The Effects on Recall and Recognition of Simple and Complex Numbers in Arithmetic Problems

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Abstract

Two experiments are reported in which college students were given arithmetic problems with simple and complex numbers. Problems involved the accounting equation "current assets + noncurrent assets = total assets." Subjects were told to remember the total assets figure and, depending on the task, either read the equation, verify the total assets figure, or verify the current assets figure. Memory for the total assets figure was tested by recall and recognition procedures. Even when the to-be-remembered information was equated for both conditions, memory was greater for simple than for complex problems by both recall and recognition measures. However, task did not affect memory. Implications are suggested for the design of course materials that include arithmetic problems and examples.

The Effects on Recall and Recognition of Simple

and Complex Numbers in Arithmetic Problems

In general terms, the present study provides an experimental examination which is focused on ways to improve knowledge acquisition. More specifically, the primary aim of the present study is to address the following question: When teaching material involving arithmetic, should one present simple or complex problems as examples for students? Many authors of introductory textbooks that include arithmetic problems, such as those in accounting (see, e.g., Bazley, Nikolai, & Grove., 1988; Davidson, Stickney, & Weil, 1988; Horngren & Sundem, 1990) and those in statistics (see, e.g., Rosenberg, 1990; Runyon & Haber, 1991) present, both in their exposition and in their homework assignments, problems with both complex numbers (e.g., 11,635) and simple numbers (e.g., 11,000). If it is important for students to remember the problems or at least the answers to the problems (e.g., when students who are studying for an exam try to recreate an example given by the instructor), then factors influencing retention should be considered. The following hypothesis concerning such factors is proposed: Using complex numbers rather than simple numbers may impair retention performance. This hypothesis is consistent with the fact that the students' memory load would be smaller for simple numbers than for complex numbers because fewer digits must be retained for the simple numbers. The initial digits of the complex numbers are embedded in a longer sequence of digits than are the initial digits of the simple numbers, and it is well known that memory for a particular word is reduced when that word is embedded in a long sequence rather than in a short sequence (see, e.g., Murdock, 1962). If such memory impairment occurs, then the use of complex numbers in examples would be

detrimental because it may impede learning of the underlying principles illustrated by the problems.

A related issue concerning memory for the answers to arithmetic problems is whether students should be led to generate the answers to the problems themselves as opposed to reading the answers provided either by the instructor or in the textbook. Across many types of materials, the retention advantage of generating rather than reading to-be-remembered information has been well documented in the cognitive psychology literature (see, e.g., Begg & Snider, 1987; Hirshman & Bjork, 1988; Slamecka & Graf, 1978; Slamecka & Katsaiti, 1987). In accounting education, it has also been shown that generating explanations for tax rules enhances retention of those rules (Schadewald & Limberg, 1990). Further, in arithmetic problem solving, it has been found that generating, rather than simply reading, the answers to arithmetic problems leads to superior retention of the problem answers (see Crutcher & Healy, 1989; Gardiner & Rowley, 1984).

In their study of memory for the answers to multiplication problems, Crutcher and Healy (1989) found that the crucial aspect of the generation effect is the activation of the relevant cognitive operations (i.e., the arithmetic procedures) rather than the act of generating or producing the information. In particular, when subjects were asked to verify the answers to multiplication problems performance was equivalent to that when subjects were asked to generate the answers. An aim of the present study was to determine whether the advantage for verification relative to reading the answers to problems could be extended to summation problems in the accounting domain. Further, the present study was aimed at determining whether or not the verification advantage would be found when subjects

verified one of the addends of the accounting equation rather than the to-be-remembered answer (i.e., the sum). It may be that verification aids retention only when the relevant information is verified, just as it has been found that generation aids retention only when the same cognitive operations are performed during generation and at the retention test (see, e.g., Glisky & Rabinowitz, 1985; Rabinowitz & Craik, 1986).

Experiment 1

Introductory accounting students were given problems based on the equation "current assets + noncurrent assets = total assets" and were told that they would be tested on their memory for the answers to the problems (i.e., the total assets figures). The answers consisted of five-digit numbers which were either simple (i.e., contained two digits followed by three zeros) or complex (i.e., contained two digits followed by three nonzero digits). There were three experimental conditions: In the "read" condition, subjects simply read and copied each problem; in the "verify-relevant" condition, subjects read and copied each problem and verified the total assets figure in the problem; and in the "verify-irrelevant" condition, subjects read and copied each problem and verified the current assets figure in the problem. Subjects' memory for the problem answers was tested by both a free recall test and a two-alternative forced-choice recognition test, in which for both simple and complex problems the last three digits of the numbers in a given pair of alternatives were identical. Memory performance, even in the recognition test, should be worse for the complex numbers, according to the hypothesis that complex numbers impair retention. Further, in accordance with the generation effect and, more specifically, the findings of Crutcher and Healy

(1989), memory performance in the verify-relevant condition should be better than that in either the read or verify-irrelevant conditions.

Method

Subjects. Fifty-three undergraduate students from the University of Colorado participated as subjects. All students were currently enrolled in a course in introductory accounting and received payment for their participation in the amount of $5.00. Subjects were assigned to conditions and counterbalancing groups according to a fixed rotation on the basis of their seat placement in the testing room.

Materials. Two sets of experimental booklets were prepared. The first booklet contained a general instruction sheet, followed by a sheet of sample problems, followed by three blocks of five experimental problems, each block preceded by an instruction sheet specific to the experimental condition, followed by a distractor task, and finally a recall task. The second booklet consisted of a recognition test and an exit questionnaire.

