

A SELF-CHECKING GROUP EXPERIMENT  
IN RATIONAL LEARNING

by

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## INTRODUCTION

This study has been undertaken to test the feasibility of adapting self-checking group technique to certain types of simple experimental material. To make such a test under actual experimental conditions, a problem has been chosen which is by itself worthy of consideration. Emphasis is therefore necessarily divided between the experiment and the technique.

Self-checking methods have received most attention in the field of mental and educational testing, with emphasis upon ease of scoring. The well known Clapp-Young device is a good example of a valuable contribution to self-scoring methods.

There has been a need for a device which, in addition to self-scoring, provides an automatic check of results for the subject. Several such devices have been developed, employing variations of punch board, form board, and paper cutting features. Mechanical complications and expense and the impossibility of making them a part of the question sheet have limited their use.

Recently there has been developed by H. J. Peterson and J. C. Peterson (4) a self-checking device which combines the advantages of ease of scoring, immediate automatic checking of results for the subject, simplicity, economy, and adapta-

bility to a wide range of multiple-choice materials. This method employs chemically sensitive inks, the color changes of which record the subjects responses and tell him whether he is right or wrong.

The value of using such a device with study question sheets and objective tests is almost self evident. That the instructional value of such material is greatly enhanced by an immediate check of results for the subject has been convincingly shown by Peterson (5) in several controlled experiments.

In many of our smaller colleges Psychology is handicapped by a lack of experimental apparatus. To promote the interest and develop the insight of its students, and to furnish experimental research materials, Psychology is in need of the development of group experiments, constructed after the fashion of objective tests, and to be used under controlled experimental conditions.

The scientific development of mental testing procedure is obliterating the distinction between the mental test method and the experimental method. Terman (12), supported by the opinions of a number of leading psychologists, says there is no distinction other than the aim of the investigation and the treatment and application of data. For the investigation of chronic mental phenomena, the mental test method may be even superior to the classical conception of

the experimental method. The mental test method of experimentation does not necessitate the sacrifice of scientific control, as is often alleged. Much worthwhile experimentation can be carried on in this way.

Interest in group experimentation has already been responsible for the development of a number of short paper and pencil experiments. Some of these can be advantageously adapted to self-checking technique. Other problems can be developed to fit the technique.

In another class we have a number of simple experimental problems which necessitate some sort of immediate progress report to the subject during the course of the experiment. Such problems are by nature limited to individual application. Characteristic of this class of material is the Rational Learning Experiment, the Disc Transfer Problem (4), and Peterson's bead experiment (3). Variations of such problems can also be adapted to self-checking group methods.

Due to the expected difficulty of finding a way to use the Rational Learning Experiment with groups, its adaptation and actual use was chosen as a preliminary test of the efficiency of this new self-checking device as a group experiment method. The material was arranged for an experiment in interference and retroactive inhibition. Although the experiment is in reality only incidental to the method or technique, I have attempted to control, present, and inter-

pret the experiment as if it were the primary consideration.

Brief mention of a few of the leading investigations in retroactive inhibition leaves us with an indefinite conception of the factors involved. Some of this disagreement is due to a loose definition of the term. While some investigators include the total effect of an interpolated activity upon the reproduction of an original activity, others are investigating only a part of this total effect.

Muller and Pilzecker, in 1900, explained retroactive inhibition as an interference with a neural "setting process" which was supposed to take place after a work period. From this they proposed the law that retroactive inhibition was inversely proportional to the time interval between original and interpolated activities.

DeCamp (1), in 1915, suggested that retroactive inhibition varied with the similarity of interpolated activity to original activity; that elements in the interpolation interfered with the neural setting process of similar elements of the original activity.

Robinson (9), in 1920, agreed that retroactive inhibition was a function of similarity of interpolated material to original material, but suggested the impossibility of deducing a definite law from the facts. In 1927, Robinson (10) gave a good definition of the broader conception of retroactive inhibition. He proposed the quantitative conti-

nuity from retroactive facilitation to retroactive inhibition, with no qualitative distinction between the two.

