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THE ROLE OF REPETITION IN LEARNING PAIRED ASSOCIATES

A Thesis

Presented to the

Department of Psychology

and the

Faculty of the College of Graduate Studies

University of Omaha

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by 784

Douglas C. Chatfield

August 1967

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Accepted for the faculty of the College of Graduate Studies of the University of Omaha, in partial fulfillment of the requirements for the degree Master of Arts.

John M. Newton — Psychology

Chairman — Department

Graduate Committee

Raymond A. Ziebarth — Secondary Ed.

Name — Department

Richard L. Ratliff — Psychology

D. B. Pedrini — Psychology

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Chairman Department

Graduate Committee

Name Department

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CHAPTER I

INTRODUCTION

Learning has been said to increase with practice ever since the early experiments by Thorndike. This idea has not only been intuitively appealing to both layman and scientist alike, but it can also be demonstrated empirically in the group-learning curve. When a person is to learn a series of associations, there must be a repetition of trials whereupon the two elements that are to be associated are presented together. Just how the strength of the association increases through repetition has sparked some controversy recently as well as in the past.

Hull (1943) proposed the idea that increments in habit strength, or the strength of an association, was a function of the number of reinforced trials. In demonstration of this, the responses of a group of subjects, taken as a whole, would be plotted against the number of reinforced trials. The resulting curve was usually described as a negatively accelerated exponential function, the coordinates of which would be determined by group performance.

Guthrie (1935, 1946) took exception to this view, however, arguing that the learning curve was an artifact of combining the responses of individual subjects. Guthrie, in looking at the individual subjects and the unit to be learned, put forth the view that learning was an all-or-none process. That is, on any single trial, an association is either made or it is not, with no gradations in the strength of the association. Since an association took only one trial to gain full strength, the function of repetition was merely to present the organisms with a series of occasions on which an association might be made. Guthrie argued that the averaging of responses of individual subjects made the learning curve take on the appearance of a smooth incremental function instead of the "step-like" function which he reasoned it to be.

For quite a few years, proponents of these two schools of thought were very much opposed to each other. It seemed as if they were looking at two different portions of the data, one stating that the group-learning curve was evidence for an incremental theory while the other held the individual response on a single item as evidence for an all-or-none theory. When the incrementalists did begin looking at the individual on a single item, the did not find it necessary to drop their incremental viewpoints as Guthrie expected them to do. Hull (1943) noticed that an individual may go several trials before responding correctly to an item. After the first correct response, the individual may go several trials before again responding correctly. As more trials are presented the individual will begin to respond correctly more frequently. On still further trials, the item is consistently being responded to correctly. This would suggest that the association is gaining strength as a result of repetition. The all-or-none position would have to predict, however, that an individual would consistently respond incorrectly to an item until the trial on which the item is learned. Since the association is then said to be at full strength, the individual should always respond correctly thereafter.

This led to an increase in the controversy in which both sides claimed voluminous support. After many years of publications, there was a general lull in the controversy. The controversy was revitalized, however, when Rock (1957) put forth the idea that the all-or-none assumption was still tenable in light of his findings. He used a unique experimental design in which items from a list of paired associates that were missed were dropped from the list and substituted by new items. He was assuming that any item, to which a correct response was given, was learned. The rationale was that a group of subjects (Ss) would not have the benefit of repetition, if on every trial, items that were missed (not learned) were replaced by new items. This group was compared with a control group which learned the items under standard procedures, i.e., incorrect items were not replaced. Using this technique, Rock found no difference between the two groups. He interpreted this to mean learning took place in an all-or-none fashion.

This finding was replicated and extended in a study by Wogan and Waters (1959). Their study was exactly the same as Rock's except that they brought the Ss back one week later for a relearning session. Upon returning, each S was given a test for retention and was then required to relearn the material to one errorless trial. For the group in which all incorrect items had been replaced, (Rock's experimental group) the list presented for relearning was the one used on the trial on which the criterion had been achieved. During relearning, no substitutions were made in the lists.

The results were that the experimental and control groups did not differ on either total errors or trials to the criterion, thus confirming Rock's results. Upon relearning a week later, it was found that neither mean errors on the first test of retention nor mean errors to criterion showed significant differences between the control and experimental groups. From this Wogan and Waters concluded that frequency neither facilitates the formation of connections nor strengthens connections already formed.

Rock and Heimer (1959) performed a series of investigations in order to forestall any possible objections to Rock's previous findings. Their first study was carried out with the purpose of controlling for the possibility that the technique of substituting new pairs for unlearned pairs eliminates the opportunities for making wrong associations. The results of the study seemed to again show that learning should be thought of as an all-or-none process and that eliminating opportunities for wrong associations by substitution does not have much effect.

Since the basis of Rock and Heimer's argument was the fact that two groups were not significantly different, in their second study they turned their attention to the possible objection that their tests were not sensitive enough. Previous experiments had used the method of recall to ascertain whether or not an association had been made. It was reasoned that the use of a matching test would provide a more sensitive test than the method of recall. The matching test was devised in such a way that a subject was given a choice of eight alternative responses for each stimulus. It was the Ss task to select the correct response from the eight alternatives which were arranged in a circular pattern.

Three trials were given in which the Ss were to learn the list of paired associates. Then the matching test of recognition was given. On the critical fourth trial, the unlearned pairs were pitted against a new group of pairs which they had not seen before. After this fourth learning trial, another recognition test was given. In analyzing the responses on this last test, it was found that significantly more of the previously unlearned pairs had been learned on the fourth trial than the new pairs which were seen for the first time. This of course was support for the incremental view and was probably unexpected.

The third study presented in Rock and Heimer's article was devoted to explaining the above mentioned results. They reasoned that one possible explanation of the outcome of Experiment II was that some of the pairs scored wrong after the third trial had been learned but because of momentary failure of memory could not be responded to correctly on the test. Experiment III was conducted to determine if this was true. In this experiment, Ss were given three learning trials and then a matching test of recognition as before. Following this, five minutes of light conversation was introduced in order to allow the S to reminisce, after which a second test was given. Now the unlearned pairs given on the fourth critical trial consisted of only those pairs incorrect on both tests. The results showed no difference between the new pairs and the previously unlearned pairs, again lending weight to the all-or-none view. From this it was concluded that the results in Experiment II could be attributed to the fact that some of the so-called unlearned pairs used on the fourth trial actually had been learned on one of the earlier trials as was shown when reminiscence was introduced.

In the last study, Rock and Heimer concern themselves with the possibility that in eliminating unlearned pairs, as was done in the original 1957 study, an advantage was given to the non-repetition group. This is brought about by the fact that the harder pairs, by their very nature, are always last to be learned. Thus for the non-repetition group these pairs are dropped from the list, and other pairs (easier on the average) are substituted in their place. The control group (under the repetition condition) is presented with the same list each time, hard items included. If all this is true, then any advantage the control group may have had through repetition, may have been compensated for by their disadvantage of not having the harder items eliminated, thus causing the two groups not to differ.

In an attempt to control for this, pairs experienced once but not learned were pitted against those of a longer list experienced four times but not learned. The assumption was made that both lists were of equal difficulty since both contained pairs the Ss had not been able to learn. It was found that there still was no significant difference between the number of pairs learned from both lists, bringing about the conclusion that repetition had no effect.

During the 1950's, Estes had put forth a statistical learning theory (Estes, 1956, 1957, and 1957: Estes and Burke 1953) which was based on Guthries' assumption that learning was an all-or-none phenomena. Part of the basis for this assumption was the studies by Rock and others. To add more weight to this argument Estes, Hopkins, and Crothers (1960) used a somewhat different experimental design. They used what they called an "RTT" paradigm in which one reinforcement trial is given (showing the stimulus with the response) followed by two test trials. If the incremental assumption holds, there should be a greater number of items responded to correctly on the second test (given that they were missed on the first test) than would be expected by chance. If the all-or-none hypothesis is true, then the probability of getting an item correct on the second test when it was missed on the first test, should be zero or at most of probability of getting the item correct by guessing. Estes, et al. found the latter to be true, i.e., the items missed on the first test tended to also be missed on the second test.