None of the sample problems occurred as experimental problems or contained numbers from either the experimental problems or the recognition test.

There were two versions of experimental problems corresponding to the simple and complex conditions of the experiment. Each version showed the sum of current assets and noncurrent assets as total assets. Both of the addends (i.e., the current assets and noncurrent assets) were four- or five-digit numbers in the range between 2,000 and 20,000, and the sum (i.e., the total assets) was always a five-digit number. The two versions of problems were identical except for the last three digits of each number. One version

consisted of simple problems, in which the last three digits of all the numbers were always 000, and the other version consisted of complex problems, in which the last three digits of all the numbers did not contain any zeros. The last three digits for the sum were selected using a random number table with the following constraints: (a) Each of the three digits had to be between 2 and 8, and (b) no two consecutive sets of the three digits had the same initial digit. The last three digits of one of the addends were also selected using a random number table, with the constraint in this case that each digit had to be between 1 and 4. The last three digits of the remaining addend was determined by the difference between the sum and the initially selected addend. This manipulation was instigated to prevent the subject from being forced to do any carries on the problems.

The order of the two addends was pseudorandom. A sample problem from the simple condition was:

Current Assets	$5,000
Noncurrent Assets	$6,000
Total Assets	$11,000

The corresponding sample problem from the complex condition was:

Current Assets	$5,113
Noncurrent Assets	$6,522
Total Assets	$11,635

Each problem was on a separate page. The problems were constrained so that every problem had a unique sum which always ranged between 11,000 and 39,999 and, as mentioned previously, never required a carry.

The first two digits of the 15 sums were selected from a pool of 30 two-digit numbers, which included all 10 numbers from each decade of the range

(i.e., 10 numbers between 10-19, 10 between 20-29, and 10 between 30-39). For the 15 sums, half of these numbers were selected in a pseudorandom manner from a random number table so that there were five numbers from each decade of the range. The first two digits of the addends were selected randomly from the possible set available for each sum given the constraints mentioned above. The problems were assigned to the three blocks in a pseudorandom manner such that the five problems in a block included at least one and no more than two sums with the first two digits from each decade. The assignment of problems to blocks, the arrangement of the three blocks, and the order of problems in each block were fixed across all subjects in both conditions.

The format of the problem sheets differed for the three tasks -- read, verify-relevant, and verify-irrelevant. There were no instructions on the sheets in the read task. However, next to the total assets figure in the verify-relevant task were the instructions: "___ Check if total assets equals current assets + noncurrent assets." Similarly, next to the current assets figure in the verify-irrelevant task were the instructions: "___ Check if current assets equals total assets - noncurrent assets."

The distractor task consisted of a sheet of instructions followed by a sheet containing a three-paragraph prose passage excerpted from an introductory book on sailing.

A single version of the free recall test sheet was prepared for both experimental conditions. The sheet consisted of 15 blank lines, preceded and followed by instructions.

Two versions of the forced-choice recognition test sheet were prepared, one for each version of the experimental problems with the same

instructions at the top of each sheet. The two versions differed only in the last three digits, which were always 000 for the simple problems and nonzero digits for the complex problems. Each total asset figure (i.e., each sum) was paired with another number from the pool of 30 as a distractor. The distractor number did not occur as a total asset figure in any of the problems but always had the same first digit and last three digits as the correct number (e.g., for the simple condition 11,000 was paired with the distractor 15,000, and for the complex condition 11,635 was paired with 15,635). The order of the two items in a pair was determined by a coin toss; thus, for 9 of the 15 pairs the correct number was first. The pairs were ordered into three sets of five pairs each, corresponding to the three blocks of experimental problems, with the pairs in the first, second, and third sets corresponding to the experimental problems in the third, second, and first blocks, respectively. The order of the five pairs within each of the three sets was random.

The exit questionnaire asked for demographic information about the subjects, including the subjects' age, whether the subjects were native speakers of English, how many accounting and psychology courses they had taken in college, and whether they were business majors. The remaining questions asked about the subjects' strategy, effort, understanding of the task, and perception of the experiment. The results of these questions are not reported.

Procedure. Subjects were tested in small groups in a classroom. After assembling into the test group the first packet was distributed. The experimenter read the general instructions aloud while the subjects read them silently. Subjects were told, "At the end of the experiment you will be tested on your memory for the total assets figures." This statement was

underlined and bold-faced for emphasis. The general instructions also

described the arrangement of the experimental problems into three blocks

and described the three tasks the subjects were asked to perform in the initial

phase of the experiment (i.e., before the distractor and memory tasks). For the

read task subjects were told simply "to copy down each of the five problems as

they are written." For the verify-irrelevant task, subjects were told "to copy

down each of the problems and verify that the current assets figure is equal to

total assets minus noncurrent assets." That is, subjects were asked to verify a

figure that was not the same as the to-be-remembered total assets figure (i.e., it

was irrelevant with respect to the subsequent memory tasks). For the verify-

relevant task, subjects were told to "copy down each of the five problems and

verify that the total assets figure is equal to the current assets and the

noncurrent assets." That is, subjects were told to verify the relevant figure

with respect to the subsequent memory tasks. For both verify tasks, subjects

were told to place a check mark next to the figure they verified if it was

correct. All problems were in fact correct, but subjects were not aware of this

fact in advance. Finally, subjects were told that they had 15 seconds to

complete each problem, that they could not go back to any problem once they

had finished it, and that they should not go on to the next problem until they

were told by the experimenter to do so with the command "turn page."

