

Generalization and Organization as Factors in Transfer and Retroactive Inhibition

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Students of psychology and of education are well aware of the voluminous body of research literature concerning the transfer of training. Many psychologists and a few educators are also showing a growing interest in the rapidly increasing experimentation on retroactive inhibition. Though a majority of the experimenters on retroaction favor a transfer theory in explaining their results, very few have attempted to study retroactive inhibition and transfer simultaneously. The present study represents an attempt to study both of these phenomena, using typical school learning materials in an actual classroom learning situation in arithmetic.

The chief purpose of this investigation was to observe transfer of training and retroactive inhibition as they appeared in the learning of the 100 addition facts by second-grade children who had been taught by three different methods of instruction, the chief variable among methods being the degree of emphasis upon organization and generalization of learning.

The Experiment

The experimental subjects in this study were 332 pupils from 14 different second grades in the public schools of the same city. The schools and individual subjects covered a wide range of ability. Data obtained at the beginning of the experiment showed a range in C.A. from 70 to 130 months, a range in M.A. from 71 to 114 months, and a range in I.Q. from 74 to 146.

The learning materials for this study consisted of the 100 addition "facts"—that is, the direct and reverse forms of all the number combinations from $0 + 0$ through $9 + 9$. These 100 facts were divided into three sets, each set being taught during a prescribed period of the study. The O (original) set of facts was taught first, the I (interpolated) set next, and the F (final) set last. The F set of facts was actually the "interpolated" learning material when the I set was considered as the "original" learning material. During the time when one of these sets of facts was being taught (25 minutes a day for approximately 5 weeks for each set), there was no instruction on facts belonging to the other two sets. This was necessary in order to have a valid basis for measures of retroactive inhibition and transfer among the sets of learning materials.

The classes which participated in this experiment were assigned at random to the three different instructional procedures. The Kuhlmann-Anderson Intelligence Test for Grade II (Fifth Revision, 1940) was administered to all groups before the experiment began. On the

basis of the results of this test, the classes which participated in the experiment were assigned to the three different instructional procedures by a stratified randomization procedure.

One very important feature in which all classes received a common treatment was that of arithmetic readiness instruction. For a two-week period preceding the actual teaching of addition facts all classes were given the same general type of instruction in number meanings.

All teachers were instructed to make no reference to subtraction facts or the subtraction process, nor to more advanced types of addition examples of the kinds to be tested in the final transfer tests.

The instructional procedures used by the teachers of each method were directed by means of teachers' meetings, manuals of instruction, and personal supervision by the experimenter. The manuals of instruction were quite detailed in their explanation of the teaching procedures which were consistent with the method being used. Points needing further clarification were discussed in the teachers' meetings and in individual conferences.

As has been previously stated, the three teaching methods were based upon different theories as to how children learn. A few definite illustrations as to exact ways in which the theories were applied may not be amiss at this point.

The G (generalization) method was based, as its name implies, upon the generalization or meaning theory of teaching arithmetic. Teachers under this method were instructed to encourage the children to build up interrelationships among facts. For instance, the addition facts were first presented to children in groups which were determined by some unifying idea or generalization. Examples of such generalizations are "To add 1 to a number, count up 1" or "Adding 0 to a number does not change the number". These generalizations were not dictated to the children as rules to be learned. Rather, the facts centered around a generalization were presented in such a way that the teacher could, by skillful questioning, lead the pupils to their own formulation of the generalization. Typical pupil expressions of the two generalizations cited above were "When you add 1, the answer is the next number" and "When you add 0, the other number stays the same."

The meaning theory holds that children should be allowed to continue relatively immature methods of arriving at answers so long as they need them as aids to understanding. Accordingly, children in the G groups were allowed to use counting, partial counting, and dependence upon easier, known combinations to help them get answers, though they were encouraged to short-cut such roundabout procedures as soon as they could do so without sacrificing understanding. Children in the G groups were also allowed to refer to groups of concrete objects as often as they needed them as aids to solving the abstract number combinations.