Other studies such as the one by Murdock and Babick (1961) which used the method of free recall to study the effect of repetition on learning, seemed to also find that repetition had no apparent effect on learning. The principle of all-or-none learning was far from being universally accepted however. Those studies showing all-or-none effects were criticized on numerous grounds, despite Rock and Heimer's attempt to forestall all possible objections. The four main areas of criticism were in the type of dependent variable used, the rate of presentation, the instructions or methods used by the Ss in learning, and most of all the problem of elimination of difficult items, even though Rock and Heimer attempted to control for it in their last experiment.

It was this last criticism that commanded the greatest attention of the investigators in the field. Several studies have shown that Rock's elimination procedure does give the non-repetitive group an advantage in eliminating the harder items (Postman, 1962; Underwood, Rehula, and Keppel, 1962; and Williams 1961, 1962). Since this advantage offsets any disadvantage accruing from lack of repetition, any reports of the two groups being equal was thought to be an artifact of the elimination procedure. In fact those studies criticizing this, report that when this selection bias in controlled, the two groups actually do seem to differ significantly with the repetition group being able to learn a list of paired-associates faster.

These studies themselves, however, are not without their own flaws. Underwood and Keppel (1962) used the Underwood-Schulz tables (1960) to try to control for item-level difficulty. Selected from these tables were paired-associates which had low-association values. Two groups were given two trials. On the second trial, the experimental groups' items which were incorrect on the first trial were replaced by new items. The control group was allowed to try the incorrect items again. This design was much like that of Rock's with the exception that only two trials were given. The results were that the two groups did not differ significantly on the second trial. When a correction was made for differences on the first trial, the difference found on the second trial was significant at the .05 level. In a second study the items missed on the first trial by the experimental group were paired with new responses on the second trial. This was to cause negative transfer in an effort to widen the difference between the two groups. Again the difference was found to be insignificant. In looking at the items however, the item difficulty was found to be significant in spite of the use of the Underwood-Schulz tables in trying to control for this. Taking this into account a statistical correction was made which finally produced a significant difference between the two groups. Underwood interpreted these findings in favor of the incremental assumption.

Those experiments showing all-or-none effects were also criticized on their rate of presentation. Lockhead (1961) and Williams (1962) argued that if the presentation rate, i.e., the rate at which each pair is presented to the S is too slow, the S will have time to rehearse each pair to himself before the presentation of the next pair. Thus with slow presentation rates, what was thought to be a single trial would actually be made up of a number of covert rehearsals. The studies by Rock (1957), Wogan and Waters (1959), and the first three studies by Rock and Heimer (1959) all presented each pair for three seconds with a five-second interval between pairs giving the S eight seconds in which he could possibly rehearse. Estes, Hopkins, and Crothers (1960) presented each pair for four seconds with four seconds between pairs which also yields an eight-second possible rehearsal interval. Lockhead (1961) compared this slow rate with a faster rate of .75 second with the pair in view and 1.25 seconds between pairs. He found that with the faster rate the all-or-none phenomena began to disappear and the effects of practice become apparent. Williams (1962) obtained similar results.

The third criticism was that Rock's dependent variable (trials to criterion) was a poor one because it lacked sensitivity. Reed and Riach (1960) report a study in which all-or-none effects were found if number of trials to a criterion was used as a dependent variable, but incremental effects if the number of errors were used. Williams (1962) went further to state that response latency would be a more appropriate measure for detecting gradual increases in the strength of an association.

Hinrichs (1965) reports a study using response latency as one of the dependent variables as did Williams. Williams had shown that after acquisition the response latencies continued to decrease, supporting the incremental position. Hinrichs also confirmed this finding in her study. However, if the incremental position is to hold, the latencies should not only continue to decrease after acquisition but also be decreasing prior to acquisition with no "sudden" decrease at the time of the first correct response. Hinrichs did not find this to be so. She found that the latency was not decreasing prior to the first correct response and that there was a sudden drop in latency at the time of the first correct response. She also found the latencies at the time of acquisition to be consistent regardless of the number of previous trials. The all-or-none position was supported again by the fact that the probability of a correct response on the second test trial, given that the response was incorrect on the first test trial, was no more than you would expect by random chance. Hinrich's study, however, used a relatively long presentation rate of seven seconds which Williams (1962) thought would be crucial.

The only conclusion that can be drawn from the studies cited here is that the question of the role of repetition in learning is unsettled. In many studies evidence for all-or-none learning has been produced, but yet discredited in other articles because of procedural flaws. The studies committing these procedural flaws are therefore denied the right to proclaim that all learning takes place on an all-or-none basis. The existence of these flaws, however, does not in turn allow one to deduce that all learning takes place on an incremental basis.

The problem is that both sides, in putting forth their opposing propositions, speak as though they are both assuming what the mathematician refers to as "universal quantifiers," i.e., implying that "all" learning is of such-and-such type. The negation of this type of proposition is not that "all" learning is of the other type, but rather that "some" learning is of the other type. This last proposition uses what is referred to as an "existential quantifier." The implication of all this is that one need not laboriously prove that "all" learning is of the other type in order to disprove the first proposition, but only need prove that at least one incidence of the other type of learning exists. The reason for bringing this up is the fact that Estes, (1959, 1960, 1961) in presenting his stimulus sampling model, essentially agrees that in some situations learning takes on the incremental characteristics that the incrementalists have shown, but yet he asserts that there "exists" conditions in which all-or-none characteristics prevail. In proof of this proposition, only one clear-cut case or set of conditions in which Ss actually learn on an all-or-none basis must be found to establish existence.

Research on this question of the role of repetition has been motivated to a large extent by the development of mathematical learning models. By their very nature, mathematical models must make a few assumptions for simplification. These assumptions are usually represented in the form of axioms. One of the axioms or assumptions currently in question is that concerning the role of repetition in paired-associate learning. In fact, mathematical learning models can be grouped into two groups according to their position on the question of repetition. Those adhering to the incremental assumption are usually referred to as linear models. Examples of these are the models presented by Bush and Mosteller (1955), Bush and Sternberg (1959), and Luce (1959). Estes (1959), Bower (1961, 1962) and Suppes and Ginsberg (1963) are some of the authors of models based on the all-or-none assumption. Norman (1964a, 1964b) presents a model which he refers to as the random-trial-incremental-model.

Recent articles offer some comparison of the models (Crothers, 1962; Estes, 1960, 1961; and Atkinson and Crothers, 1964) on the basis of goodness-of-fit. A good portion of the research seems to point favorably toward the models which include the all-or-none properties.

Research to date has not been conclusive in regard to the question of the effects of repetition in learning, thus the present study was done in an attempt to shed some light on the subject. Since the present study was not inclusive enough to put an end to the controversy, it was hoped that it might at least lend support to one side or the other and point out the direction for further research which might ultimately bring the question of repetition to a conclusion.

The rationale behind the present study was influenced by the discussions in the literature of two learning models with Markovian interpretations which were proposed by Estes (Estes 1961, 1960; Koch 1959; Atkinson and Estes, 1960). These were known as the stimulus sampling model and the single element pattern model.

The reasoning behind the first model was that every stimulus which elicits a response is made up of a number of smaller stimulus elements. Not all of these elements are available for conditioning on every trial. On a single trial a certain proportion of the elements (the ones available) are conditioned in an all-or-none fashion. On the next trial, a proportion of the elements left are sampled and again conditioned in an all-or-none fashion. This sampling of elements continues over trials. The strength of the stimulus-response association at any one time is represented by the number of the smaller stimulus elements which have been conditioned up to that point.

When a stimulus is made up of only one element, the single element pattern model should provide a better fit to the data. Here the whole stimulus pattern is assumed to be made up of one single element which is learned on an all-or-none basis.

The stimulus sampling model under certain conditions, is algebraically equivalent to Bush and Mosteller's linear operator model, (Koch, 1959) which is based on the incremental assumption. Thus the two models in some situations are equivalent. The pattern model, however, clearly differs from the linear operator model. It is used when the total stimulating situation, to which a response is to be conditioned, is represented in a pattern or is such a small unit that parts of the unit cannot be conditioned without the whole unit being conditioned. It has been shown that in certain situations in learning paired associates, the pattern model provides a better fit to the data than a model based on incremental assumptions, (Atkinson and Crothers, 1964).

