1-1-1988

Acquisition and Application of Expertise at Computer Text Editing by Younger and Older Adults

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ABSTRACT

Groups of younger and older adults learned to use a computer text editor. Measures of both knowledge and performance were collected at regular intervals. Better recall of material learned was correlated with better performance; there were no age group differences in recalled knowledge or in performance. Models of more skilled individuals showed richer knowledge representations and more sophisticated performance rules than models of less skilled individuals. Age accounted for very little of the variation in skilled performance.

INTRODUCTION

There are clear differences between older and younger adults in learning as it is studied in the psychological laboratory. It is an open question whether the same phenomena appear in learning that more closely represents that which occurs in everyday life. Intentional learning in everyday life is frequently done not for the purpose of being tested, but, rather, so that problems can be solved. An individual masters a body of knowledge so that the acquired expertise can be applied to achieve some necessary or desired ends. To explore learning-for-problem-solving, younger and older adults were taught to use a microcomputer for word processing in a program of computer-assisted instruction. A computer-based skill was selected for two reasons. First, computerization of society has been both rapid and extensive. Mastery of computer-use skills will soon be essential to adults of all ages both in and out of the workplace. Second, although late middle age and elderly adults have been characterized as slow to adopt and master innovations, there is little empirical evidence to validate this claim. Text editing was selected because it is a paradigmatic example of human computer interaction (Card, Moran, & Newell, 1983). Text editors are probably the most widely used computer application, they are representative of a broad range of applications, and they become a tool that can be an unconscious extension of the skilled user.

METHOD

Participants were 12 older and 12 younger adults (aged 65-75 and 18-30 years, respectively) who had no prior experience with computer use. They learned to use a word processing program (called EDITOR) that surreptitiously recorded the user's actions and the time taken to select and execute them. EDITOR is a "line-oriented"

text editor, that is, one in which line numbers are displayed next to each line of text and the user issues a single-letter command and specifies to which line it is to be applied. The principal commands allow the user to print a line (P), delete an existing line (D), insert a new line (I), replace an existing line (R), find a specified string of characters in the text (F), change a specified character string, replacing it with another (C), or request help with any command (H). The general format for a line command is Command+Line Specification: P200 or D100. The general format for a string command is Command/String Specification/Line Specification: F/string/320 or C/remove string/insert string/165. A command can operate over several lines if line range is specified.

Eight computer-assisted lessons took place over six separate sessions. The lessons included presentation of text editing concepts, commands and functions, examples, simple practice exercises on new concepts, and more complex exercises that drew on all the material covered to that point. At the beginning and end of every session, learners were asked to provide a written recall of what they had learned to that point. This was done to prompt rehearsal and consolidation of the material, and to provide evidence about the current state of declarative knowledge. Evidence of procedural knowledge was obtained from the time-stamped protocols of EDITOR use.

The major findings from the study concerning recall and performance were summarized by Hartley, Hartley, and Johnson (1984): At the end of training, there were no significant differences between younger and older adults either when overall recall was considered or when the material was separated into concepts, names, functions, and procedures. It is interesting to note that subsequent research on individuals from the populations studied here (many of whom also participated in this study) has found that recall of both word lists and connected prose is significantly lower for older than for younger adults (Hartley, 1986). These results are consistent with other findings of age differences in laboratory memory tasks, and they reduce the likelihood that the absence of age differences in recall of information about EDITOR is due to subject selection artifacts. The younger and older adults also did not differ in the correctness or efficiency with which editing operations were carried out. The older adults, however, worked more slowly, completing fewer tasks in the time allotted.

The present report is concerned with the relations between memory and performance. First, "macro" measures of each will be described and relations among them reported. Next, more fine grained, "micro" analyses of knowledge and of performance will be presented. Finally, possible relations at the micro level will be explored.

RELATIONS BETWEEN RECALL AND PERFORMANCE

The measures of recall selected for analysis were written protocols taken at the end of the last session of instruction (R1) and at the end of the next session, which was devoted entirely to editing problems with no additional instruction (R2). The measures of performance were taken from the final problem session: the

proportion of the tasks that were attempted in the limited time (ATT), the proportion of tasks attempted that were completed correctly (COR), and the average efficiency (EFF), defined as the optimal number of operations per task divided by the actual number of operations. Several individual difference measures were also collected in order to assess the general level of cognitive functioning of the participants: (a) the reading span measure described by Daneman and Carpenter (1980) which provides an index of working memory capacity (RS), (b) a measure of vocabulary (VOC), (c) a measure of abstract reasoning (ABS), and (d) a measure of reading comprehension (COM).