Robinson's definition is in sharp contrast to the definition by Skaggs (11), in 1926. Skaggs restricts his definition of retroactive inhibition to "deal with a permanent loss of an associate and must exclude all emotional and affective influences. It must exclude all cases of decreased efficiency in recall brought about by wrong associative tendencies due to partial identities. It must exclude all cases of lessened efficiency in recall due to factors operating at the time of recall and now generally known as reproductive inhibitions." According to those who accept the more inclusive definition of retroactive inhibition, these factors which Skaggs would exclude from consideration are factors of which retroactive inhibition is a function. The question becomes, "If these factors are separately recognized and their effects segregated, must still another factor be considered before the picture is complete?"

#### MATERIALS AND PROCEDURE

The Rational Learning Experiment has been both partially standardized as an intelligence test (7) and used in racial comparisons (8) by Joseph Peterson. The problem consists of associating each of the first ten letters of the alphabet with some assigned number between 1 and 10, the num-

bers having been assigned in random order.

As administered by Peterson (6) and as directed in the laboratory manual of Foster and Tinker (2), the experimenter, after explaining the total nature of the problem, directs the subject to guess some value of A between 1 and 10, inclusive. The subject is told when he is right, and when he is wrong he is required to guess again. All responses are recorded by the experimenter. When the correct value of A is guessed, B is treated similarly, and so on through the series of ten letters.

It is very evident that, excepting perseverative errors or the repetition of wrong responses, the trials to locate the value of the first letter are pure guesses. But the total situation has been changed for the letter B, as one possible value has been eliminated. For C, two possibilities have been eliminated, etc. The first time through the series of ten letters involves mainly the elimination of possible responses. At the beginning of the second series, or the first repetition, the situation has again changed, the recall of specific associates being now required. For those that cannot be recalled, the elimination process of the first series must again be resorted to. The series of ten letters is repeated until the subject can go through two series in succession without error.

The Rational Learning Experiment presents to the sub-



ject a situation which is continually changing. It permits the subject to use various degrees and kinds of rational organization, and it is practically independent of variations in past experience.

### Preparation of Material

By utilizing the chemically sensitive inks already referred to, the Rational Learning Experiment has been adapted to the requirements of group testing. The experiment, as adapted, is diagrammatically presented in Figure 1.

<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>	<u>G</u>	<u>H</u>	<u>I</u>	<u>J</u>
1 o	1 o	1 o	1 o	1 o	1 o	1 o	1 o	1 o	1 o
2 o	2 o	2 o	2 o	2 o	2 o	2 o	2 o	2 o	2 o
3 o	3 o	3 o	3 o	3 o	3 o	3 o	3 o	3 o	3 o
4 o	4 o	4 o	4 o	4 o	4 o	4 o	4 o	4 o	4 o
5 o	5 o	5 o	5 o	5 o	5 o	5 o	5 o	5 o	5 o
6 o	6 o	6 o	6 o	6 o	6 o	6 o	6 o	6 o	6 o
7 o	7 o	7 o	7 o	7 o	7 o	7 o	7 o	7 o	7 o
8 o	8 o	8 o	8 o	8 o	8 o	8 o	8 o	8 o	8 o
9 o	9 o	9 o	9 o	9 o	9 o	9 o	9 o	9 o	9 o
10 o	10 o	10 o	10 o	10 o	10 o	10 o	10 o	10 o	10 o

Figure I

The letters A to J and the numbers 1 to 10 are used. The letters are printed across the top of the sheet one inch apart. Under each letter are printed all of the ten numbers. At the right of each number is a dot of yellow water color ink. The ink in nine of these dots, representing the incorrect responses, has been treated with a chemical indicator

which turns red upon the application of a base. The ink in the remaining dot, representing the correct response, has been treated with a different chemical indicator which turns blue. The printing process is the same as in three color work, requiring three separate plates and impressions, one for the dots that turn red, one for the dots that turn blue, and one for the letters and numbers.

To carry out experiments in interference and retroactive inhibition, two forms of this problem were prepared, both employing the same letters and numbers but with all letter values different. Table I represents the letter values of each form.

Table I. Letter Values

	A	B	C	D	E	F	G	H	I	J
Form I	9	6	2	10	8	1	5	4	7	3
Form II	5	9	8	3	10	2	7	1	6	4

Each sheet is cut into ten strips of one letter each. These strips are assembled or piled in the order in which the experimenter wishes to present letters to the subject. A blank strip of different color is inserted between each two series of ten letters.