It was the feeling of this author that the size of unit to be learned (i.e., the size or complexity of the stimuli in a list of paired associates) would be critical in testing the effects of repetition. If the stimulus to be associated is large enough to be considered to be made up of many small elements, the item will give the appearance of being learned in increments since the smaller elements would be learned independently of each other. However, if the stimulus were small enough to be considered one single element in itself, it might display all-or-none properties. The goal then would be to find the size stimulus unit that will display all-or-none properties, if such a unit exists.

The strategy of the present study was to perform an experiment using a variation of Rock's elimination procedure. Two types of paired-associate items were to be used, one type in which the stimulus members would be simple and the other type in which the stimulus members would be relatively complex. This letter type was to be created in such a way that it would be feasible that a part of the stimulus might be associated with the response on any one trial without the whole stimulus being associated. Thus you would essentially have the sampling of stimulus elements to be conditioned on each trial, which Estes (1950) refers to in his stimulus sampling theory. This more complex type of stimulus should then give the appearance of being associated with a response in an incremental fashion. Using larger and more complex types of paired-associate items then should result in incremental models such as Hull's or Bush and Mosteller's (1955), fitting the date more accurately than all-or-none models.

The smaller type of stimulus would be predicted by the all-or-none theorists to be learned in one trial, if the stimulus is composed of only one element. However, even if composed of more than one element, the fewer the elements, the more it will take on an all-or-none appearance. Using these two types of stimuli then should show whether or not this "complexity" variable has any effect on whether or not a paired-associate item is learned in increments or in an all-or-none fashion. If stimulus complexity is a factor then further research defining the limits of just what is to be called a complex stimulus may show that those studies reporting incremental effects, were using complex stimuli. It might be worth noting that a large portion of the studies reporting all-or-none effects used only one or two letters as stimuli, whereas the majority of those reporting incremental effects used stimuli of three or more letters.

As a small, supposedly single-element stimulus, the present study used a two-letter digram. A single letter would have been used except that it seriously restricted the number of items available. A single digit number was used as the response so that complications with encoding assumptions could be avoided. One group used a list of paired associates made up of the digrams while another group of subjects used a list comprised of larger units. These were made up of four consonants paired with two numbers which were referred to in the present study as quadragrams. Those learning the quadragrams were to be compared with subjects learning the smaller digrams. It was believed that since the quadragrams were more complex and thus might comprise more than one element, they might be learned in increments. The smaller digrams, it was thought, should tend to manifest all-or-none properties.

A design suggested by Crothers, referred to as an RTRT design, was used as a test of the all-or-none assumption. This is where a reinforcement trial (R) is followed by a test trial (T) which is in turn followed by a reinforced trial followed again by a second test trial. A reinforced trial consisted of a presentation of the complete list of paired associates showing the response to each item. A test trial was a presentation of the items in which the subject was to call out verbally the response to each of them.

A procedure similar to Rock (1957) was used in conjunction with the RTRT design. The subjects using the list of digrams were divided into a control group and an experimental group. For the experimental group, the items missed on the first test trial were replaced by new items. The items missed by the control group were not replaced. The test of the all-or-none assumption rested in these items. The second reinforced trial (R_2) for the control group was comprised of only the items missed. The second reinforced trial (R_2) for the experimental group was made up of the new items which were replacements for the items missed on the first test (T_1). Neither group was shown any items during R_2 which has been correct on T_1.

On the second test (T_2) the experimental group was being tested on new items, while the control group was being tested on items which they had missed on T_1. If any increase in strength of association had taken place, even though the items had been missed, the control group should get a higher proportion of items correct than the experimental group. If the two groups were the same in terms of the number of correct items on T_2, this would be an indication that the items were learned in an all-or-none manner.

There was a replication of the previously mentioned design using quadragrams in place of digrams as the material to be learned. The use of more complex items was to result in learning taking place on an incremental basis. In other words, the control group would make more correct responses on T_2 because it had the advantage of seeing the items for the second time even though they had not reached the threshold of correct recall, to use Hull's terms.

Thus, to put what has been said in the form of hypotheses, they would be: (1) There would be no significant difference between the two groups when the digrams were used indicating that these smaller stimuli were associated with their responses on an all-or-none basis. (2) There would be a significant difference when the quadragrams were used indicating incremental learning.

Support for these hypotheses would indicate that stimulus complexity, or theoretically the number of elements in a stimulus, needs be taken into account in studies on repetition. It would also be a start in defining the area of paired-associate learning in which Estes' all-or-none pattern model would provide a better fit than the stimulus sampling model or any incremental model. If it can be said that the present study instituted controls for the procedural flaws found in the studies of Rock, then verification of the first hypothesis would be further evidence of the existence of all-or-none learning.

CHAPTER II

METHOD

Pilot Study

The material which the subjects in the present study were to learn was of two types. One type referred to as "digrams" was made up of two letters which were paired with a number. Both consonants and vowels were used. The number which was paired with the two letters varied from one to nine inclusive. The subjects using the digrams were confronted with a list of twelve.

The second type of paired associate material consisted of four letters paired with two numbers. The four letters, which were considered the stimulus portion, were arranged in two rows and two columns (Fig. I). The response portion of an item, (the two numbers) were arranged one over the other. Each of these numbers were allowed to vary from one to three inclusive.

FIGURE I

TYPES OF PAIRED-ASSOCIATE ITEMS USED

Digram	Quadragram
AJ 7	QX 3 TL 1

It has been shown (McGeoch 1930) that paired associates have differing association values which affect the rate at which they will be learned. Because of this, it was deemed advantageous to run a pilot study. Here a large pool of possible paired-associate items were indexed according to their association value. From the large pool, homogeneous items with low-association values were selected to form the lists of paired associates to be used in the main portion of the study.

The procedure used in the pilot study was patterned after a study by Glaze (1928) with some modification. One hundred thirteen students (both male and female) from a freshman psychology course at the University of Omaha during the fall semester of 1965 were used in the pilot study. The subjects (Ss) were run in three groups consisting of 24, 36, and 53 persons.

The Ss were seated in a classroom with a screen at the front of the room. Ordinary typing paper was passed out and pencils were given to those who needed them.

Prior to this 250 2" x 2" projector slides had been made. Two hundred combinations of letter pairs were generated by a table of random numbers. Fifty four-letter combinations were generated the same way. The letters were printed on the slides with the use of black acetate ink.

It was decided that the presentation rate of three seconds would be used in flashing the slides on the screen. This short interval would take into account the discussion by Williams (1962) when she criticized the longer presentation rates in other studies.

The Ss were instructed to watch the slides being flashed on the screen. They were instructed to write down all letter-pairs (or 4 letters in the second type of items) for which they could associate something. The instructions were as follows:

> This is an experiment in learning a list of nonsense syllables and not a psychological test. We are interested in certain complex relationships of the learning process common to all people and not at all concerned with your personal reactions.
>
> On the screen in the front of the room you will see two letters such as I have now flashed. A long series of these will be presented on the screen with this slide projector. It will be your task to look at these as they are presented. If you associate any of these with something (e.g., I associate Charles Dawson with this), you are then to print the pair or letters on the sheet of paper that was just passed out to you. Thus in this case, I would print "cd" on the sheet but I would not print "Charles Dawson." Then when the next pair of letters is flashed if it makes me think of something that I can associate with it, then I would print that pair of letters under the first pair and so on. Remember to write down only the pairs of letters that make you think of something and not any that you cannot think of something to associate it with.
>
> A pair of letters will be flashed every three seconds so you will have to print fast but print legibly. Listen for the noise of the mechanism in the projector so you will be able to tell when a new slide is being flashed in case you are looking down

at your paper at the time. Two hundred slides, each with a pair of letters, will be shown to you first. Then fifty slides will be shown containing four letters each. With this last fifty, the instructions are the same, i.e., write down the four letters with which you are able to associate something.

The instructions were designed to motivate S to try to think of associations, but not to think he has to make an association for every slide.

The results of the pilot study are shown in Table I. Upon tabulating the results, some of the slides were found to be repeats, i.e., two slides were found with the same letters. When repeats were found, both slides were omitted from the results along with any slides damaged during the study. This brought the number of two-letter slides down to 181 and the number of four-letter slides to 47. The association value for a specific item is represented by the proportion of the 113 Ss which had written down the item indicating that they were able to make an association with it.