After completing the general instructions, the experimenter and

subject together completed three sample problems, one for each task, placed

in the order read, verify-irrelevant, and verify-relevant on a sheet of paper

following the general instruction sheet. After completing the sample

problems, subjects were given a final opportunity to ask questions before the

start of the experimental problems. Next subjects silently read the specific

instructions for their first block of five problems, which varied depending on the subjects' counterbalancing condition. There were six counterbalancing groups within each subject condition (simple or complex problems), each group corresponding to a different one of the six possible permutations of the three tasks. Subjects went through the experimental problems at a pace determined by the experimenter who said "turn page" every 15 seconds with the aid of a stopwatch. Again before each of the subsequent two blocks of problems, subjects read an instruction sheet silently. At the conclusion of the third block the experimenter read aloud the instructions for the distractor task, which lasted 90 seconds. Subjects were asked to read a one-page article and circle every instance of the word the in the article, which was three paragraphs long. The purpose of the distractor task was to eliminate any recency advantage (i.e., advantage for the last problems) due to short-term memory storage (see, e.g., Postman & Phillips, 1965).

Immediately after the distractor task, the experimenter instructed subjects to turn to the following page which contained the recall test. Subjects were told, "Write down all the total assets figures you can remember." Subjects were told they had 90 seconds to complete the task. After finishing the task, subjects were told to place the packet upside down on their desk. The second packet was then distributed. This packet contained a cover sheet, the recognition test sheet, and the exit questionnaire sheet. The experimenter read aloud the instructions for the recognition test and subjects were allowed 90 seconds to complete the test. Subjects were told to "circle the one number in the pair that was a total assets figure in one of the accounting problems you were given during the prior study phase." For the exit questionnaire, subjects were given as much time as they needed.

Design. There were two measures of retention, one based on free recall and the other on forced-choice recognition. For each measure, there were two between-subjects factors--problem difficulty condition (simple, complex), and counterbalancing group--and one within-subjects factor--task (read, verify-irrelevant, verify-relevant). An alternative within-subjects factor was block position (first, second, third).

Results

Recall. The results are summarized in Table 1 in terms of the mean number of correct responses per five-problem block as a function of problem difficulty condition and task. Only the first two digits of the five-digit numbers were scored as correct or incorrect, because those two digits were the same for the simple and complex problems. A mixed factorial analysis of variance was conducted including the factors of condition, counterbalancing group, and task. The analysis revealed a large main effect of problem difficulty condition ($\underline{F}(1,41)=58.49$, $\underline{MS}_e=2.531$, $\underline{p}<.001$), with simple problems yielding more correct responses ($\underline{M}=2.42$) than complex problems ($\underline{M}=0.50$). There were no other significant main effects or interactions. In particular, there was no significant effect of task.

Insert Table 1 about here

A separate analysis of variance was conducted replacing the task factor with the factor of block position. That analysis revealed a marginally significant main effect of position ($\underline{F}(2,82)=3.02$, $\underline{MS}_e=1.201$, $\underline{p}=.05$); see Figure 1. Subjects showed the worst performance on the second block, suggesting the typical bow-shaped serial position function, despite the presence of the interpolated distractor task (see, e.g., Estes, 1972, for a similar finding). This

effect of block position may have overwhelmed any effect of task. There were no significant interactions involving block position.

_____ Insert Figure 1 about here _____

Recognition. The results for the recognition test are summarized in Table 2 in terms of the mean number of correct responses as a function of problem difficulty condition and task. A mixed factorial analysis of variance was conducted including the factors of problem difficulty condition, counterbalancing group, and task. As for recall, the analysis revealed a significant effect of problem difficulty condition ($F(1,41)=27.53$, $MS_e=1.141$, $p<.001$), with simple problems ($M=3.79$) yielding more correct responses than complex problems ($M=2.89$). There was also a significant three-way interaction of problem difficulty condition, task, and counterbalancing group, ($F(10,82)=2.40$, $MS_e=1.043$, $p<.05$). This interaction is best understood in terms of block position, as described below.

_____ Insert Table 2 about here _____

As for the recall data, a separate analysis of variance was conducted on the recognition data replacing the factor of task with the factor of block position. That analysis revealed both a significant main effect of block position ($F(2,82)=3.66$, $MS_e=1.043$, $p<.05$) and a significant interaction of problem difficulty condition and block position ($F(2,82)=4.78$, $MS_e=1.043$, $p<.05$). As illustrated in Figure 2, the typical bow-shaped function was evident only for the complex problems; for the simple problems performance on the second position was equivalent to that on the first position and somewhat better than that on the third position.

_____ Insert Figure 2 about here _____

Experiment 2

Experiment 1 revealed a strong retention advantage for simple relative to complex problems. That advantage for the recall test could be attributed, at least in part, to the fact that subjects were not told at the time of test that only the first two digits would be scored. Experiment 2 was aimed to determine whether the problem difficulty effect would be obtained in recall even when subjects were told at test that only the first two digits would be scored. Because the effect of problem difficulty was obtained in Experiment 1 on the recognition test as well as the recall test, it was expected that the effect would be found in recall even with the new instructions, but it may be diminished in that case because subjects would make more recall responses when less information was required.

Method

Subjects. Sixty undergraduate students from the University of Colorado participated as subjects. All students were currently enrolled in a course in introductory psychology and received course credit for their participation. Subjects were assigned to conditions and counterbalancing groups in the same manner as in Experiment 1.

