AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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1. SUBJECT CLASSIFICATION

A. PRIMARY: Education

B. SECONDARY: General Education

2. TITLE AND SUBTITLE

A study of Rule Retention and Accessibility - Working Paper

3. AUTHOR(S)

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4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1973	23 p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

Florida State University, College of Education, Center for Educational Technology, Tallahassee, Florida 32306

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

Reports the methods and results of a study designed to investigate the retention of intellectual skills, specifically, rules. Two rules were learned by 33 undergraduate mathematics students by means of specially designed self-instructional materials that differed in terms of the examples used. In one set of materials, all examples were of practical, meaningful applications of the rules. In the other set, all examples consisted of abstract applications. After an interval of seven days, the two groups of students were given tests that measured their retention of the rules. The results showed no difference in the retention of students who learned the rules by means of either set of materials. The results also showed that when a retrieval cue was used in conjunction with the retention test, performance was substantially improved, for both rules and for both groups of students. That finding supports the conclusion that such intellectual skills are not forgotten or lost, but merely become inaccessible due to a faulty retrieval scheme. Thus the distinction between availability and accessibility is important in the study of retention of rules.

10. CONTROL NUMBER

PN-AAC-529

11. PRICE OF DOCUMENT

12. DESCRIPTORS

13. PROJECT NUMBER

14. CONTRACT NUMBER

CSD-2945 211(d)

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

CSL - 2945 211(d)
PN-AAC-529

FLORIDA STATE UNIVERSITY / COLLEGE OF EDUCATION / CENTER FOR EDUCATIONAL TECHNOLOGY

WORKING PAPER

Hannum, Wallace. "A Study of Rule Retention and Accessibility."

CENTER FOR EDUCATIONAL TECHNOLOGY

PAPER

"A Study of Rule Retention and Accessibility"

College of Education/Florida State University

1973

A Study of Rule Retention and Accessibility

Wallace H. Hannum

The learning that takes place in school settings must obviously be retained by the student if it is to be of use to him on subsequent occasions of further learning or use. Statements of purposes of education typically emphasize the future use or benefit to be derived from learning (Davis, 1966). To achieve the goal of retention, the outcomes of instruction must include consideration of what is learned over various time intervals, and not solely the immediate effects of a learning event.

A number of studies of retention of school subjects indicate a considerable loss over various intervals of time. Forgetting to the extent of eighty per cent is not an uncommon finding on tests of course materials over intervals ranging from two to twenty-four months (Davis, 1966).

Some investigations have found differences in retention related to the kind of materials learned. For example, Tyler (1933) found a retention loss of 80 per cent in recall of specific information from a course in zoology after 15 months, but no loss in the application of general principles. Differential retention of motor skills and verbal word pairs has also been reported (Leavitt and Schlosberg, 1944), confirming the common impression of relatively high retention of motor skills over long periods of time. In his review of studies of retention in school learning, Davis (1966) sees the evidence as indicating marked forgetting of facts and detailed information,

and a less severe loss of "functional abilities," those which may be called intellectual skills.

Another factor affecting conclusions regarding retention is the method used to assess what is remembered. The students may be asked to recall or reproduce what they have learned on a previous occasion, or they may be asked to relearn the original material. In the case of recall, the students' responses are compared with some criterion and assigned a score to measure retention. In the relearning method the student must relearn the original task, and the percentage of time saved is used as the measure of retention.

A distinction has been made between the condition pertaining to learned items that are available for recall at the time of retention, and the condition of items that are accessible (Tulving and Pearlstone, 1966). There is some indication that accessibility in recall of previously learned items is a function of having a method to retrieve items that are retained. Thus the failure to reproduce what was learned could result from a true lack of retention (the items were not available) or from the inability to retrieve the items (the items were not accessible).

Conditions during the learning have been shown to affect the retention of what is learned. The best known is repetition, or overlearning, emphasized by Underwood. However, the question remains as to whether repetition works to "directly strengthen" learned associations, or to provide additional opportunities for such processes as rehearsal and subjective organization to have their effects. In any case, there is some indication of

the absence of the effect of "overlearning" in the learning and retention of certain intellectual skills such as rules (Gagné, 1970; Gagné & Bassler, 1963; Gibson, 1969; Reynolds & Glaser, 1964). Overlearning, in the sense of repeated examples, has not been found to be as important a variable in the retention of rule learning as in the learning of information.