Thirty-two two-letter items were selected from the list of 181. These were the 32 items having the lowest proportion of persons indicating they had made an association with them. Sixteen four-letter items were also selected in the same manner from the list of 47. The lists of 32 and 16 were later shortened to 24 and 12 respectively. Number responses were assigned to the stimulus stems of the paired associates through the use of a table of random numbers. The completed items were then divided into four lists as shown in Table II. As can be seen the items are fairly homogeneous in that the association values only range from .08 to .19 for digrams and .01 to .11 for quadragrams.

Subjects

A total of 217 Ss participated in the present study. In the pilot study 113 Ss were involved. Forty Ss took part in the main study before it was decided to shorten the lists from 16 and 8 items to 12 and 6 respectively. Thus the tests of the hypotheses rests on the remaining 64 subjects which used the shorter lists. Of these 64 Ss, 31 were female and 33 were male. All subjects were enrolled in an introductory psychology course at the University of Omaha.

Experimental Design

The subjects were divided into four groups of 16 each, Groups A, B, and C had 8 women and 8 men each. Group D had 9 men and 7 women due to an error in scheduling. Groups A and B had the task of learning digrams while Groups C and D used quadragrams.

Only two cycles were used in the analysis. A cycle is defined as one reinforced trial (R) and one test trial (T). Each S in Group A was paired with another S in Group B. Subjects in Group C were likewise paired with Ss in Group D.

TABLE I

PERCENTAGE OF Ss INDICATING THAT THEY WERE ABLE TO MAKE AN ASSOCIATION WITH EACH DIGRAM

%	%	%	%	%
AA - 83	EP - 35	KE - 39	QV - 12	WR - 33
AC - 89	ER - 50	KG - 51	QX - 12	WW - 42
AD - 92	ET - 71	KI - 42	RA - 50	XA - 17
AF - 92	EX - 53	KJ - 24	RE - 44	XI - 47
AI - 52	EZ - 66	KL - 30	RO - 51	XN - 07
AL - 85	FA - 56	KQ - 18	RZ - 19	XT - 09
AO - 52	FW - 39	KS - 56	SE - 81	XV - 13
AR - 59	GP - 44	LA - 86	SM - 65	XY - 28
AX - 62	GE - 75	LM - 73	SN - 61	YB - 24
BG - 69	GG - 45	LN - 49	SO - 80	YC - 23
BM - 74	GJ - 17	LO - 71	SU - 63	YF - 15
BO - 87	GL - 36	LR - 46	SZ - 30	YI - 21
BP - 27	GN - 40	LS - 61	TF - 53	YJ - 09
BT - 72	GW - 43	LX - 30	TJ - 74	YN - 21
CB - 67	HB - 59	LZ - 33	TL - 32	YQ - 10
CE - 42	HD - 58	MD - 96	TM - 59	YR - 32
CH - 61	HH - 57	MF - 58	TR - 52	YS - 40
CM - 38	HS - 86	MM - 79	TS - 74	YU - 50
CP - 66	HW - 42	MO - 83	TT - 56	YW - 18
CO - 81	IC - 57	MZ - 18	UB - 32	YZ - 14
CV - 29	IF - 83	NJ - 70	UF - 48	ZB - 19
CW - 49	IH - 19	NT - 50	UR - 38	ZD - 11
CZ - 12	IP - 33	NW - 63	UV - 15	ZE - 24
DA - 71	IQ - 94	NY - 97	UY - 12	ZG - 19
DC - 97	IR - 41	OB - 65	VE - 40	ZF - 08
DG - 65	IT - 85	OC - 40	VM - 31	ZI - 32
DI - 46	IV - 51	OR - 80	VV - 23	ZM - 15
DM - 62	IY - 15	OV - 35	VW - 42	ZO - 53
DS - 52	JE - 44	PC - 44	VX - 13	ZQ - 07
DT - 72	JH - 51	PK - 50	VY - 12	ZR - 13
DX - 74	JK - 72	PQ - 29	WV - 38	ZU - 38
EA - 40	JR - 69	PS - 90	WD - 31	ZY - 08
EB - 42	JT - 28	PU - 86	WF - 35	ZZ - 35
EH - 24	JV - 37	PV - 25	WG - 28	
EL - 62	JX - 28	QA - 27	WL - 30	
EN - 43	KA - 43	QH - 12	WM - 62	
EO - 26	KB - 43	QL - 13	WN - 35	

TABLE I -- Continued

%	%	%	%	%
AC HB - 22	EB YF - 07	KG IY - 12	GH MZ - 03	VJ XH - 01
AO LN - 19	ET VY - 10	KQ PK - 11	QX TT - 08	WV LZ - 05
AR MD - 61	GE EX - 19	LC RC - 16	RG AL - 32	XY YB - 10
AX KI - 22	GL JS - 12	LC RZ - 06	SS OU - 55	YJ JX - 06
BA GU - 20	GZ GM - 11	LH XS - 04	SZ ZY - 11	ZF IR - 08
BP AA - 36	HD UY - 11	MZ XA - 19	TD LG - 12	ZI AL - 22
CV SM - 11	HH DM - 27	NP WC - 31	TE IO - 27	ZR YR - 09
DA CP - 31	HI DX - 26	OO CR - 21	TS EA - 37	ZU XN - 07
DS WD - 17	IY YI - 21	QL CB - 15	VI FB - 18	ZZ LA - 29

TABLE II

THE ITEMS SELECTED FOR THE FOUR LISTS

Digrams				Quadragrams			
List I		List II		List III		List IV	
%	Items	%	Items	%	Items	%	Items
.08	ZY 7	.18	KQ 8	.04	LH 3 XS 2	.01	MZ 2 XA 2
.13	VX 9	.13	QL 4	.11	GZ 3 GM 1	.11	SZ 1 SY 2
.15	IY 9	.12	QX 7	.09	ZR 1 YR 3	.10	ET 1 VY 3
.15	YF 2	.12	QV 2	.03	QH 2 MZ 1	.01	VT 1 XH 1
.13	XV 4	.19	ZG 9	.11	KQ 3 PK 1	.08	EB 3 YF 3
.09	YJ 6	.19	IH 1	.08	QX 2 TT 3	.11	CV 3 SM 2
.17	XA 2	.19	YW 6				
.18	MZ 3	.09	XT 2				
.12	VY 7	.09	YQ 3				
.14	YZ 8	.13	ZR 3				
.12	CZ 1	.11	ZD 6				
.17	GJ 8	.18	XN 6				

A subject in Group A was shown a list of digrams complete with answers on R_1. On T_1, the S's task was to call out verbally the answer to each item. His responses were recorded during T_1. After the first cycle was thus completed, the S would retire to a different room for a six minute interval while his responses were being scored. During the six minute interval, a new list of six items was compiled from the previous list of 12 items. The six items on this smaller list were randomly selected from the items S had missed on T_1. The six-item list was then presented (with the responses) on R_2 after the six minute waiting period. On T_2, S was tested over the items presented on R_2.

As stated before, each S in Group A had been paired with an S in Group B. Group B was shown List II on the first cycle. On the second cycle, however, each S in Group B was given the six-item list that the partner had during his second cycle. This was to be a second control for the selection bias that was present in Rock's study (Williams, 1961). He reasoned that if the shortened list, which was made up of incorrect items, was any harder than the items gotten correct, then the partner in Group B would have had the same hard list.

Group C had the same treatment as Group A with the exception of having quadragrams used in place of digrams. List III, which consisted of six items, was given during the first cycle. Of the items missed on T_1, three were selected to form a short list which was presented on the second cycle. Group D was given the same lists on their second cycle that had been shown to their partners.

From this it can be seen that on T_2 both Groups A and B were tested over the shortened form of List I while Groups C and D were tested over the shortened form of List III. The dependent variable was thus the number of correct items on T_2 for all four groups. If the incremental assumption is to hold, Groups A and C should have had the advantage in that they had seen the items presented on T_2 before, even if they had missed them the first time. If learning takes place in an all-or-none fashion, Groups A and C should have had no such advantage in that no learning took place during the first cycle on those items they had missed.