In these experiments, in order to prevent learning by building up a simple number sequence without letter-number

associations, the letters of each series were arranged in a different random order. To facilitate assembling a rack was constructed from which the strips could be taken in the proper order.

The alkaline solution, sodium carbonate, is applied with a "chemapen." The "chemapen" in the form here employed is simply a round metal pencil-lead box containing a roll of felt which has been dipped in the sodium carbonate solution. For timing, a large clock was used by which each subject timed his own work.

### Subjects

Two large classes in beginning Psychology furnished the subjects for experiment A. Most subjects were first and second year students. These two groups were approximately equal in mean, range, and standard deviation of Freshman Test ranks. The experimental group contained 46 subjects from which 30 complete records were secured. The control group of 40 subjects netted 26 complete records. A few records were incomplete because of absence. The remainder were eliminated because of inability to complete some one of the problems during one class period. This selection did not materially effect the relative distributions of Freshman Test ranks.

The subjects for experiment B were from four smaller

Psychology classes. As it was possible in this experiment to have both experimental and control subjects working at the same time, each class was divided into an experimental group and a control group, the groups being matched for Freshman Test ranks. Complete records of twenty-five control and twenty-five experimental subjects were obtained.

#### Administration and Directions

With this material two separate experiments were carried out. We shall first consider experiment A.

The following set-up was used:

	<u>Control</u>	<u>Experimental</u>
Learning on Monday .....	learn form I	learn form I
Interpolation on Wednesday .....	regular class work	learn form II
Relearning on Friday .....	relearn form I	relearn form I

To equalize a possible difference between the difficulty of form I and form II, one-half of each group was given form I and the other half of each group was given form II. But for simplicity the set-up is considered from the standpoint of one control and one experimental subject.

Each subject was given a bundle of ten series, a champaign, and a metal guide into which the subject lays his used strips.

In experiment A, both the control and experimental groups received the following directions on the first day:

"We shall conduct a short experiment, the accuracy and value of which will depend upon your effort and cooperation. It employs a method which is entirely new and different and I believe you will find it interesting."

"To introduce the method of procedure we will solve a sample of the problem on the board." (E. puts following problem on board).

<u>R</u>	<u>S</u>	<u>T</u>	<u>U</u>
15	15	15	15
16	16	16	16
17	17	17	17
18	18	18	18

(E. then asks one subject to turn his back to the board).

"There are four letters and the same four numbers under each letter. To each of these letters we will assign a different one of these four numbers." (E. checks R = 17, S = 15, T = 16, and U = 18 so remainder of group can see what the proper values are). "The problem consists of at first guessing until the value of each letter is found and then repeating the series until you are able to remember the value of each letter." (Subject is given problem by individual method as directed in Foster and Tinker, except that letters are presented in a different random order in each series.

All responses written on board by E.).

"There is another method of solving this problem so that a number of subjects may work at the same time." (E. shows class a different four letter series prepared on card-board with chemically sensitive inks, for demonstration). "This problem is of the same kind as the one that was just solved. I have made a number of sheets just like this one and cut each into strips of one letter each. These strips have been piled in random order with a blank strip between each series of four letters." (E. takes this test as a demonstration, explaining use of chemapen and significance of color changes).

"Your problem is of the same kind as this one, but you will associate each letter from A to J with its assigned value between 1 and 10 inclusive."

"Take the cap from your chemapen. Open your bundle being careful not to disarrange it. Take off the strip upon which your name is written and lay it face down in the metal guide. Now let us try our chemapens upon several strips from which the letters have been cut." (Two such strips are included in first bundle, immediately under name strip).

"Brush the wet felt of your chemapen across the dot at the right of 1. To what color does it turn?" (Etc. until blue dot is found). "Lay this strip face down in the metal guide. Now you may experiment at will upon the next letterless

strip."

"We are now ready for the problem proper. The first time you go through the series of letters you must experimentally find the correct value by the semi-guessing method you have observed. You will repeat the series until you can go through two series in succession without error. After each series mark the time in minutes and seconds upon the blank separator strip."