Another factor in the learning situation that has been shown to affect retention is the meaningful organization of the learning materials (Ausubel, 1968). In general, more meaningfully organized material is retained better than material lower in meaningful organization. However, most studies concerned with the effect of meaningfulness on retention have dealt with the retention of information and not of intellectual skills.

Thus the evidence about retention of school subjects is in general not well systematized. Large losses in retention are frequently reported, and these appear to be influenced by differences in the nature of what is being retained, particularly specific information vs. intellectual skills. Results also appear to be affected by how retention is measured--whether by recall or relearning. A more recently suggested distinction between availability and accessibility appears to be of particular relevance. The conditions under which material is learned also appear to affect retention--particularly, the factor of meaningful organization.

This study has the purpose of investigating the retention of intellectual skills, specifically, rules. Can one find a difference in the retention of rules when viewed as a) available or b) accessible? Can one find a differential

effect of a meaningful context during learning on the retention of rules, when these two different measures of retention (availability--accessibility) are considered?

RELATED STUDIES

Studies of school subject retention

It is not uncommon to find rather large losses in the retention of school subjects. This is particularly true in the case of verbal information. McDougall (1958) studied retention on a unit on measurement in an educational psychology course and found greatest loss in factual knowledge rather than in the translation, interpretation, or extrapolation of knowledge. Tyler (1933) measured retention of zoology over a fifteen-month interval. He tested for recall of specific information and found a loss of 80 percent. However, when testing for application of principles he found neither loss nor gain, and the ability to interpret new experiments showed a considerable gain. Wert (1937) found similar results when studying retention of zoology over a three year interval. He reported a 50 percent loss on tests requiring the matching of names with structure, and gains of 60 percent and 20 percent in the application of principles and the ability to interpret new experiments.

These studies indicate that the retention of specific information is usually quite low. The retention of skills, however, seems to be somewhat

greater. There do appear to be rather marked differences in the retention of information and the retention of intellectual skills, including rules.

Studies of rule learning and retention

Studies of rule learning have failed to demonstrate the effect of repetition or overlearning on retention (Reynolds & Glaser, 1964). The amount of practice, that is, the number of different examples, has a very small effect on the retention of rules. This finding appears to stand in marked contrast to the learning and retention of information (Underwood, 1964).

In an investigation of the retention of mathematical rules, students learned four rules to a common criterion of solving two successive problems requiring application of each rule (Gay, 1971). Using the relearning method to measure retention she found no savings in the number of examples necessary to reach the same criterion. Reynolds and Glaser (1964) found that there was no relation between the amount of original learning in terms of the number of examples and the degree of retention. Gibson (1969) found that overlearning rules had no effect on retention or transfer.

It should be pointed out that in these studies of retention of rule learning, the distinction between availability and accessibility was not made.

Studies of the effect of meaningful context or organization on retention

A number of studies have investigated the effect of meaningfulness on learning and retention. Ausubel (1968, 1969) reports several studies that demonstrate greater learning and retention of meaningfully organized materials, i.e., those materials that were organized so that they could be related to existing ideas in the students' cognitive structures.

Several researchers have demonstrated that it is much easier to learn material in a meaningful manner than to memorize the material in a rote, verbatim fashion (Jones & English, 1928). Studies have shown that some problem-solving tasks (card tricks, matchstick problems) are retained longer when the underlying principles are learned rather than when the solutions are rotely memorized (Hilgard, Irvine, & Whipple, 1953; Katona, 1940). Dowling and Braun (1957) demonstrated that the decline in retention was dependent on the meaningfulness of the material. Klausmeier and Feldhusen (1959) found evidence that the retention of meaningful material was considerably greater than non-meaningful material by children of low, average, and high intelligence. McKeachie and Soloman (1957) report very high retention of meaningful material over an eight-month interval.

These studies tend to support the position that meaningful material is retained better than material that is less meaningful. In most cases the researchers were concerned with the retention of information and not the retention of intellectual skills.

Effect of the availability vs. accessibility distinction on retention

Tulving and Pearlstone (1966) made the distinction between items that were available for recall but were not accessible. They stated that many words not recalled in a free recall situation were available in memory storage, but were not accessible for retrieval. The use of a retrieval cue, category name, greatly increased the recall of words in that category. They concluded that the accessibility of information depends not only on its

availability but also on the use of retrieval cues. Although this distinction has not been empirically applied to research on rule learning, it appears to be of potential importance. It may be that learned rules remain highly available in memory, and that the lack of retention is a lack of accessibility, not availability.