Experimental Apparatus

Presentation of the paired-associate items was done by flashing the items one at a time on a screen. The screen was made of a frosted plastic sheet with the glossy side toward the subject. It was installed in a solid red panel of heavy cardboard. The screen had rounded corners and was shaped much like a television screen. The screen was thirteen inches wide and eleven inches high. It was centered on the panel which was 28½ inches wide and 22 inches high.

The panel was situated upon a table. On the opposite end of the table was the projector. The screen was placed between the projector and the subject so that the items could be flashed from behind the screen. The panel's function was to block from view any of the apparatus which might be distracting. The subject did not sit directly in front of the screen, but rather at a slight angle in order to reduce the amount of glare from the screen.

Figure I of the appendix shows a diagram of the layout in the experimental room. The room was a small 9' x 5'10" cubicle. The room was fully lighted during the experimental sessions.

Each item had been printed on a 2" x 2" slide using Decadry lettering. The letters were 16 pt. upper-case modern print with the response being arabic numerals of the same size and type of print. When projected on the screen, the letters were approximately 3½" to 4" high. This seemed to be an advantage over the size print usually used in memory drums. The use of slides enabled the experimenter to make a new list of paired-associates momentarily by adding or taking out slides.

The timing of the presentation of items was controlled by a cam-timer. It was connected to the projector in such a way that a pulse of electricity would trigger the automatic slide-changing mechanism every three seconds.

The waiting room in which each S was to wait for approximately six minutes between the first and second cycle was somewhat smaller than the experimental room. The room was empty with the exception of a table and chair.

Experimental Procedure

Each subject had an individual appointment. Upon entering the laboratory, they were instructed to have a seat. In the waiting area was a sign giving information regarding the project.

The Ss were taken one at a time into the experimental room and seated. The following instructions were read for those Ss learning digrams:

> This is an experiment investigating the learning process in general. This is not a test of your personal skill. We are investigating the properties of how a person acquires an association between two letters and a number. The experimental session will be divided into two short periods with a brief rest between.
>
> You will notice a screen in front of you. In back of the screen is a projector which will flash a picture of two letters and a number on the screen--like this (flash sample slide). Your job is to remember that this number seven is to be paired with these two letters NW. Twelve of these letter-number pairs will be flashed at 3-second intervals. After you have seen the complete list of twelve pairs, I will test you on them. In testing you, I will show you only the two letters (flash example). You are then to tell me aloud what number was paired with these two letters. In the case of our example here, you would tell me seven. In showing you the list when testing you, I will flash the two letters every three seconds. This means you will have to think quickly and speak clearly. In case you do not know the answer, you are to take a guess. This is made easier in that the numbers run

from only one to nine. This means that you have one-ninth of a chance of getting an item correct merely by guessing. So remember you are always to guess when in doubt.

In the first part of this session, I will give you a short practice run. I will show you five letter-number pairs and then test you on them by showing the five slides with only the letters in which you are to call out the numbers that go with each of them. Then I will show you a list of 12 letter-number pairs and test you on them. You will then take a short rest period by going into the little room marked "waiting room." I will come and get you for the second part and bring you back in here. If there are any questions I will be glad to repeat the instructions.

I will now begin with the practice trials. Watch the screen closely. (Show practice slides).

For those _Ss_ learning quadragrams, these were the instructions read:

This is an experiment investigating the learning process in general. This is not a test of your personal skill. We are investigating the properties of how a person acquires an association between four letters and two numbers. The experimental session will be divided into two short periods with a brief rest between.

You will notice a screen in front of you. In back of the screen is a projector which will flash a picture of four letters and two numbers on the screen--like this (flash sample slide). The four letter pattern that you see here, J.S., we will refer to as one single "item." The answer or response that is to be associated with this item are the numbers one and three. It will be your task to remember the two numbers that were paired with this item. I will flash a list of six different items with their responses on the screen. After you have seen all of them, I will flash them again, in a different order, but this time it will be the item alone without the response--like this--(flash example). You are then to tell me aloud what two numbers were paired with this item. Always be sure to tell me the top number first. In this case it would be one and three. In case you do not know the answer you are to guess. This is made easier in that each single number can only vary from one to three. This means that there are only nine possible combinations of the two numbers at a time. So remember, you are always to guess when in doubt.

In the first part of this session, I will give you a short practice run. I will show you a sequence of five items. Then I will test you on them by showing you the items without the responses. Then for the actual trial, I will show you a list of six items and then test you on them. You will have to watch the screen closely because a new item will be flashed every three seconds.

If there are any questions, I will be glad to repeat the instructions. If not, I will begin with the practice trials. (Show practice items).

It should be noted that during the reading of the instructions an example was shown to the S. After the example, a brief training list of five items was shown to the S. The importance of this preliminary training has been demonstrated by Ward (1937).

Depending on the group in which the S was placed, he was shown the list he was to get on R_1 after he had completed the training list. If the S was to be in Group A, he was shown List I (R_1) and tested on it during T_1. If he was in Group C, he would be shown List III. The procedure for Groups B and D will be explained later.

The experimenter (E) then read the following statement:

Now we come to the rest period. Would you step into the room marked "waiting room" and wait for me to call you? Please do not talk to anyone on your way there.

The S was then ushered into the waiting room where he sat for six minutes with the door closed and no planned interpolated activity. During the six minute rest period, all slides were taken from the projector's cartridge. The items were separated into two groups; those responded to correctly on T_1, and those responded to incorrectly. The rate of presentation and length of lists were engineered so that a subject always missed more than six digram items and more than three quadragram items. In only one case did a S miss less than six digrams, which made it necessary to delete him from the experiment.

The reason for having each S miss six or more items was to enable the experimenter to randomly select from these six items the shorter list to be presented on the second cycle. This way everyone would be confronted with the same length of list on R_2 and T_2.

A list was randomized as to the presentation order of items each time it was to be shown to a subject. Each slide was assigned a number. A round, wooden disc was numbered for each slide. A device was built in which the round discs could be shaken and poured through a slot from which the numbers could be read in the order that they came through the slot. This device was used to generate random permutations of certain numbers. The slides were then placed in the projector cartridge in the order their number appeared on a list. This meant that throughout the two cycles, the slides had been randomized four times, once for each of the four presentations.

A random permutation list of numbers was used to select items from the ones that a subject had missed on T_1. The items were selected as their number appeared in the list reading from top to bottom. This had the effect of causing the list presented on R_2 to be a random selection of items from the pool of incorrect items from T_1.

After the six minute rest interval, the Ss were brought back into the experimental room. One of the following statements was read to them, depending on whether they were learning digrams or quadragrams.

Digrams

> This session will be just like the first one with the exception that the list will be only six items long instead of twelve. You will be shown the complete list first and then tested the same way as before.

Quadragrams

> This session will be just like the first one with the exception that the list will be only three items long instead of six. You will be shown the complete list first and then tested the same way as before.

The Ss were then shown the items with the responses (R_2) and then tested on them (T_2).

Both R_1 and R_2 consisted of flashing the items with their responses, one at a time, at three second intervals. T_1 and T_2 consisted of flashing the items again (without the responses) at three second intervals. The subject would call out the response verbally that went with each item as stated before, while E recorded each response on the data form shown in the Appendix.

The procedure for Groups B and D is the same as the procedure mentioned previously for Groups A and C with a few exceptions. Groups B and D were shown Lists II and IV respectively. This was to insure that Groups B and D would have had as much experience going into the second cycle as Groups A and C. On R_2, however, they were shown the same list their partners in Groups A and C had been shown in R_2. That is, when an S in Group A was processed, the S with the following appointment was automatically put into Group B and was designated as the partner of the S in Group A who had just finished. This way, when a shortened list had been compiled from the incorrect responses of the S from Group A, it was set aside and used on the second cycle of the next S who had been assigned to Group B. It was shown to the second S in the same order in R_2 and T_2 as it was shown to the first S.

The next S was assigned to Group C. The list compiled from his incorrect responses on T_1 were not only shown to him on R_2 and T_2, but were also shown to the S having the next appointment on his R_2 and T_2. The fourth S of course was assigned to Group D. The S following him would be assigned to Group A and the process would begin again. Thus the Ss were assigned to groups in the order they had appointments so that the order was A,B,C,D,A,B,C,D,A,B,C,D, etc. This was to control for any biasing effects accruing from certain _S_s having tendencies to volunteer for appointments early in the semester while others would wait until the last of the semester.