Finally, drill or practice was not discarded in the G method. The time spent on drill was limited because of the large amount of time spent in guiding children to develop the generalizations. Practice on

the number facts occurred *after* the generalizations had been formulated, and *during* rather than *before* the development of understanding.

The emphasis placed by meaning theorists upon the organization of the number system is represented in the G method by grouping the facts around generalizations, by allowing children to derive new number facts from related ones, by building up the decimal idea in teaching the adding of 10, and by allowing much original manipulation of number relations in connection with a miscellaneous set of facts during the final instructional period.

The D (drill) method was based, presumably, upon connectionistic or drill theory. Assuming that the learning of each addition fact is a discrete "bond" or connection to be formed, the facts under this method of instruction were presented as abstract "facts-to-be-learned" in a miscellaneous order rather than in any systematic pattern. The order of presentation was arrived at by combining the results of three drill "difficulty studies," namely, those by Knight and Behrens,¹ Thiele,² and Wheeler.³

According to the oft-repeated warnings of drill theorists in the field of arithmetic that children should not be allowed to reason out the answers to combinations by roundabout procedures, the teachers of D classes were instructed to discourage any counting or other devious ways children might use for deriving answers. If a pupil hesitated or gave the wrong answer when a combination was presented to him, the teacher told him the correct answer, showed it to him, or had him refer to a chart or similar "authoritative" source.

Speed of response was emphasized in drill classes, both as a means of discouraging dependence upon other facts or upon counting, and also as a way to accustom children to giving prompt, automatic responses of the type needed by adults. The largest part of the time in D classes was spent on drill. To be consistent with connectionistic theory, repetition had to have a prominent place in this method. Because facts were presented by the teachers with answers given, little time was spent on the developmental part of the lesson. Teachers were instructed to follow accepted principles of effective drill, e.g., make the drill interesting to the children; vary the drill exercises; avoid practice in error; repeat most often the facts which seem to be most difficult, etc.

Method X was included as a third instructional procedure to represent that middle ground between drill and meaning theory which might be called common practice. Just what "common practice" is can hardly be stated by anyone with certainty. However, a careful examination of a large number of arithmetic books and other teaching materials con-

¹Knight, F. B., and Behrens, M. S., 1928. The learning of the one hundred addition combinations and the one hundred subtraction combinations. New York.

²Thiele, C. L., 1938. The contribution of generalization to the learning of the addition facts. Teacher College Contribution to Education. No. 763.

³Wheeler, Lester R., 1939. A comparative study of the difficulty of the 100 addition combinations. Journal of Genet. Psych., 54:295-312.

vinced the investigator that "common practice" was represented by drill procedures with two important modifications.

The first concession which is quite commonly made to meaningfulness is that each fact is presented concretely or semi-concretely, e.g., by pictures of concrete objects, at the time of its first introduction. Accordingly, the X teachers were directed to give the children the experience of "verifying" each *new* addition fact by counting and manipulating concrete objects. Afterwards, drill procedures followed the same method used in D classes.

The second variation introduced in the X method was that the addition facts were presented in groups which depended upon organization by size-of-sum. All combinations yielding the same answers were, accordingly, presented to the children for study at the same time. Pupils were discouraged, as in the D groups, from making other generalizations of number relations. However, they could hardly fail to notice that reversal of addends made no difference in the answer, because the direct and reverse forms of a combination were always presented in the same size-of-sum group. The teachers, however, never called attention to the generalization for reversed addends. The X method, then, was a drill method with certain concessions made to the ideas of concrete meaning and organization.

Timed tests on the 100 addition facts occurred at five points in the experiment: (a) at the beginning of the study; (b) between the study of O facts and I facts; (c) between the study of I facts and the Christmas vacation; (d) between the vacation and the study of F facts; and (e) at the end of the F instructional period. Three transfer tests (one in subtraction, one in decade addition, and one in advanced addition) were given at the end of the study.

Analyses of variance (for both M.A. and initial total addition score) showed that the variation *among* the three method groups at the beginning of the study was not significantly greater than the variation *within* those groups.

The design of the present experiment placed the major burden of analysis of data upon one statistical technique, the analysis of covariance. By this technique it was possible to adjust the outcome means for differences in initial arithmetic score and M.A. means.