Purpose of study

The purpose of the present study was to examine the effect of two factors, meaningfulness and availability-accessibility, on the learning and retention of two mathematical rules. Specifically, the rules for finding the number of combinations and the number of permutations were taught using two different contexts. In one context the examples were meaningful; in the other context, the examples were less meaningful. The retention of these rules was measured under two conditions, retrieval cue vs. no retrieval cue, to examine the availability-accessibility distinction.

METHOD

Subjects

Thirty-three undergraduate students enrolled in two freshman mathematics courses at Florida Agricultural and Mechanical University took part in this investigation. It was determined that none of these students had any prior knowledge of either permutations or combinations. There were three students that failed to reach criterion on the original learning materials and were subsequently omitted from the retention phase of the study.

Learning materials

In order to investigate the research questions for this study, two similar but different rules were chosen as the skills to be taught. The first rule was the rule for finding the number of permutations of a set of objects. The second rule was the rule for finding the number of combinations of a set of objects. In order to teach these rules the writer developed two versions of a set of self-instructional materials that differed in the context of the examples that were used. In one set of the materials all the examples referred to practical, meaningful applications of the rule. The examples in the other set of materials consisted of abstract applications. The first set of materials will be referred to as having a meaningful context, the second set a non-meaningful context.

Both sets of materials were programmed in a linear, large step fashion. The material was designed to teach the student to apply the two different but highly similar formulas to find the number of permutations or combinations of a set of items. The initial version of the materials was revised considerably using suggestions made by two colleagues who are professors of mathematics. The final version of the materials consisted of twenty-three frames, fourteen on permutations and nine on combinations. The number of frames for permutations is greater because it includes a section on the use of factorials which is a necessary prerequisite skill to learning the rules. At the end of the section on permutations and at the end of the section on combinations the student was presented a series of five problems requiring

the use of the rule they had just learned. If a subject worked two consecutive examples correctly it was assumed that he had learned the rule.

Performance measure

Retention was measured in this investigation by having the students solve four problem examples for each of the two rules. Thus the retention test consisted of eight problems that were presented in a random order. Each student received the same retention test. On the retention test the students were required to recall which of the two rules applied to the particular example and to correctly use that rule to solve the problem. In scoring the responses, arithmetic errors were disregarded if the student had otherwise used the rule correctly. If a student correctly worked at least three out of four problems for each rule he was considered as having retained the rule. A student who failed to correctly work at least three examples for either rule was considered as not having reached criterion for retention.

The problems on the retention test were presented in a format that was consistent with the examples and with the problems in the original learning materials. In no case, however, were the identical problems given.

Two forms of the retention test were constructed since the students were to be measured twice for retention. An item pool was constructed for each rule and four items were assigned at random to one test and four to the other test. Thus two highly similar equivalent tests were constructed for use in the present study.

Experimental design

The dependent variables in this investigation were the students' responses on two retention tests administered in the same session following a seven day time interval. Scores on the first retention test (R_1) reflected any loss during the time interval. This could be a loss in the skill (ability to use the specific rule), or in information regarding when to apply the rule. Prior to the second retention test (R_2), all students were given a retrieval cue consisting of a brief statement that presented the mathematical notation for the two formulas and told when the rule applied. Thus any loss in R_2 was purely a loss in intellectual skill and not a loss in verbal information. Figure 1 presents this experimental design.

Context of Learning Material	Retention 1		Retention 2
Meaningful	N = 15	presentation of retrieval cue	N = 15
Non-meaningful	N = 15	presentation of retrieval cue	N = 15

Figure 1. Experimental Design

R_1 and R_2 both contained eight problems (four for each rule) presented in a random order. Students were scored as having reached criterion if they correctly worked at least three out of the four problems for each rule. R_1 measured the students' ability to retain both verbal information and intellectual skill. R_2 measured the students' ability to retain the intellectual skill.

Procedure

The two experimental sessions were conducted as part of the two mathematics courses in which the students were enrolled. The students were randomly assigned to two groups--one received the learning materials with a meaningful context. All students proceeded through the materials working independently at their own rate.

Immediately after the section on permutations, the students were given five problems on permutations. After each problem they were instruced to raise their hands to let their instructor check their work before they proceeded. Their regular instructor monitored the experiment and checked their work on these criterion problems. As soon as they worked two consecutive problems correctly they were given the section of learning materials on the combination rule. At the end of the learning materials on combinations there were five criterion problems. As soon as the students worked two consecutive examples correctly, they were excused for the day. During the one and a half hour session only three students failed to reach the criterion. These three students were discarded from the study.