CHAPTER III

RESULTS

Williams (1961) reported an artifact in Rock's data and was able to show that some of the items were harder than others. Underwood and Keppel (1962) attempted to control for differences in item-level difficulty in two ways: (1) by giving the control group on T_2 the same items their partners missed on T_1 (This was the same technique as used in the present study) and (2) by selecting homogeneous items from the Underwood-Schulz tables (1960). They found, however, that the attempt to select homogeneous items was not completely successful. It was found that the items differed in their difficulty level.

The present study attempted to select homogeneous digrams and quadragrams from their association values found in the pilot study. It has been shown (Underwood and Schulz, 1960) that the association values of the response portion of the item can effect item-level difficulty as can the stimulus portion. Since the responses were numbers, the Battig-Spera (1962) tables were used as indications of the association value of each number. Table III shows the association values for the responses used. As can be seen, the numbers seem to be fairly homogeneous. It should also be noted that they have relatively high association values which make response

TABLE III

ASSOCIATION VALUES FOR THE NINE NUMBERS USED AS RESPONSES

Response	Association Value	S. D.
1	3.38	1.20
2	3.11	1.28
3	2.55	1.51
4	2.71	1.35
5	2.57	1.45
6	2.23	1.40
7	2.62	1.50
8	2.21	1.34
9	2.29	1.46

TABLE IV

RESULTING CHI-SQUARE FOR EACH ITEM

Group A			Group B		
Item	Frequency	χ^2	Item	Frequency	χ^2
ZY 7	5	1.33	KQ 8	1	2.02
VX 9	2	.33	QL 4	2	.81
IY 9	4	.33	QX 7	6	1.35
YF 2	2	.33	QV 2	2	.81
XV 4	3	.00	ZG 9	3	.15
YJ 6	3	.00	IH 1	9	7.35
XA 2	4	.33	YW 6	4	.01
MZ 3	2	.33	XT 2	4	.01
VY 7	4	.33	YQ 3	4	.01
YZ 8	2	.33	ZR 3	3	.15
CZ 1	2	.33	ZD 6	6	1.35
GJ 8	3	.00	XN 6	1	2.02
Total		3.97	Total		16.04

Group C			Group D		
Item	Frequency	χ^2	Item	Frequency	χ^2
LH 3			MZ 2		
XS 2	2	.01	XA 2	7	5.33
GZ 3			SZ 1		
GM 1	4	1.54	ZY 2	1	1.33
ZR 1			ET 1		
YR 3	1	.63	VY 3	4	.33
QH 2			VJ 1		
MZ 1	3	.32	XH 1	3	.00
KQ 3			EB 3		
PK 1	3	.32	YF 3	2	.33
QX 2			CV 3		
TT 3	0	2.17	SM 2	1	1.33
Total		4.99	Total		8.67

learning minimal, as Underwood, Runquist and Schultz (1959) and Schulz (1965) report that this is important in learning paired associates.

As a check to see if the items did in fact differ in their difficulty level, a chi-square goodness-of-fit test was run on the data from T_1. It would be expected that if the items did not differ in difficulty level, that each item would have the same number of correct responses, i.e., the distribution would be rectangular. Table IV shows the frequencies with which each item was correct and the resulting chi-squares. Groups A and B each had 11 degrees of freedom while groups C and D had five degrees of freedom each. Setting alpha at .05 the critical values would be 19.68 and 11.07 respectively. Thus none of the four groups of items showed a significant difference in difficulty level.

Underwood and Keppel (1962) found that their items differed by randomly dividing the Ss into two groups thus obtaining two sets of frequencies. A correlation was then computed to find if items receiving many correct responses in one group also tend to receive many in the other group. The product-moment correlation obtained was found to be .74 which was significant at the .01 level. Thus they concluded that the items differed in difficulty level.

The Ss in the present study were also divided randomly into two groups in order to make a comparison with Underwood and Keppel. Subjects in groups A and B were combined into one group while Ss in groups C and D were combined. It was desirable to keep groups A and B, and C and D separate because of the use of differing types of items. These two combined groups were randomly split again so that the A/B and C/D proportions were the same for each side. The product-moment correlation was .173 for the A-B groups and .390 for the C-D groups. Both correlations were insignificant at the .05 level for 23 and 11 degrees of freedom respectively. Thus it cannot be said that the items seem to differ in difficulty level.

Since there were four groups of Ss, A and C being considered experimental groups which were to be compared with the control groups B and D, it was desirable to make a check to ascertain whether the control groups were equal to the experimental groups in ability to learn paired associates. Thus the experimental and control groups were compared in a three-way factorial design along with two other factors. The second factor was that of sex. In case there was a difference in the ability of the two sexes, it should be known and so it was included in the analysis. The third factor was the type of paired-associate used; digram, or quadragram.

The data on T_1 was used as the dependent variable with which to test these three factors. The design used to test the three factors was a 2 x 2 x 2 factorial design. Table V shows the results of the analysis of variance.

As can be seen from the table, there were no significant differences between the control groups and the experimental groups. Nor did this factor have a significant interaction with any other factor. Thus it could not be said that the groups differed initially in their abilities. It was also found that the differences between the sex along with any possible interactions were insignificant. The only factor found significant was the effects of the two types of paired-associate items which could be expected since one group had only half as many items. This factor did not, however, interact with any thing.

To test the hypothesis of incremental vs. all-or-none learning, the number of items correct for each subject on T_2 was taken as the dependent variable. The design was considered to be a two-factor experiment with repeated measures on one factor. The first factor (A) had two levels which were considered nominal in character. The two levels were the types of item used, digrams or quadragrams. The second factor (B) also had two levels which were repetition and no repetition. Groups A and C were considered to have repetition since the items presented to them on the second cycle were being shown for the second time even though they were missed on the first cycle. To groups B and D, however,

TABLE V

SUMMARY OF ANALYSIS OF VARIANCE FOR T_1 DATA

Source	df	M.S.	F
A) Sex	1	.765	1.02
B) Exp. Group	1	2.640	3.51
C) Type of Item	1	40.640	54.04**
A x B	1	.767	1.02
A x C	1	.767	1.02
B x C	1	.017	--
A x B x C	1	.763	1.01
Within cell	56	.752	
Total	63		

**significant beyond the .01 level

TABLE VI

SUMMARY OF THE ANALYSIS OF VARIANCE FOR T_2 DATA

Source	df	M.S.	F
Between Ss	31	1.875	
Item type A)	1	19.141	14.735**
Ss within groups	30	1.299	
Within Ss	32	1.047	
Rep or N-Rep B)	1	2.641	2.678
A x B	1	1.265	1.283
B x Ss within groups	30	.986	

**significant beyond the .01 level

these items were completely new, thus there was no repetition.

Since each S in group A and C had a corresponding partner in B and D, these pairs were considered as experimental units. Since these units are observed under both levels of factor B, the design must be considered as a repeated-measures design with the repeated measures across B. As the Ss in groups B and D received the same lists on T_2 as their partners, it was expected that there would be some covariance between the two levels of factor B.

In the context here, factor A was the type of items to be learned, i.e., digram or quadragram, while factor B referred to repetition or the lack of it. Thus the design was a 2 x 2 factorial design with repeated measures across factor B.

The assumption of homogeneity of covariance was not considered since factor B has only one degree of freedom. Both factors A and B were considered to be fixed while the subject variable was considered to be random.

The results of the analysis are shown in Table VI. Since the Ss within-group mean square was the error term in testing factor A, and B x Ss within-group mean square was the error term in testing factor B and the AB interaction, the assumption of homogeneity of variance in respect to those two error terms had to be satisfied.

The F_{max} statistic was used in this conjunction. This was not an extremely powerful test but then Box (1954) states that the F tests are robust with respect to minor violations of the assumptions of homogeneity of variance. The F_{max} statistic on Ss within group variance turned out to be 1.23 while the test on the interaction variances of B x Ss within groups turned out to be 2.05. The critical value for both tests with 2 and 15 degrees of freedom was 2.86 at the .05 level. Thus neither were significant and the assumption of homogeneity of variance was considered to be satisfied.

