances may have resulted from the procedure of multiplying the actual dependent variable, trials to criterion, by the independent variable, presentation rate, in order to obtain total learning time scores. Stubin et al. (1970) have indicated that this procedure may result in differential overestimates of actual learning time. In addition, this operation differentially increases the variances in each of the experimental groups since trials are multiplied by different presentation rates. As a result, the within-group variance estimates used in both the analysis of variance and in the intergroup comparisons, become so large that it is extremely difficult to obtain differences which are statistically significant. Note that in the study conducted by Heimer (1968), the total learning times of the 9- and 19-second groups were 58.78 and 108.46 seconds. However, in spite of the fact that total time almost doubled, the differences between these scores was not statistically significant.

Proponents of the TTH may argue that the inferior performance of the Paced 18-second group was due to either difficulties in correctly pronouncing the pairs or to satiation effects (Amster, 1964) caused by prolonged repetition. However, a number of factors argue against this explanation. The repetition rates which have been used to demonstrate satiation, e.g., 2-3 repetitions per second (Lambert and Jakobovits, 1960), are considerably faster than the 1 per second rate chosen for the Paced condition. In an unpublished study by Hodge and Battig[1], satiation effects were reported when Ss were instructed to repeat items as rapidly as possible, while no such effects were found with a repetition rate of 1.5 times per second. More directly, no difficulties in pronounciation were either observed by E during the experiment, or were reported by Ss during the postexperimental interview. In fact, Ss stated that overt rehearsal became easier on successive trials. This finding would not be expected if pronounciation difficulties or satiation had

[1] Unpublished study entitled "Effect of Rate of Repetition upon Verbal Satiation," 1963, cited by Amster (1964).

affected performance. It should be noted that the post-experimental interview consisted of a thorough series of questions regarding the possibility of satiation effects and/or pronounciation difficulties. An analysis of the interview protocol found no evidence to indicate that these factors had hampered performance.

General Discussion

The results of Exps. I and II clearly indicate that presentation rates do affect total learning time, and that these effects are not solely due to differential short-term memory benefits. Equating the presentation-test intervals of the 5- and 40-second presentation rates, either by the review trial or by extending the interval, failed to alter the superior performance of Ss working with the 5-second rate. While the manipulations prior to testing were effective in altering performance, the 5-second groups performed at a higher level under all three conditions, with no interaction between the two experimental treatments. The failure to find any relationship between the length of the presentation-test interval and the proportion of items correctly recalled, further questions the differential short-term memory explanation. However, the results of Exp. I to some degree support Bugelski and McMahon's (1971) argument regarding differential short-term memory benefits. This support is indicated both by the relatively

large increase in the performance of the 40-second condition due to the review trial, and by the smaller difference between the scores of the 5- and 40-second groups having equal presentation-test intervals. However, since presentation-test intervals inherently vary as a function of presentation rate, Bugelski and McMahon's (1971) comment regarding this source of methodological confounding, rather than being a criticism, actually represents a partial explanation of why presentation rates should be expected to affect paired-associate learning. That is, if both recall scores and presentation rate are inversely related to the length of the presentation-test interval, recall scores would have to vary directly with presentation rates. Interestingly, although Bugelski and McMahon (1971) have argued against the efficacy of presentation rates, their criticism actually furnishes an important reason why an invariant learning time relationship should not be expected to hold.

Bugelski and McMahon (1971) have also criticized the procedure followed by Stubin et al. (1970) on the grounds that differences in the number of opportunities

for self-testing existed among conditions. However, it was precisely for this reason that Stubin et al. (1970) adopted their modified study-test procedure. Since there was only one test, and inasmuch as both stimulus and response members were always presented simultaneously, it is unclear as to how rapid rates allowed for additional self-testing.

Bugelski and McMahon (1971) have suggested a third possible reason for the failure of Stubin et al. (1970) to confirm the TTH. This explanation states that the poorer performances associated with longer exposures may actually have been caused by motivational factors such as boredom and lack of attention. However, the rationale behind this explanation does not appear to come from empirical evidence, but seems to be due to subjective interpretations of the experimental situation. A thorough examination of the experimental tasks used by Stubin et al. (1970) and also employed in Exp. I, renders this motivational explanation highly questionable. Although the 40-second presentation rate may seem rather prolonged when compared with 5-second exposures, Ss could not have made this com-

parison since they were only assigned to one condition. Those Ss participating in Exp. I evidenced the typical uncertainty, nervousness and evaluation apprehension that is usually attached to participation in a psychological experiment. There were no observable indications, e.g., looking around the room, that Ss in either condition were not devoting their full attention to the learning task. It should also be noted that for Ss in either the 5- or 40-second condition, participation required a total of only 6 minutes and 30 seconds; insufficient time to become bored in the context of an experimental situation. In fact, a number of Ss in the 40-second exposure condition expressed their surprise at the brevity of the experiment, something which would not be expected in a boring situation. Results of the postexperimental interview confirm the contention that motivational factors did not differ between presentation rates. The two items which were concerned with the question of motivational differences were an overall satisfaction rating of the effectiveness of the particular presentation rate, and more directly, Ss were asked if they had been able to study the material for the entire duration of

the experiment. Although Ss in the 5-second condition were slightly more satisfied with that rate, there were no differences between conditions with regard to the ability of Ss to devote their full attention to the learning task for the duration of the experiment.