Following a seven-day interval all students were administered the same retention test. This test consisted of three parts. Part one was eight problems (four for each rule) presented in a random order. Part two was a retrieval cue in the form of a statement giving the mathematical notation for each rule and a brief statement describing when the rule should be used. Part three was another set of eight problems presented in random order. The students worked independently on all three parts of the retention test.

Both the original learning session and the session for retention testing were monitored by the usual instructor so that this investigation could proceed as unobtrusively as possible. The instructor met with the experimenter on three occasions prior to the experiment to discuss the classroom procedures. In order to determine if there were any interactions that might have influenced the results of the experiment, the whole experimental session was recorded on audio tape. The play back of this tape did not reveal any interaction of instructor and student that could have influenced the results of this study.

Results

The results of the original learning indicate that both sets of learning materials were successful in teaching the two rules to the students. Only three students failed to attain the criterion after completing the learning materials. This finding is consistent with previous findings in the area of instructional development and programmed instruction.

Data from the retention tests (R_1 and R_2) for each student were analyzed to determine the number and proportion of students reaching the criterion level. These data are presented in Figure 2.

This figure shows the number and precent of persons reaching the criterion of at least three correctly worked problems for each rule (C for the combination rule and P for the permutation rule) on both retention tests. Performance on R_2 is considerably better than performance on R_1. It appears that on R_1 the rule for permutations was better retained than the rule

Context of Learning Materials	R_1		R_2	
	C	P	C	P
Meaningful	1 6%	6 44%	15 100%	15 100%
Non-meaningful	2 12.5%	8 50%	14 94%	14 94%

Figure 2 Number and Percentage of Students Reaching Criterion on Retention Tests

for combinations. This difference was not present on R_2. There were no apparent differences in terms of the context of the learning materials (meaningful vs. non-meaningful) on either of the two retention tests or for the two different rules.

These data seem to indicate a marked increase in the retention of the two rules as a result of the retrieval cue. This effect was present for both rules and for all students regardless of the context of original learning. There are no indications of any differential effect of the two sets of learning materials.

In order to examine the data several non-parametric statistics were computed. The first hypothesis pertained to any difference in the number of students reaching the criterion of three correctly worked examples out of four. The hypothesis stated that there would be no difference as a result of the two contexts--meaningful (M) and nonmeaningful (NM) or as a result

of either rule--combinations (C) or permutations (P). The data for this is presented in Table 2.

	C	P
M	1	7
NM	2	8

Table 1. Number of Students Reaching Criterion on R_1

Due to the small expected frequencies in this table the Fisher's Exact Probability test was chosen as the appropriate statistic (Siegal, 1956). The probability of this occurrence under the null hypothesis is greater than .01 therefore the null hypothesis cannot be rejected. There were no significant differences on R_1 between the two rules or between the two contexts.

The second hypothesis dealt with the same comparison on R_2. These data are presented in Table 2.

	C	P
M	15	15
NM	14	14

Table 2. Number of Students Reaching Criterion on R_2

Since the expected frequencies were large enough, chi square was chosen as the statistic to compute. The value of X^2 for these data is less than 1. The probability of obtaining the data in Table 3 under the null hypothesis is greater than .01. Therefore the null hypothesis cannot be rejected. There were no significant differences on R_2 between the two rules or between the two contexts.

It is apparent from these analyses that the students retained the two rules equally well and that the context of the learning materials had no effect on retention. This was observed on both retention tests.

In order to examine any differences that resulted from the retrieval cue, it was necessary to compare performance on R_1 and R_2 for each rule and each context. Thus there are four sets of data to be analyzed: 1) meaningful context, combination rule, 2) meaningful context, permutation rule, 3) nonmeaningful context, combination rule, and 4) nonmeaningful context, permutation rule. For each of these four groups the number of students reaching criterion on R_1 and R_2 was analyzed using the Fisher Exact Probability Test. Table 3 presents the data for the meaningful context and the combination rule.

	Pass	Fail
R_1	1	14
R_2	15	0

Table 3. Number of Students Reaching Criterion on the Combination Rule who Learned in a Meaningful Context.

The probability of this occurrence under the null hypothesis is less than .01. Therefore the null hypothesis was rejected. There was a significant difference on the two retention tests for the combination rule when the rule was initially learned in a meaningful context.

The number of students reaching the criterion for the permutation rule is presented in Table 4. These data are for those students who learned the rule using the materials with a meaningful context.