As can be seen in Table VI, only factor A was significant indicating that there was a difference in the type of paired associate used. This is in agreement with the previous findings but is relatively unimportant since there were only half as many quadragrams as digrams. Of more importance, however, is factor B and A x B interaction both of which were insignificant.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Experimental Controls

The present study attempted to control for all irrelevant factors which were reported to have crept into other studies finding all-or-none effects. A test was made in order to determine whether or not there were any initial differences between the experimental and control groups in their ability to learn paired associates. In looking at their performance on T_1 where the groups had not yet been differentially treated, it was found that the differences were not significant.

It was thought that there might be a difference between the learning ability of males and females. To control for this each of the four groups had an equal number of males and females. In the analysis of the responses on T_1, a test was made on the factor of sex. It was found to be insignificant.

As indicated earlier, there were four main criticisms of the studies finding all-or-none effects. One of these criticisms was that long presentation rates had been used. Rock (1957) presented an item for three seconds with five seconds between presentations giving S eight seconds in which he could rehearse the item. Estes, Hopkins, and

Crothers (1960) also used eight-second intervals as did Rock and Heimer (1959) in three of their four studies, while Hinrichs (1965) used an interval of seven seconds. Lockhead (1961), who had shown presentation rates to have an effect, presented each item for .75 seconds with 1.25 seconds between items giving each S only three seconds in all to rehearse the item. With this, incremental effects were found. The present study attempted to take this criticism into account by also giving S only three seconds to rehearse. Using a slide projector and a cam-timer a new item was flashed on the screen every three seconds.

A second possible factor needing acknowledgment found by Brackett and Battig (1963) was that specific instructions to the Ss to attempt to learn only a few pairs on each trial (part method) would result in no significant differences between repetition and non-repetition groups. Moreover, instructions to attempt to learn all the pairs on each trial (whole method) would result in incremental effects. The authors went on to state that in the absence of specific instructions Ss seem to use the "whole method." In looking at the instructions given in the present study, there seems to be an absence of instructions as to any specific method to be used, thus the Ss should have adopted the "whole method" which has a tendency to result in incremental effects.

A third factor influencing previous studies was that the new items which replaced items that were missed, were easier. This selection artifact which had been found in Rock's studies had been reported by several investigators as mentioned previously. Two procedures were used to control for this. One procedure was to run a pilot study in order to find out the association values of the stimuli. Stimuli (both digrams and quadragrams) with low association values were selected, thus they should have been a relatively homogeneous group. In addition, each S in the repetition group had a partner in the non-repetition group. This partner was tested during T_2 on the same items as the first S. Thus whether or not the items were easier or harder, both Ss received the exact same set of items. As a check on whether or not the items differed in difficulty level, a chi square was run. The chi square along with the product moment correlations was found to be insignificant. It would seem to follow from this, then, that the item selection, which Williams (1961 and 1962) refers to, did not effect the present study.

The fourth major criticism of Rock's studies, was the choice of dependent variable. Trials to a criterion were thought to be a relatively insensitive dependent variable. It had been suggested that response latencies might be a good dependent variable to work with concerning the effects of repetition. The present study, however, was concerned with prediction of recall using an all-or-none mathematical learning model. Because of this, a recall test was used with the number of errors as a dependent variable. For further study of the effects of repetition, the question of latencies should be investigated. As it stands now, the effect of repetition on latencies is not at all clear, as Hinrichs (1965) has shown.

It would seem then, that in a review of the criticisms of the previous studies, the present study has attempted to consider all criticisms with the possible exception of the last one concerning the choice of dependent variable. Thus it was hoped that the results would reflect the true effects of repetition.

Theoretical Implications

As mentioned before, Estes has created what has been called, a one-element pattern model with the following axioms:

1. The stimulus member of each paired-associate item is considered to be a single hypothetical stimulus element.
2. On each trial the element is in exactly one of two learning states. Either the element is in state C (associated to the correct response) or the element

is in state $\bar{C}$ (not associated to the correct response).

3. On each reinforced trial, the probability of a transition of the element from $\bar{C}$ to C is c; the probability of a transition from C to C is one.
4. If the stimulus element is in state C when the subject responds, he makes the correct response with probability one. If the stimulus element is in state $\bar{C}$ when the subject responds, he guesses the correct response with probability g.
5. At the beginning of the experiment, the element is in the unconditioned state $\bar{C}$.

In terms of these axioms, transition probabilities from one state to another can be represented in the following matrix:

$$\text{Trial } n \quad \begin{array}{c} \\ C \\ \bar{C} \end{array} \overset{\text{Trial } n+1}{\begin{bmatrix} \overset{C}{1} & \overset{\bar{C}}{0} \\ c & 1-c \end{bmatrix}} \qquad \overset{\text{Pr (correct response row state)}}{\begin{bmatrix} 1 \\ g \end{bmatrix}}$$

Using these axioms, it was possible to derive probabilities of the two events with which the model is concerned, that of making an error, and that of getting the item correct. Given that an item begins a trial in state $\bar{C}$, there is then only one way an error can be made; that is, if the item is not learned when shown correct response which happens with probability (1-C) and that the S was not able to get the item correct by guessing which has a probability of (1-g).

Thus the probability of making an error on an item, given that the item began in state $\bar{C}$, was (1-c)(1-g). Given that the item begins a trial in $\bar{C}$, a correct answer could be obtained in two ways. The item could have been learned on that trial with probability c or the item could have stayed in the unlearned state with probability (1-c) but gotten correct by guessing with probability g. Thus the probability of getting an item correct was c (1-c)g.

In looking at the data obtained, the number "one" could be assigned to every error and the number "zero" assigned to every correct answer. In doing this, the expected value of this new random variable could be obtained for a single item. Using the probabilities found previously it would be:

$$E(x) = (0)\left[c + (1-c)\, g\right] + (1) \cdot (1-c)(1-g) = (1-c)(1-g)$$

From this, the probability of an error, given state $\bar{C}$ at the beginning of the trial, would be (1-c)(1-g). The expected number of errors made by 16 Ss on n number of items would be:

$$(4.1) \qquad T = (16)(n)(1-c)(1-g)$$

what T is the total number of errors. In solving for c the following formula was obtained:

$$(4.2) \qquad c = 1 - \frac{T}{(16)(n)(1-g)}$$

Since the parameters on the right side were dictated by the experimenter, except for T which was observed, Eq. 4.2 was used to estimate c from the data.

For comparison with the one-element model described above, the single-operator linear model presented by Bush and Sternberg (1959) was selected. This model, in contrast to the first one, is built on the assumption of incremental learning. If q_n is defined as the probability of an error on trial n, then the model is said to generate a series of these; q_1, q_2, q_3,--one for each trial. Since this is a linear model, it assumes that the operation of transforming q_n into q_{n+1} is linear. This operation may be written as:

$$q_{n+1} = \alpha q_n$$

This is where α is a fraction representing the extent to which the error probability on trial n is reduced as a result of reinforcement on that trial. If q_0 is defined as the probability of making an error before any reinforcement, i.e. (1-g), then the probability of an error on the first trial would be:

$$q_1 = \alpha q_0$$

The predicted number of errors made by the 16 Ss on n items would be:

$$T = (16)(n)q_1$$

(4.3) $$= (16)(n)(\alpha)\quad(1-g)$$

To estimate α from the data we find

(4.4) $$\alpha = \frac{T}{16(n)(1-g)}$$

It is also quickly seen from Eq. 4.2 that:

$$\alpha = 1-c$$

when they are estimated from the data. Substituting 1-c for α in Eq. 4.3 and comparing it with Eq. 4.1 it can be seen that both models are algebraically identical in this situation. Where the two models differ, however, is in their assumptions. For the one-element model Eq. 4.1 provides an estimate of the number of errors made on a set of unlearned items, even though the items may have been presented before. However Eq. 4.3 from the linear model may only be used on a set of items never seen before. If there had been a prior showing, i.e., a prior trial, then the probability of an error becomes:

$$q_2 = \alpha q_1$$

Since $q_1 = \alpha q_0$ the equation becomes:

$$\begin{aligned} q_2 &= \alpha(\alpha q_0) \\ &= \alpha^2 q_0 \\ &= \alpha^2(1-g) \end{aligned}$$

To obtain an estimate of the total number of errors:

$$\begin{aligned} T &= (16)(N)q_2 \\ &= (16)(n)(\alpha^2)(1-g) \end{aligned} \tag{4.5}$$

As can be seen Eq. 4.5 now clearly differs from Eq. 4.3 and Eq. 4.1.