"Do not become nervous if you are late in finishing because you will be scored on the number of errors, the number of series required, and the time. So although your time may be slow you may have a good error score. Work at your own natural rate."

"Please remember:

To lay strips face down and not look at them again,

That the letters do not appear in the same order in each series,

That each of the ten letters has a different value, but the value of any one letter remains constant throughout the problem,

To mark the time on each separator strip,

To work until you have gone through two series in succession without error."

"After finishing rubber together both used and unused

strips in the original order and quietly wait until everyone is through."

The directions given to experimental group for interpolated problem on Wednesday are as follows:

"This problem is similar to your first problem and is to be solved according to the same rules. It employs the same letters and same numbers but the letter values may be different."

The directions given to both control and experimental groups for relearning problem on Friday are as follows:

"This problem is identical to your first or Monday problem, and is to be solved according to the same rules. Recall as many of the letter values as you can and relearn those you have forgotten."

All subjects were kept ignorant of the experimental set-up. Therefore there was no motive for practice during the time intervals between problems.

In experiment B, learning, interpolated learning, and relearning were all accomplished at one time with no time interval between problems. The problems were shortened to five-letter series, or halves of the original problem. The following set-up was used:



	<u>Control</u>	<u>Experimental</u>
Learning .....	first half, form I	first half, form I
Interpolation ...	second half, form I	first half, form II
Relearning .....	first half, form I	first half, form I

Each subject was given a bundle containing all three problems, numbered in the order to be solved. The blank facing strip of each problem prevented subject from knowing what problems remained to be solved.

Those parts of the directions that coincide with the directions for experiment A will not be repeated here. The beginning directions and demonstrations are identical. The first difference occurs after the second demonstration problem, as follows:

"Your problems are of the same kind as this one but you will have five letters and ten numbers from which to learn the five assigned values. You have been given three separate problems to work in the order in which they are numbered. You may have the letters A to E of form I for one problem, or the letters F to J of form I. You may have A to E of form II, or F to J of form II. You may have any combination of these possibilities and it is possible that two of your problems will be alike."

"At the beginning of each problem determine whether you are using form I or form II because the letter values of

form I may be different from those of form II. Any two problems involving the same five letters of the same form are identical problems."

Chemapens were tried on letterless strips as in experiment A.

"Before beginning each problem mark the beginning time in minutes and seconds upon the top blank strip. Then take off this strip and lay it face down in the metal guide. Use each strip in the order in which it appears and pile each used strip, including separator strips, face down in the metal guide."

"As soon as you have gone through the required two series in succession without error, mark the finishing time in minutes and seconds upon the next separator strip. Then lay both used and unused strips together in the original order, rubber the problem together, and lay it aside. Then you are ready to start to work immediately on problem 2. Mark beginning time and proceed as you did on problem 1. After finishing it, lay it aside and start on problem 3."

"Please remember:

To work each problem separately and in the order indicated,

To mark beginning and finishing time on each separate problem,

To lay used strips face down and not look at them

again,

To work on each problem until you can go through two series in succession without error."

"If you run out of material raise your hand and I will give you more."

"You will be scored on each problem on time, errors, and the number of series required. You will not all finish at the same time as you have different combinations of problems and some may be much more difficult than others. So work at your own natural rate and pay no attention to your neighbor's progress."

### Scoring

Scoring was facilitated by originally assembling all bundles in the same order, and checking errors of each subject on a similarly arranged check sheet. Each subject was scored on time, total errors, (counting each wrong number as one error) number of letters on which errors were made (termed "letter errors"), and number of series. However the series criterion did not prove to be sufficiently variable for "subject for subject" pairing so was not used.

In the individual form of the Rational Learning Experiment, "perseverative" errors, or the repetition of wrong responses to the same letter, are considered. It is evident that such errors are impossible in the group form. It is

possible to identify "logical" errors, or the failure to eliminate previous correct responses within any one series. Such errors were the only ones counted in the first series of the original and interpolated problems. But as our problem does not involve a qualitative analysis of individual learning records, such errors were not given separate consideration beyond the first series as stated above. As Peterson (7) found a correlation of .99 between total unclassified errors and a total error score including weighted classified errors, such weighting would hardly afford another criterion for quantitative comparison.