Explanations involving motivational differences, which have been used to account for those cases of nonsupport, are further questioned by the results of Exp. II. Since intrapair intervals for all three conditions were the same, it would be expected that those factors determining S's motivation would also have remained relatively constant. However, with this factor equated, a 50% increment in study time failed to bring about any increase in the number of recalled items.

In Exp. III motivational differences were controlled for by having Ss overtly rehearse each pair for the entire stimulus-response interval. Under this condition, there was a dramatic breakdown of the TTH at the 18-second presentation rate.

In view of all of the evidence cited, it is unreasonable to maintain that the differences in per-

formance originally found by Stubin et al. (1970) and replicated in Exp. I were due to differences in Ss' motivation.

A curious aspect of the TTH has been its lack of theoretical basis. A review of the literature in this area reveals that only Cooper and Pantle's (1967) concept of representational response has been offered as a theoretical account of the process underlying the phenomenon of total time invariance. This account simply equates amount of learning with the number of contiguous stimulus-response repetitions. However, this explanation is tenuous in view of the results of Exp. III. In spite of the fact that within the Paced condition, Ss in the 18-second group made no fewer representational responses than Ss in either the 5- or 8-second groups, the performance of the 18-second group was significantly worse than that of the remaining two conditions.

Attempts at demonstrating the superiority of distributed over massed practice in paired-associate learning traditionally have failed to achieve the positive results obtained with perceptual-motor skills

(Underwood, 1961; Underwood and Ekstrand, 1967). However, recent research in this area has dealt with the spacing of individual pairs (Izawa, 1971; Melton, 1970), rather than the traditionally used paradigm of distributed list practice. This evidence indicates that prolonged or massed exposure to a single pair of items is not as efficient as when rehearsal of that pair is spaced. In the set of experiments reported by Izawa (1971), the question of massed versus distributed practice in paired-associate learning was examined with regard to the following variables: spacing of lists, pairs and tests; anticipation versus study-test procedure. This investigation unequivocally demonstrated the advantages of spaced over massed practice. In addition, and of more direct concern, was the finding that when practice times were examined, eight of the nine experiments making up this study failed to confirm the TTH.

Zacks (1969) has suggested that Ss may allocate their study time in a manner different from the presentation rate set by E. For example, under prolonged exposures Ss may study pairs which are not currently being presented, while with rapid exposures they may

concentrate on only a few of the pairs during each trial. In Exp. III, this time-sharing was hindered by requiring Ss to rehearse only the pair which was currently being presented. Support for this time-sharing hypothesis was indicated by the dramatic increase in the total learning time required by Ss in the Paced 18-second condition.

Although Zacks (1969) has suggested that a distinction must be made between presentation rate and rehearsal time allocation, she did not carry this argument to its apparent conclusion. If Ss covertly redistribute study time, what results is not total time invariance, but rather, rehearsal distribution invariance. There are no actual differences in rehearsal when Ss study four pairs of items, for five seconds each, during one 20-second exposure, or when they study a new pair of items which is presented every five seconds. When redistribution of study time is combined with the insensitivity of the anticipation method, the obtained results may well appear to demonstrate total time invariance. However, one has no basis to assume that the process underlying this phen-

omenon involves a reciprocal relationship between study time and trials.

Direct support for the hypothesis that Ss rehearse other items than the pair currently being presented, comes from an examination of the postexperimental interviews. In each of the three experiments, at least 80% of the Ss reported that their rehearsal was not limited to the exposed items. In general, the number of items studied from memory was directly related to the exposure duration.

In addition to being able to account for a number of cases of apparent total time invariance, the concept of time-sharing also indicates why presentation rates should affect performance. Obviously, in many instances memory is not as accurate as the actual presentation of items. As the number of items studied from memory increases, so does the likelihood that these items will be incorrectly rehearsed. Evidence for this statement comes from a number of studies. Carroll and Burke (1965) found that as lists became longer, there was an increase in the effectiveness of more rapid presentation rates.

In the study by Baumeister and Hawkins (1966) previously cited, note that Ss in Group 1, in which stimulus-response pairs were presented for only 2 of 19 seconds of total item time, required an additional three trials or 57 seconds per item to master the same list Ss in Group 3, having 15 seconds of stimulus-response time, were required to learn. Schulz and Runquist (1960) have reported that Ss required 22.5 presentations to reach criterion when 80% of the presentations were blank, i.e., 18.0 blank trials and 4.5 study trials, while Ss having all study trials required only 17.5 presentations. Finally, a number of studies (Calfee and Anderson, 1971; Stubin et al., 1970; Carroll and Burke, 1965; Johnson, 1964) have found optimal presentation rates of between two and five seconds. In fact, Bugelski and Rickwood (1963) have found that under self-pacing conditions the average exposure duration, as set by Ss was five seconds. The efficacy of these rates probably results from the fact that while time-sharing can take place, there is little opportunity for incorrect rehearsal since Ss rehearse only those additional items that they know well.