The first series of analyses of covariance was designed in such a way as to hold constant M.A. and corresponding⁴ initial addition score. They provided a means of testing the significance of the differences among method groups on each of several outcome scores, after the effects of M.A. and the corresponding initial score had been ruled out.

A second series of covariance problems provided tests of the same outcome variables; but M.A. and immediately-preceding addition score were held constant instead of M.A. and initial score. This series took the place of analyses of variance of losses and gains during inter-test

⁴The "corresponding" initial score is that score on the initial addition test which corresponds to the particular outcome score being considered. For instance, if the outcome score being analyzed is on the 0 set of facts, the corresponding initial score would be that on 0 facts.

intervals. That part of the variance associated with previous score on the same item having been removed, the residual variance really represented the gain or loss between the two tests.

A third miscellaneous set of problems dealt with the analysis of O, I, and combined O and I scores for the whole period following instruction.

The fourth and final set of analyses of covariance dealt with the three transfer tests—one in subtraction, one in decade addition, and one in miscellaneous advanced addition. The residual variance on each of these was analyzed after removing that part of the variance associated with M.A. and total score on the addition pre-test.

Each analysis of covariance problem was, of course, preceded by tests for homogeneity of variance and of regression.

In order to check on the exact location of significant differences which appeared in the analyses of covariance, "t-tests" were made for each of the three possible inter-method comparisons.

All inter-test gains or losses by each of the method groups were also tested to determine whether or not they were statistically significant.

Limitations of time and space prevent a detailed presentation of the statistical results. Therefore, only a brief summary will be given of the learning, retention, retroactive inhibition, and transfer data which were collected.

Learning Results

The term "learning" in this summary refers to learning during instruction, i.e., increase in knowledge of any set of facts during the period when those facts were being directly taught.

The scores on knowledge of O (original) facts, which were of very similar difficulty from one method to another, were not significantly different from one method group to another at the beginning of the period of study. During the instructional period, however, the G group gained a highly significant⁵ advantage over each of the other two groups. Of the two other groups, D was significantly superior to X.

During instruction on the I (interpolated) facts, the three groups made gains which were not significantly different. In fact, there was less difference among groups at the end of the instructional period than there was at the beginning. The X group, with the easiest set of facts, was the one which lost its superiority, though this change was not statistically significant.

Unfortunately, the pre-instructional performance on the F facts was significantly different. Though this difference, in favor of the G group, was still apparent at the end of the instructional period, adjustments for pre-instructional differences accompanied by heterogeneity of residual variance and of regression caused the difference to dis-

⁵ The terms "highly significant" or "highly superior" in the subsequent discussion indicate that the difference was beyond the .01 level of probability; the terms "significant" and "superior" refer to differences which were between the .05 and the .01 levels of probability.

appear. The G group had the easiest set of F facts and made the lowest raw gain.

Finally, of the three sets of facts, the learning gains during instruction were significantly different only in the case of the O facts, in which case the order of performance was G, D, and X. All inter-method differences on O fact gains during instruction were highly significant.

Retention Results

The term "retention" here refers to retention from the end of the direct instructional period for a set of facts to the end of the experiment.

The evidence on retention of previously learned sets of facts (O, I, and combined O + I) is as follows: (a) in those cases in which there were significant inter-method differences in the number of facts known at the end of the instructional period, those differences were maintained throughout the remainder of the study; (b) for the retention periods themselves, independent of previous learning, there were no significant differences among method groups; and (c) retention was very good throughout the study, such losses as occurred being very slight.