## RESULTS AND DISCUSSION

We have provisionally accepted Robinson's more general conception of retroactive inhibition as any reduction in the ability to reproduce original material which is due to the effect of an interpolated activity. The comparisons here made are between the relearning records of Control groups and Experimental groups, with no distinction made between retention and relearning.

From the entire Control and Experimental groups two smaller groups were paired "subject for subject" for time in original learning problem, and compared for relearning mean time-scores. The same was done for total error scores and letter error scores.

To permit an evaluation of the relative independence of each of these three criteria, intercorrelations are presented in Table II.

Table II. Intercorrelations Between Criteria  
Based on Original Learning  
Scores of All Subjects

	Time with total errors	Time with L. errors	Total errors with L. errors
Exp. A.	.73	.81	.94
Exp. B.	.81	.85	.94

In Table III are presented the results for both experiments A and B. Although groups are paired for learning scores, learning mean-scores are included to show the relative gain from learning to relearning.

Table III. Summary of Results

	Paired for	G	N	Learning mean- score	Interpol. mean- score	Relearn. mean- score	Relearn. $M_e - M_c$ $\pm \sigma$ diff.	$\sigma$ of relearning scores
Experiment A	time	C	21	17.57		3.87		2.34
		E	21	17.85	13.17	4.73	0.86 $\pm$ 0.89	2.84
	errors	C	20	72.20		5.65		8.21
		E	20	71.95	42.50	8.10	2.45 $\pm$ 3.13	11.84
	letter errors	C	19	24.68		3.11		3.47
		E	19	24.31	18.52	3.94	0.83 $\pm$ 1.09	4.21
Experiment B	time	C	18	5.12	5.16	3.27		1.75
		E	18	5.03	4.98	3.34	0.07 $\pm$ 0.55	1.57
	errors	C	19	12.00	17.05	24.68		14.03
		E	19	12.26	11.21	28.63	3.95 $\pm$ 5.09	15.29
	letter errors	C	19	7.52	7.47	5.79		2.26
		E	19	7.42	5.68	7.47	1.68 $\pm$ 1.33	4.16

(G = group, Control or Experimental.  $M_e - M_c \pm \sigma$  diff. = difference between re-learning mean-scores of Control and Experimental groups  $\pm$  standard error of the difference).

The differences between learning mean-scores of C and E groups are probably negligible. They are due to the small differences that had to be allowed between the learning scores of paired subjects.

Standard errors of the differences between relearning mean-scores were determined by use of the regular long formula for the standard error of the difference between two means (13):

$$\sigma_{(M_1-M_2)} = \sqrt{(\sigma_{M_1})^2 + (\sigma_{M_2})^2 - 2r_{12}\sigma_1\sigma_2}$$

None of the differences between relearning mean-scores are statistically significant when compared to the standard error of the difference. However, the differences which do exist are all in the same direction, in favor of the Control groups. There is much disagreement as to the value of the persistence of small differences. But in spite of this and the intercorrelations between criteria, the second and third pairings introduce some new elements and some new subjects into the comparisons, undoubtedly decreasing the probability that the differences are due to chance.

A careful consideration of the data from experiment A reveals the importance of considering such factors as tend to obscure the differences which probably exist:

First, by all criteria a gain in performance is as-

sociated with a reduction in the raw numerical score. For both groups and by all three criteria the net reductions from learning mean-scores to relearning mean-scores are from approximately 4 to 13 times greater than the relearning mean-scores. This brings relearning mean-scores from 4 to 13 times nearer to numerical zero scores, and still nearer to the limits of performance, than learning mean-scores. This approach to the limits of performance undoubtedly causes the relearning scores of the control and experimental groups to approach each other more closely numerically than in actual performance, but it is impossible to define this effect quantitatively and make the necessary correction.

Second, the control group was given no interpolated problem. Therefore it is very probable that the relearning performance of the experimental group was facilitated by the additional positive transfer effect from the interpolated problem. The amount of this transfer effect from interpolation to relearning could be determined approximately from the performance of a third group having first and second problems like those of the experimental group, but a third problem employing entirely different letters and numbers. The gain of this group from second to third problem would roughly approximate the part of the gain of the experimental group from interpolated problem to relearning



problem due to positive transfer effect.