Under prolonged exposures, effective time-sharing becomes more difficult since Ss are more reliant upon, and place more demands on, memory. For example, with a 5-second presentation rate, Ss may study the item being presented and one additional pair which has been seen relatively recently; however, with 20-second exposures, Ss may attempt to study three additional pairs. Not only are more items studied in the latter condition, but the intervals between presentation and covert recall also become longer due to the increased exposure duration. In this connection the results of Exp. II are particularly relevant. The RRR versus RDR comparison indicates that the middle portion of a relatively long exposure does not function in an effective manner. While the DT had no adverse effects when located within a presentation, there was a significant decrease in performance when the task was moved to a position between successive pairs. Based on these results, it appears as if the initial portion of an exposure is devoted to studying the presented pair. This is followed by or alternated with the rehearsal of as many other items as is possible. The limit of this time-sharing rehearsal

is set either by the exposure duration or by memory. Note that once the number of available items has been rehearsed, further increases in exposure time would not benefit learning. The last glimpse of an item would allow that pair to be easily recalled during the presentation of the following pair. In Exp. II, once the number of available items had been rehearsed, increased presentation time was of no significant value. However, by placing the DT between successive items, Ss were prevented from making immediate comparisons of pairs. These comparisons are necessary for the establishment of intralist discriminations.

Additional support for the time-sharing hypothesis was obtained from the postexperimental interview. Ss in the slower presentation rate condition stated that they were able to maintain up to three additional items in memory besides the item which was being presented. This finding may account for the apparent support of the TTH with presentations of 18 seconds or less, and for the breakdown of this relationship with longer exposures. Since Ss report being able to maintain up to four pairs in memory, Ss' allocation of 18 seconds

of presentation time may have been very similar to the optimal rates previously indicated. However, per item rehearsal time would have been increased to the point of inefficiency when the maximum four pairs were distributed over 40 seconds. This explanation would account for the differences between the findings of Bugelski (1962) and Heimer (1968).

While the Cooper and Pantle (1967) review article appears to support the TTH in paired-associate learning, a re-examination of the studies they cite indicates that the evidence in favor of the TTH is not as substantial as originally suggested. A limiting condition of most of the studies which were cited as favorable to the TTH (e.g., Goss, Morgan and Golin, 1959; Wilcoxon et al., 1961; Newman, 1964; Hovland, 1949) was that the continuum of presentation rates was so restricted (less than 6 seconds in each study), that Ss could easily have overridden the indicated distribution of rehearsal time. Secondly, either Cooper and Pantle (1967) or the original authors tended to select only those instances of support and have not indicated the number of times the TTH was not confirmed. For example,

of the large number of total learning time comparisons which could have been conducted in the Newman (1964) study, only two were reported. Although the two comparisons which Newman (1964) reported happen to support the TTH, the significance of this fact can not be determined without the results of the remaining comparisons. In citing the work of Baumeister and Hawkins (1966), Cooper and Pantle (1967) failed to include the results of all five experimental groups. In each of the three groups which were cited, the total exposure time per trial was 19 seconds. The total learning times required by these three groups were 231.8, 207.1 and 174.8 seconds, respectively. The total exposure times of the two omitted groups were 6 and 11 seconds per trial. A comparison of the learning times obtained under these two conditions, 105.6 and 122.1 seconds with the three scores which were reported by Cooper and Pantle (1967), actually appears to question rather than support the TTH. Unfortunately, Baumeister and Hawkins (1966) did not statistically analyze these differences.

Taken together, the results of the three experiments reported in the present study indicate that presentation rates do effect performance in paired-associate learning. They further suggest that the efficacy of more rapid exposures can not be entirely attributed to short-term memory and/or motivational factors. Finally, it appears that those instances of total time invariance can easily be explained in terms of time-sharing. A review of the literature in this area, as previously indicated, reveals that experiments favorable to the TTH have used restricted presentation rates, items of low intralist similiarity and short list lengths. Note that all of these factors would enable Ss to more effectively rehearse items other than the pair currently being presented.

Within psychology, established instances of reciprocity, e.g., Bunsen-Roscoe and Ricco's Law, have only been found to hold over a limited set of values. However, even within the range of times which have supported the TTH, it appears that these results were not due to a time-trial trade-off, but rather to the reallocation of exposure time.

Bugelski and McMahon (1971) have argued for a reformulation of Bugelski's (1962) original equation. This modification would replace presentation time with learning time. Considering the probable nature of total time invariance, any manipulation which would reduce Ss' ability to override inefficient rehearsal time distributions would quite likely eliminate even those situations in which reciprocity has been observed.

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