Materials. The same materials were used as in Experiment 1 except for a change in the distractor task and a change in the instructions printed at the top of the recall test, as described below. The distractor task consisted of a single sheet of instructions, which also served as a response sheet.

Procedure. The same procedure was employed as in Experiment 1 except for changes in the distractor and recall task. For the distractor task subjects were asked to listen to two short (single-sentence) passages on a tape recorder and write down any word in the passages containing a target sound.

This distractor task was used as a means of data collection in another experiment. Importantly, for the recall task, subjects were told, "Write down the first two digits of all the total assets figures you can remember." That is, rather than recalling the entire five-digit number, subjects were asked to recall only the first two digits, which were the same for the simple and complex problems.

Design. The design was the same as in Experiment 1.

Results

Recall. The results are summarized in Table 3 in terms of the mean number of correct responses as a function of problem difficulty condition and task. As in Experiment 1 and in accord with the subjects' instructions in the present experiment, only the first two digits of every five-digit number were scored for analysis. A mixed factorial analysis of variance was conducted including the factors of condition, counterbalancing group, and task. The analysis revealed a large main effect of problem difficulty condition ($F(1,48)=14.74$, $MS_e=1.403$, $p<.001$), with simple problems yielding more correct responses ($M=1.67$) than complex problems ($M=0.99$). In addition, there was a significant interaction of task and counterbalancing group ($F(10,96)=2.34$, $MS_e=1.094$, $p<.05$). This interaction can be best understood as a main effect of block position, described below.

Insert Table 3 about here

A separate analysis of variance was conducted replacing the task factor with the factor of block position. That analysis revealed a significant main effect of block position ($F(2,96)=3.87$, $MS_e=1.094$, $p<.05$); see Figure 3. Subjects showed the best performance on the third block. Thus, the typical recency effect was evident; however, unlike Experiment 1, no corresponding primacy

effect was observed. There were no significant interactions involving block position.

_____

Insert Figure 3 about here

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<u>Recognition</u>. The results for the recognition test are summarized in Table 4 in terms of the mean number of correct responses as a function of problem difficulty condition and task. A mixed factorial analysis of variance was conducted including the factors of problem difficulty condition, counterbalancing group, and task. As for recall, the analysis revealed a significant effect of problem difficulty condition ($\underline{F}(1,48)=11.08$, $\underline{MS}_e=1.572$, $\underline{p}<.01$), with simple problems ($\underline{M}=3.58$) yielding more correct responses than complex problems ($\underline{M}=2.96$).

_____

Insert Table 4 about here

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As for the recall data, a separate analysis of variance was conducted on the recognition data replacing the factor of task with the factor of block position. That analysis revealed a significant main effect of block position ($\underline{F}(2,96)=4.36$, $\underline{MS}_e=.989$, $\underline{p}<.05$). As illustrated in Figure 4, surprisingly, the serial position function was the reverse of the typical bow shape in this case, with performance best for the second block.

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Insert Figure 4 about here

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<u>Comparison of Experiments 1 and 2.</u> Mixed factorial analyses of variance were conducted on the combined data of Experiments 1 and 2. These analyses were the same as those reported for the separate experiments with the additional factor of experiment. Only the effects involving that factor will be reported here. For the analyses of recall, there was a significant interaction of experiment and problem difficulty condition ($\underline{F}(1,89)=17.42$, $\underline{MS}_e=1.923$, $\underline{p}<.001$). As illustrated in Figure 5, the difference between the simple and

complex problems was much greater for Experiment 1 (in which subjects were to recall all five digits of each number although only the first two were scored) than in Experiment 2 (in which subjects were to recall only the first two digits of each number). There were no other significant effects involving experiment for the analyses of the recall data.

Insert Figure 5 about here

For the analyses of recognition, importantly, the interaction of experiment and problem difficulty was not significant ($F(1,89)=1.13$, $MS_e=1.374$, $p>.250$) Thus, the difference in instructions did not change the magnitude of the difference between simple and complex problems in recognition. There was, however, a significant interaction of experiment, problem difficulty condition, and task ($F(2,178)=3.44$ $MS_e=1.014$, $p<.05$), but for each combination of experiment and task the simple problems were recognized better than the complex problems. In addition, there was a significant interaction of experiment by block position ($F(2,178)=4.03$ $MS_e=1.014$, $p<.05$). This interaction can best be understood by examining the different serial position functions for the two experiments, which are shown in Figure 6.

Insert Figure 6 about here

General Discussion

This research was directed to two sets of issues concerning memory for the answers to arithmetic problems: First, is retention affected by the complexity of the numbers to be recalled? Second, is retention aided by requiring students to perform the arithmetic calculations in the problems, rather than simply requiring them to read the problems with the answers,

and does it matter whether these calculations are relevant to the to-be-recalled numbers? The findings of both experiments yielded a clear-cut positive response to the first issue, but the results were inconclusive for the second issue. In Experiments 1 and 2, subjects in the simple problem difficulty condition showed superior memory relative to those in the complex problem difficulty condition, both in terms of recall and recognition measures, for the first two digits in the to-be-remembered total assets figures. In contrast, there were no indications in either experiment either that the verify conditions promoted better retention than the read condition or that the verify-relevant condition yielded better memory performance than the verify-irrelevant condition. One possible explanation for this finding is that serial position effects, although different for the two experiments and for the two measures of retention, may have overwhelmed any advantages that could be attributed to the students verifying the relevant arithmetic calculations.