	Pass	Fail
R_1	6	9
R_2	15	0

Table 4. Number of Students Reaching Criterion on the Permutation Rule who Learned in a Meaningful Context

The Fisher Exact Probability Test was used to determine the probability of obtaining these data if the null hypothesis was true. This probability was less than .01, therefore the null hypothesis was rejected. There were significant differences between R_1 and R_2 on the permutation rule for students who learned the rule in a meaningful context.

Table 5 presents the data on the retention tests for students who learned the combination rule in a nonmeaningful context.

	Pass	Fail
R_1	2	13
R_2	14	1

Table 5. Number of Persons Reaching Criterion on the Combination Rule who Learned with a Nonmeaningful Context.

The probability of obtaining these data under the null hypothesis is less than .01. The null hypothesis was therefore rejected. There was a significant difference in the number of students reaching criterion on the two retention tests for the combination rule when the original learning used materials in a nonmeaningful context.

The data for the retention of the permutation rule when the original learning was in a nonmeaningful context is presented in Table 6.

	Pass	Fail
R_1	8	7
R_2	14	1

Table 6. Number of Students Reaching Criterion on the Permutation Rule who Learned with a Nonmeaningful Context.

The Fisher Exact Probability Test was computed for these data. The probability of obtaining these data under the null hypothesis was less than .01. Therefore the null hypothesis was rejected. There was a significant difference in the number of persons reaching criterion on the two retention tests for the permutation rule when it was learned in a nonmeaningful con text.

The results from this study seem to indicate that the context of the original learning has little effect on the retention of rules. The data also indicate a considerable difference in the retention of rules when the factor of availability vs. accessibility is taken into account.

DISCUSSION

The present study investigated the influence of two factors, meaningful context and the use of a retrieval cue on the retention of rules. The data did not indicate any difference in the retention of students who learned in a meaningful context and those who learned in a nonmeaningful context. However when a retrieval cue was used in conjunction with the retention test, performance was substantially improved. This improvement in retention was found for both rules and for both the meaningful and nonmeaningful contexts.

The effectiveness of the retrieval cue provides support for the position that intellectual skills are not forgotten or lost. The lack of ability to reinstate a previously learned intellectual skill, such as a learned rule, may be due to a faulty retrieval scheme rather than to a loss of the skill. Apparently the distinction between availability and accessibility is important in the study of the retention of rules. When the distinction is not taken into account, the losses in the ability to reinstate the rule may mistakenly be attributed to a true loss in the ability to retain the rule. As the present study demonstrated, this loss may be due to the lack of accessibility and not a lack in availability. This study provides support for the distinction in retention of verbal information and intellectual skills (Gagné, 1970). There is considerable indication that previously learned intellectual skills are not lost or forgotten as verbal information appears to be.

The failure to find any difference as a result of the context of the learning materials is not entirely consistent with previous research. Much of the previous research on the factor of meaningfulness would lead one to expect greater retention for the group that learned the rules in a meaningful context. In the present study only two rules were used; this may have been an insufficient number of rules to study the effect of meaningfulness. The use of additional rules would have placed a higher memory load on the students and then perhaps the distinction between a meaningful and nonmeaningful context would be apparent.

An alternate explanation for the failure to find any difference as a result of the context is that the contrast between meaningful and nonmeaningful contexts was not sufficiently great to cause any difference in retention. The difference used in this study was that the examples in one group referred to practical situations while the examples in the other group were more abstract. A greater contrast between meaningfulness-nonmeaningfulness may result in differences in retention.

The results from this study seem to support the position that the retention of intellectual skills is quite high in terms of availability of the skill. The failure to reinstate the skill is more likely a failure in the ability to retrieve the skill rather than an actual loss in the skill.

In order to examine more adequately the retention of intellectual skills further research is called for. The present study examined only one factor, meaningful vs. nonmeaningful contexts, in original learning that may affect

retention. The rule of other factors needs to be examined further. Some specific factors in the original learning that may influence the retention of rules are: a) overlearning of rules, b) learning rules by deriving them rather than by being presented the rule in final form, c) the number of rules to be learned, d) discovery method versus an expository method, and e) the degree of similarity in the rules. In addition to these factors that are involved in the original learning, the use of a retrieval cue to distinguish between availability and accessibility of rules needs to be further examined.

It would also be interesting to extend this type of research to other intellectual skills such as problem solving and concept learning. It may be that these intellectual skills are highly retained in the sense of being available but are not accessible. Additional studies are necessary to identify the factors that influence the availability and the accessibility of previously learned intellectual skills.

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