Retroactive Inhibition Results*

The term "retroactive inhibition" here pertains to losses in the mean performance of any method group in their knowledge of a previously learned or partially-learned set of facts during an interpolated activity—whether that activity was instruction on another set of facts or a vacation period. Bearing in mind this definition of retroactive inhibition, one notes the following summarized results: (a) retroactive inhibition of previously learned addition facts did not appear during the learning of another set of addition facts (true of all method groups and all interpolated instruction periods); (b) the only interpolated activity which resulted in retroactive inhibition was the Christmas vacation; (c) the O facts, taught several weeks before the vacation period, did not show retroactive inhibition during the vacation; (d) the I facts, taught immediately preceding the holiday period, were subject to inhibition in all method groups; (e) the net results for the combined O and I facts showed a loss for all method groups during the vacation; (f) the raw score measures of retroactive inhibition for the I facts during the vacation period showed significant losses for the X and D groups but not for the G group; (g) the differences among method groups in O + I losses during vacation were statistically significant only in the superiority of the G group over the D group; (h) retroactive inhibition also occurred for only the D group in one set of partially learned but untaught facts (the F set) during the vacation interval; (i) on this last comparison the differences among groups were highly significant, both X

* Usually, "retroactive inhibition" refers to losses during an interpolated activity over and above losses during an interpolated rest period. In this experiment, the greater losses occurred during the vacation (rest) period, necessitating a modified use of the term.

and G groups being highly superior to the D group. The G group also surpassed the X group by a significant amount; but neither one showed retroactive inhibition on F facts during vacation.

Transfer Results

The term "transfer" here pertains to gains in the mean performance of any method group in knowledge of a certain set of facts during instruction on another set or during the vacation period.

The summarized state of affairs concerning transfer within the 100 addition facts, adjusted for M.A., was as follows: (a) the amounts of transfer among the addition facts, except for the vacation period, were usually significant for all method groups; (b) the amounts of transfer to previously taught facts were, in general, not significantly different from one method group to another; (c) the amounts of transfer to untaught facts were usually significantly different; (d) the G group was significantly superior to the X group five times, compared with once that the X group was significantly superior to the G group; (e) the G group was significantly superior to the D group six times compared with once that the D group was significantly superior to the G group; and (f) the X group transferred significantly more than the D group in two situations.

In summary of the transfer post-test results, adjusted for M.A. and initial total score on addition facts, the following relationships were revealed: (a) there was a significant difference among method groups in their knowledge of subtraction facts after study of addition facts; (b) the order of performance was, from highest to lowest, G, D, and X; (c) the advantage of the G group over the other two groups on knowledge of the upper decade facts was not statistically significant; and (d) the D and G groups, almost equal in their performance on the advanced addition transfer test, both showed a highly significant advantage over the X group.

Net Results

With intelligence and appropriate initial scores controlled, the net results on the three separate sets of facts for the whole experiment may be summarized as follows: (a) the G group made the highest net achievement record for the O facts, I facts, and F facts; (b) the advantage of the G group on net results for O facts was highly significant in comparison with the X group and significant in comparison with the D group; (c) the differences in net I fact achievement were non-significant, but the G group had overcome a significant disadvantage in initial knowledge of I facts; (d) the G group earned a highly significant advantage over the D group and a near-significant advantage over the X group for net achievement on F facts, while the X group achieved a highly significant advantage over the D group for the same facts.

With intelligence and appropriate pre-test total scores held constant, the net total results for various periods of the experiment were as follows: (a) the G group made the highest net total achievement for

every period of the study and for every combination of adjacent periods which was analyzed; (b) the advantage of the G group over each of the other groups was statistically significant in eight comparisons (seven of these highly significant); (c) the six comparisons for which the G group advantage was not statistically significant dealt with periods for which no other group had any significant advantage either; (e) the D and X groups fluctuated between second and third places in the net total results, with the D group ahead of the X group in five out of seven comparisons; and (f) in no case did any group except the G group have a significant total advantage over any other method group.

The general conclusion from all these results seems to be that second-grade children taught by the generalization method seemed to have an advantage over those taught by drill or modified drill methods. With intelligence and previous addition knowledge controlled, they learned the original set of facts more quickly; they retained what they had learned as well as the other groups during subsequent instructional periods; during the vacation they forgot fewer of the facts learned just preceding vacation; they made larger transfers of knowledge from taught to untaught addition facts; and they made transfer gains to subtraction and advanced addition which were equal to or better than those of the other two groups. Finally, in net total results for the whole experiment, all significant advantages which appeared were held by the G group.