The advantage for simple relative to complex numbers can be explained in a number of different ways. Readers should take these various explanations into account when interpreting the results of the present study. First, the advantage found for simple numbers could be explained by the fact that the amount of to-be-remembered information requested may be overwhelming in the case of the complex numbers, so that subjects may not take seriously the instructions to remember the total assets figure. However, that explanation cannot account for the fact that when memory was tested in a more sensitive way (e.g., by recognition rather than by recall), subjects' performance did indicate that they had attended to the instructions. Specifically, the superior performance on the recall test of Experiment 2

relative to that of Experiment 1 and the above-chance performance on the recognition test of both experiments suggests that subjects did indeed attempt to remember the complex total assets figures, as instructed.

Second, the advantage found for simple numbers could be caused by the fact that the extra digits in the complex numbers (i.e., those occurring after the first two digits) became confused with the to-be-remembered digits (i.e., the first two digits). The extra digits could degrade the memory representation for the to-be-remembered digits. Alternatively, rather than causing storage problems, the extra digits could cause problems in retrieving the to-be-remembered digits. A related concern for simple as well as complex numbers is that the addends in each problem could be confused with the answers. Further, subjects may confuse the numbers in the examples with the numbers in the experimental problems.

Third, the advantage for the simple numbers may rely on the assumption that the simple problems are familiar to the subjects. If the subjects ignore the irrelevant zeros in the simple numbers, they are likely to recognize the problems as ones they have encountered on many previous occasions. In contrast, it is very unlikely that subjects have previously encountered any of the complex problems in their entirety, and subjects are less likely to ignore their last three digits, all of which were nonzero. For example, $5+6=11$ should be much more familiar to the subjects than $5{,}113 + 6{,}522 = 11{,}635$. Familiarity with the problem could allow subjects to retrieve the to-be-remembered answer on the basis of information derived from the addends. For example, subjects may use their memory that 5 and 6 occurred together as addends and their knowledge that $5+6=11$ to prompt, or cue, their response on the memory test for the answer, 11. Crutcher and Healy (1989)

used a similar argument based on subjects' verbal protocols of their processes when recalling the answers to simple multiplication problems. With the complex numbers, such a prompting by the addends seems unlikely because the addends are probably too large to be stored in memory and there would be no familiar knowledge representation for the whole problem.

Fourth, and most interesting, the advantage for simple numbers may be due to the fact that the subject's memory load would be smaller in that case because fewer digits must be retained. An important consequence of the reduced memory load is that it would allow for more resources to be devoted to other processes. Subjects may commit to memory the additional nonzero digits in the complex numbers, thus taxing their available processing resources. In a classroom setting, having more cognitive resources available would allow students to process other information, including general principles and concepts being illustrated by the problems.

The results of the present experiments have straightforward implications for the design of course materials that involve arithmetic problems and examples. Specifically, teachers and authors of textbooks, whenever possible, should use simple, familiar problems as examples both to promote the students' memory for the illustrations and, possibly, to facilitate their understanding of the underlying principles or concepts being illustrated. An extension of this argument is that simple problems might become even more beneficial as the complexity of the principles and concepts increases.

References

Bazley, J. D., Nikolai, L. A., & Grove, H. D. (1988). Financial accounting: Concepts and uses. Boston, MA: PWS-KENT Publishing Company.

Begg, I., & Snider, A. (1987). The generation effect: Evidence for generalized inhibition. Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 553-563.

Crutcher, R. J., & Healy, A. F. (1989). Cognitive operations and the generation effect. Journal of Experimental Psychology: Learning, Memory and Cognition, 15, 669-675.

Davidson, S., Stickney, C. P., & Weil, R. L. (1988). Financial accounting: An introduction to concepts, methods, and uses (Fifth Edition ed.). Chicago, IL: Dryden Press.

Estes, W. K. (1972). An associative basis for coding and organization in memory. In A. W. Melton & E. Martin (Eds.), Coding processes in human memory (pp. 161-190). Washington, D.C.: V. H. Winston & Sons.

Gardiner, J. M., & Rowley, J. M. C. (1984). A generation effect with numbers rather than words. Memory & Cognition, 12, 443-445.

Glisky, E. L., & Rabinowitz, J. C. (1985). Enhancing the generation effect through repetition of operations. Journal of Experimental Psychology: Learning, Memory, and Cognition, 11, 193-205.

Hirshman, E., & Bjork, R. A. (1988). The generation effect: Support for a two-factor theory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 14, 484-494.

Horngren, C. T., & Sundem, G. L. (1990). Introduction to financial accounting (Fourth Edition ed.). Englewood Cliffs, NJ: Prentince-Hall, Inc.

Murdock, B. B., Jr. (1962). The serial position effect of free recall. Journal of

Experimental Psychology, 64, 482-488.

Postman, L., & Phillips, L. W. (1965). Short term temporal changes in free

recall. Quarterly Journal of Experimental Psychology, 17, 132-138.

Rabinowitz, J. C., & Craik, F. I. M. (1986). Specific enhancement effects

associated with word generation. Journal of Memory and Language, 25,

226-237.

Rosenberg, K. M. (1990). Statistics for behavioral sciences. Dubuque, IA: Wm.

C. Brown.

Runyon, R. P., & Haber, A. (1991). Fundamentals of behavioral statistics

(Seventh ed.). New York: McGraw-Hill.

Schadewald, M., & Limberg, S. (1990). Instructor-provided versus student-

generated explanations of tax rules: Effect on recall. Issues in

Accounting Education, 5, 30-40.