In the case of the present experiment, both models were used to predict the number of errors on T_2 (the second test in the RTRT design), on both the digrams and the quadragrams. In the case of the two non-repetition groups, the items presented on R_2 and T_2 were seen for the first time. In this case both of the models would give identical predictions. Since it is the first presentation of these items, Eq. 4.1 and Eq. 4.3 would be used. Since the test of the two models did not rest on the non-repetition groups, the data from these two groups were used in order to obtain estimates of α and c for the two models. For the non-repetition group learning digrams the parameters were:

$$\alpha = 1-c = \frac{T}{16(n)(1-g)} = \frac{63}{16(6)(1-1/9)} = .738$$

This is where g is the probability of getting an item correct merely by guessing which is 1/9, as set up in the design of the experiment. The number of items presented to the non-repetition group on T_2 was six which was substituted for n in the equation above. The number of errors made was 63. For the non-repetition group using quadragrams;

$$g = 1/9, \; n = 3 \text{ and } T = 37.$$

Substituting these values in Eq. 4.4:

$$\alpha = 1-c = \frac{37}{16(3)(1-1/9)} = .867$$

For the repetition groups on T_2 the models clearly give different predictions. Even though the list presented on T_2 had been presented during R_1 and T_1, these items were assumed by the one-element to be unlearned since they were incorrect on T_1, thus they were all said to be in state $\overline{C}$ going into R_2. Therefore Eq. 4.1 would be used to predict the number of errors made. Since the items presented on R_2 had been presented before, even though they were incorrect, the linear model predicts that some association strength is present and thus uses Eq. 4.5 to estimate the number of errors made on T_2. Using these two equations for the two models, and the two parameters, for digrams and quadragrams Table VII presents the observed number of errors along with the estimates of the two models.

As can be seen from the data, the one element model makes a better prediction than the linear model in the case of the digrams, but the linear model makes a better prediction in the case of the quadragrams. This was the hypothesis of the present study, i.e., an incremental model will provide a better fit to the data when associating complex stimuli with responses, but that the all-or-none model would provide a better fit with simple stimuli. This hypothesis was confirmed in light of the present findings. This then provides some evidence as to when the two types of models should be used for optimal description of the data.

It should be recalled that the present study set out to study the effects of the size of the stimulus portion of the paired associates on the incidence of all-or-none

TABLE VII

PREDICTIONS OF ERRORS
MADE BY REPETITION GROUPS ON T_2 DATA

	Actual Errors	Linear	One-element
Digrams	61	46.46	63.00
Quadragrams	26	32.06	37.00

effects with two purposes in mind. One was to see if the size or complexity of the stimuli used, should be a factor in deciding between a model with all-or-none properties, and one incorporating incremental properties. As was shown above, it seems as if this should be a factor to consider.

The second purpose was to find out if size or complexity of the stimulus was a factor to be considered when investigating the theoretical problem of the effect of repetition on learning apart from the use of mathematical models. It was found in the results mentioned previously that there was no significant difference between the repetition and non-repetition groups learning digrams, in terms of the mean number of items correct on T_2, the means being 2.18 for the repetition group and 2.06 for the non-repetition group. With a difference of only .12 it would seem that repetition did not have any appreciable effect. For those groups learning the quadragrams, the mean number of correct items for the repetition group was 1.37 while the non-repetition group had a mean of .69, a difference of .68. Thus the repetition group learned twice as many items as the non-repetition group. However, the large difference was not significant, evidently because of a large amount of error variation. Thus we cannot reject the null hypothesis that there was no difference even though a large difference was obtained. The large error variance may be due in part to the fact that there was 1/9 of a chance of getting an item correct just by guessing. This would add to any variation due to individual differences.

The fact still remains, however, that all-or-none effects were found using the digrams, while attempting to control for the factors causing criticisms of other studies finding all-or-none effects. The reason the present study found all-or-none effects when some of the other studies in attempting to control these factors, found incremental effects, may have been due to the use of large and complex stimuli. Williams (1962) had used four-letter words as stimuli while Lockhead (1961), Postman (1962), Brackett and Battig (1963), and Martin and Nelson (1963) all used nonsense syllables of three letters or more. Thus they had shown that with large and complex stimuli, incremental effects show up. But the present study has shown that if smaller stimuli are used, an all-or-none model provides a better fit than an incremental model and that repetition does not seem to effect learning these items.

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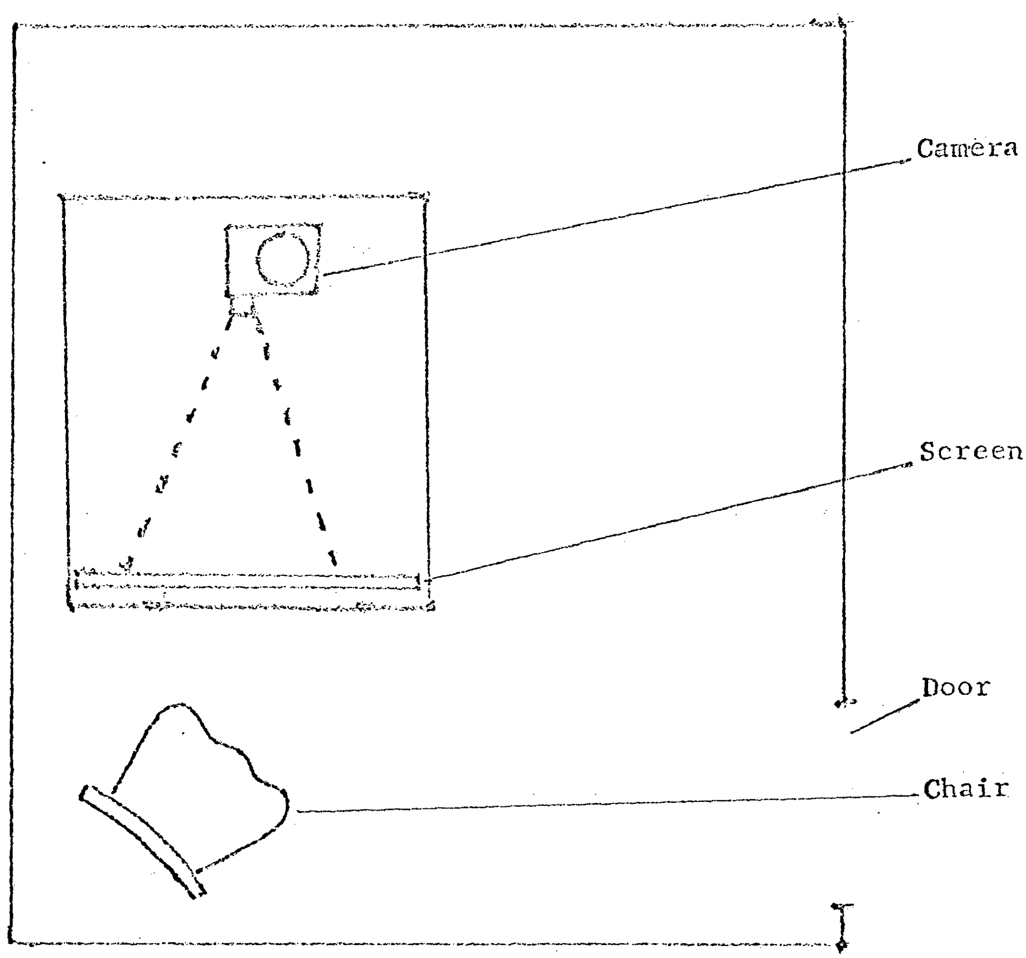
APPENDIX



Layout of Expermental Room

Project #002

D.C.Chatfield

Data Sheet
Subject-Trial-Pair

Name _________________________ Time __________ Date __________

R		T			R		T		
#	Item	#	Item	Answ	#	Item	#	Item	Answ

Name _________________________ Time __________ Date __________

R		T			R		T		
#	Item	#	Item	Answ	#	Item	#	Item	Answ