So far our direct comparisons have been quantitative. A qualitative analysis of errors indicates the direction and location of the interference experienced by the experimental group. Let us designate as "interference" errors those wrong responses in form II which are correct responses in form I, and vice versa. We find that in the interpolated problem, excluding the first series, errors are just as likely to be made on any of the other wrong numbers as on the "interference" numbers, that is, neutral errors occur with the same probability as "interference" errors. But in the final problem "interference" errors are about two and one-half times as likely to be made as neutral errors. Even after excluding the first series, in which there had been opportunity for some relearning by elimination, the frequency of "interference" errors is three times greater than the frequency due to pure chance. This indicates a marked interference of the interpolated problem with the relearning of original problem. This evidence agrees with the opinions of several investigators that the detrimental effect of an interpolated activity is due to a proactive effect of interpolation upon recall and relearning rather than to any retroactive effect of interpolation upon original learning.

The results of experiment A do not substantiate either

theory of the time function of retroactive inhibition. Our qualitative evidence agrees with the view that there is no retroactive inhibition unless the interpolated activity follows immediately or within a few minutes after original activity. A consideration of only the quantitative data, which shows some indication of retroactive inhibition when interpolation follows after an interval as long as 48 hours, is in agreement with the view that there is no relation between retroactive inhibition and the time interval. This dilemma of interpretation indicates the need for further research with materials that permit the segregation and evaluation of negative transfer effects.

Experiment B was planned for the analysis of "interference" errors under the condition of no time intervals between problems. If two hour laboratory sections had been available for subjects, ten-letter series would have been used in each problem. But as one hour classes had to be used, the problems were shortened to five-letter series. This arrangement precludes direct comparisons with experiment A. And as these five-letter series were halves of the original ten-letter series, each problem presented to the subject five numbers which were not values of any of the five letters involved. Responses made to these irrelevant numbers so complicated the analysis of errors as to prevent the determination of "interference" error probability.

The results of experiment B indicate that an interpolated activity involving the same objective stimuli (in this case, letters) and different final responses (number associates) offers more resistance to the reproduction of original material than does an interpolated activity of the same type involving both different stimuli and different responses. However this statement must be qualified by admitting the impossibility of defining either the total stimulus or the total response. The total stimulus is probably not limited to the letter presented, but is some broader aspect of the total problem situation. The total response to this stimulus may include all of the possible numbers, those numbers spatially adjacent to the correct number, the values of spatially adjacent letters, or the correct value of a given letter in the other form of the problem, or perhaps any combination of the above and additional possibilities. Such complications prevent the formulation of definite laws concerning the function of similarity in interference and retroaction.

## CONCLUSIONS

### Concerning the Experiment

The results of experiment A suggest the advantage of using experimental materials from which an analysis of re-

sponses can be made. By utilizing variations of the material and set-up of this experiment, we may be able to demonstrate that all so called retroactive inhibition can be explained in terms of negative transfer effects. This is a suggestion for further research.

The motor activity involved is the same for all responses. Therefore, with the motor element controlled, the retroactive inhibition experienced by the experimental groups has probably all occurred on a higher plane than that of simple motor reaction. Many of the results of experimentation on retroactive inhibition with ideational materials are in part a function of effects experienced on a motor level. Materials which necessitate handwriting or the arrangements and rearrangements of objects introduce this factor.

#### Concerning the Technique

The preparation of material and administration of this experiment can be greatly simplified when this type of material is printed in large quantities. Limited resources and equipment necessitated cutting the sheets and assembling the letter strips as described. The resulting complications of presenting the problem to the subject were responsible for the complexity of the directions. With better equipment it will be possible to print from ten to fifteen ten-letter series on one long sheet. The subject can solve the

problem by covering the used part of the sheet with some sort of cover paper.

The results of this test experiment justify the recommendation of this new self-checking device as a useful contribution to the methods of group experimentation. It will make possible the use of several experimental problems which cannot otherwise be administered to groups. It will increase the experimental and educational value of other problems already designed for group use.

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