Slamecka, N. J., & Graf, P. (1978). The generation effect: Delineation of a

phenomenon. Journal of Experimental Psychology: Human Learning

and Memory, 4, 592-604.

Slamecka, N. J., & Katsaiti, L. T. (1987). The generation effect as an artifact of

selective displaced rehearsal. Journal of Memory and Language, 26, 589-

607.

Author Notes

Table 1

Mean Number of Correct Recall Responses (out of five) as a Function of

Problem Difficulty Condition and Task in Experiment 1

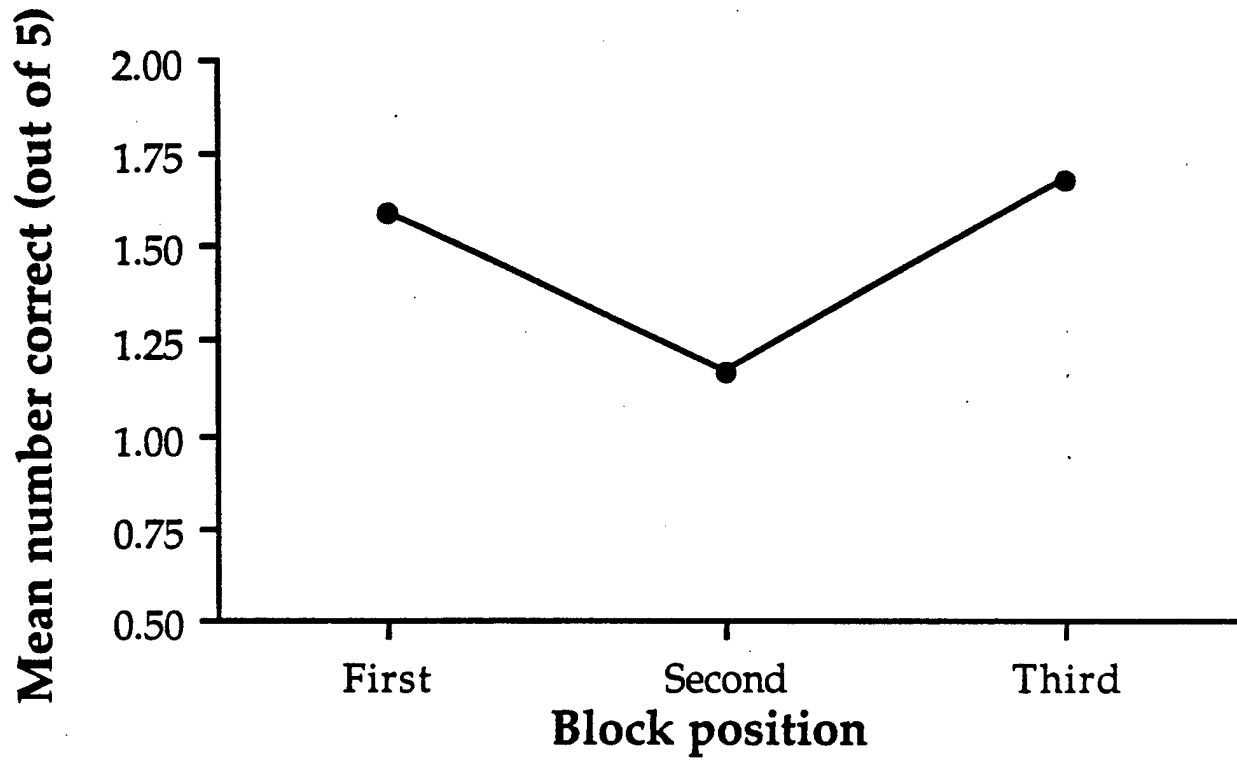|	Mean	Std. error
Simple (n=27)		
Verify-Relevant	2.444	.269
Verify-Irrelevant	2.148	.301
Read	2.667	.320
Complex (n=26)		
Verify-Relevant	.308	.155
Verify-Irrelevant	.462	.149
Read	.731	.189

Table 2

Mean Number of Correct Recognition Responses (out of five) as a Function of

Problem Difficulty Condition and Task in Experiment 1

	Mean	Std. error
Simple (n=27)		
Verify-Relevant	3.852	.157
Verify-Irrelevant	3.667	.214
Read	3.852	.205
Complex (n=26)		
Verify-Relevant	2.962	.188
Verify-Irrelevant	3.115	.290
Read	2.577	.185

Table 3

Mean Number of Correct Recall Responses (out of five) as a Function of

Problem Difficulty Condition and Task in Experiment 2

	Mean	Std. error
Simple (n=30)		
Verify-Relevant	1.500	.234
Verify-Irrelevant	2.000	.209
Read	1.500	.224
Complex (n=30)		
Verify-Relevant	1.067	.203
Verify-Irrelevant	0.833	.180
Read	1.067	.166

Table 4

Mean Number of Correct Recognition Responses (out of five) as a Function of Problem Difficulty Condition and Task in Experiment 2

	Mean	Std. error
Simple (n=30)		
Verify-Relevant	3.433	.184
Verify-Irrelevant	3.900	.154
Read	3.400	.201
Complex (n=30)		
Verify-Relevant	2.967	.217
Verify-Irrelevant	2.900	.246
Read	3.000	.198

Figure Captions

Figure 1. Mean number of correct recall responses (out of five) as a function of block position in Experiment 1.

Figure 2. Mean number of correct recognition responses (out of five) as a function of problem difficulty condition and block position in Experiment 1.

Figure 3. Mean number of correct recall responses (out of five) as a function of block position in Experiment 2.
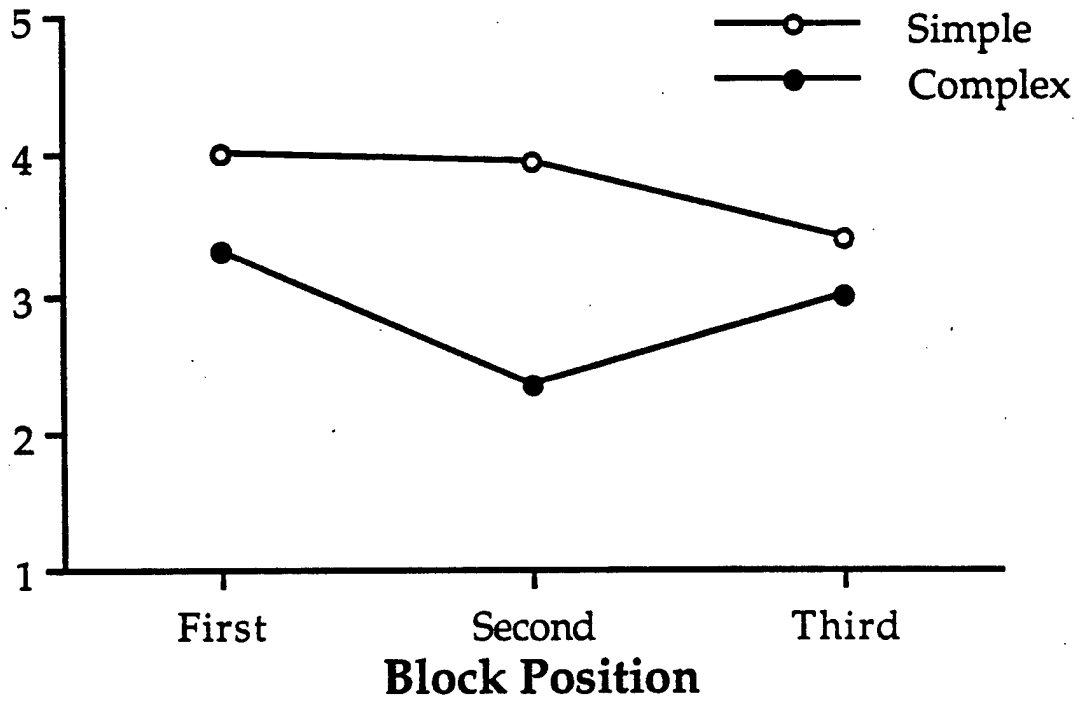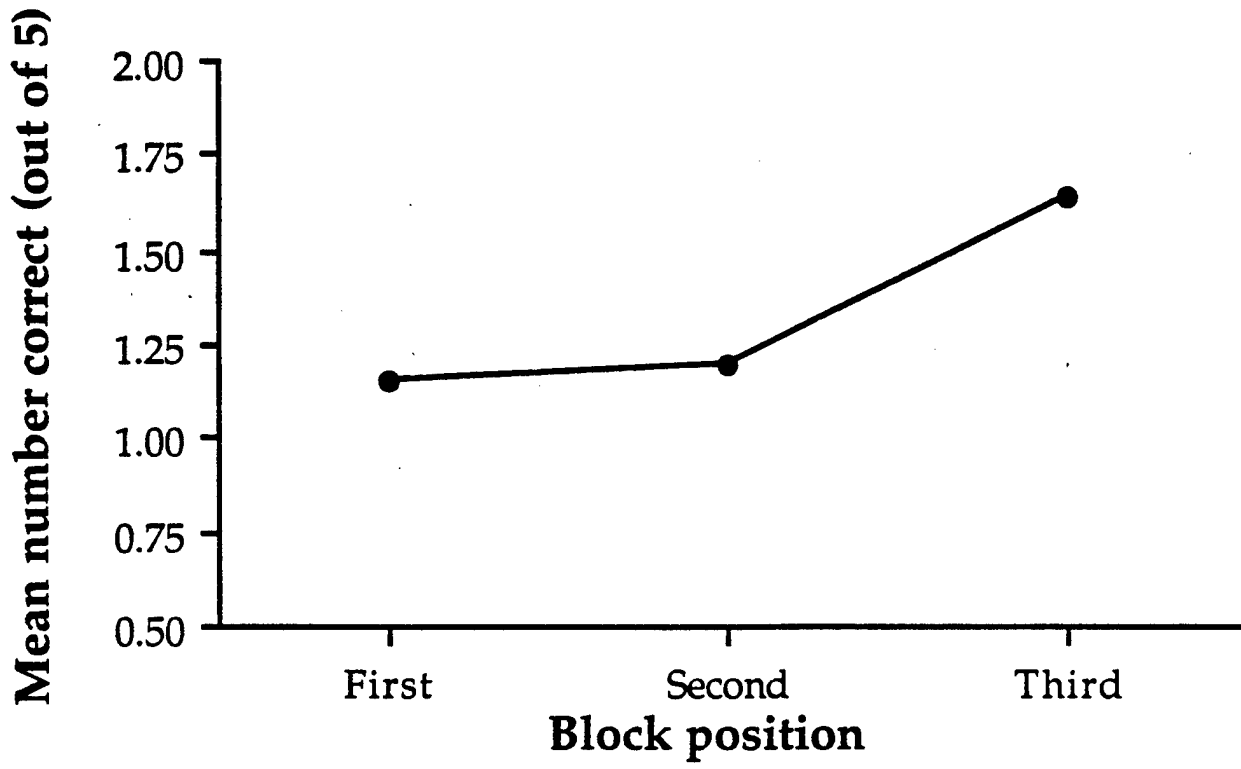
Figure 4. Mean number of correct recognition responses (out of five) as a function of block position in Experiment 2.

Figure 5. Mean number of correct recall responses (out of five) as a function of problem difficulty condition in Experiments 1 and 2.

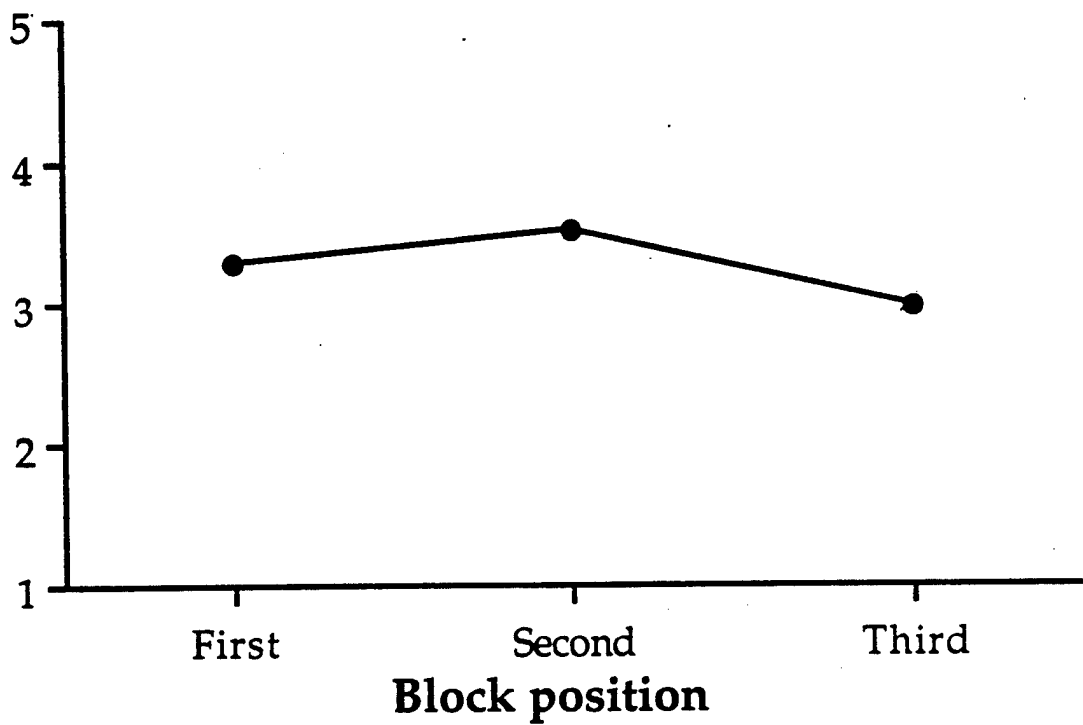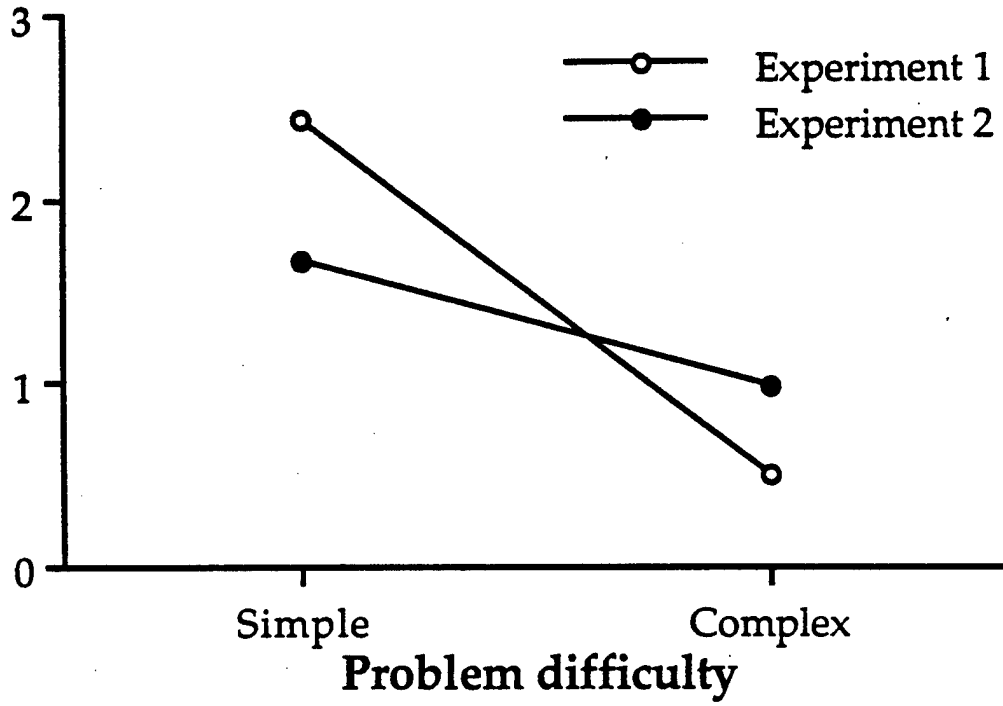Figure 6. Mean number of correct recognition responses (out of five) as a function of block position in Experiments 1 and 2.