Table 1. Correlations Between Measures of Memory, Performance, and Individual Differences

R2	.81							
EFF	.54	.26						
ATT	.61	.64	.21					
COR	.44	.33	.28	.49				
VOC	.58	.51	.40	.50	.13			
COM	.47	.30	.61	.53	.43	.57		
RS	.38	.36	.35	.49	.09	.47	.60	
ABS	.17	.08	.17	.43	-.13	.06	.22	.58
	R1	R2	EFF	ATT	COR	VOC	COM	RS

(Coefficients greater than .36 are significant at $p<.05$)

The only significant difference between older and younger adults for recall and performance measures was in the proportion of editing tasks that were attempted. For the individual difference measures, however, older adults scored lower on the reading span and abstract reasoning measures and higher on the vocabulary measure. Because of this pattern of age differences, correlations between the three sets of measures (recall, performance, and individual differences) were determined with the effect of age controlled. Table 1 shows the partial correlation coefficients among the measures. The memory measure that was most predictive of performance was the amount of declarative knowledge at the end of the last lesson: All three measures of performance were related to the amount recalled at this point. In the set of individual difference measures, reading comprehension was the best predictor of performance, but both vocabulary and reading span showed substantial correlations with the efficiency and tasks-attempted measures. The same individual difference measures were related to the memory measures as well. Within the performance measures, the only significant correlation was between the tasks-attempted and tasks correctly accomplished measures. The pattern of relationships suggests that general level of verbal competence and working memory resources may determine both the acquisition of information about a text editor and the performance of problem-solving tasks with the

text editor. Further, declarative knowledge was a good predictor of procedural knowledge in both older and younger adults.

MICROANALYSIS OF RECALL

To examine the form of declarative knowledge, a subset of the research participants was selected for finer-grained analysis. Three older and three younger adults who were judged to be high skill individuals, and an equivalent number who were judged to be low skill individuals, were selected for this analysis. The selection was based on a combination of recall and performance measures, with the teaching assistant's judgment of overall competence used as an additional criterion. Declarative knowledge representations based on recall protocols were constructed for each of these participants. The sequence of information from each of seven recall periods during learning and one following the final editing problems session was coded to show the connections between concepts. Concepts were defined as being connected in a network if they appeared adjacent to each other on two or more occasions. A summary of the information obtained from these representations is shown in Table 2, and includes the total number of concepts that appeared at least once on a recall protocol, the average number of connections that each concept had associated with it, the number of concepts that were part of the knowledge network (defined above), and the percent of those concepts recalled that were included in the network. The numbers reported in Table 2 are averaged over the three participants in each of the age/skill groups.

Table 2. Characteristics of Knowledge Networks

	High Skill		Low Skill	
Measure	Young	Old	Young	Old
Concepts Recalled	42.7	42.3	31.7	34.7
Connections	11.1	9.2	5.0	4.1
Concepts in Network	34.0	34.7	17.3	15.3
% Concepts in Network	79.5	77.6	52.4	44.6

Because of the small number of cases examined, statistical analyses of these data were not appropriate. However, it is apparent that the networks of younger and older learners were quite similar. The primary distinction between the ability groups was in the connectedness of the networks: The high skill individuals had twice as many links between concepts, twice as many concepts in the networks, and a greater percentage of the recalled concepts were included in the networks.

MICROANALYSIS OF PERFORMANCE

A generic Goals-Operators-Methods-Selection (GOMS) model of text editing, similar to that proposed by Card, Moran, and Newell (1983), was constructed (Figure 1) and editing performance for the subsets of participants was examined. GOALS derive mostly from analysis of

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GOAL:  EDIT_MANUSCRIPT
   .   GOAL:  ACQUIRE_TEXT
   .   GOAL:  EDIT_UNIT_TASK until no more or out of time
   .   .  GOAL:  ACQUIRE_UNIT_TASK
   .   .  GOAL:  EXECUTE_UNIT_TASK
   .   .   .select  USE_DELETE_METHOD
                      if all of a line to be removed
                    USE_INSERT_METHOD
                      if a new line to be added
                    USE_DELETE/INSERT_METHOD
                      if more than 40 characters to
                      be removed or if a line of fewer
                      than 20 characters to be completed
                      or if...
                    USE_REPLACE_METHOD
                      if more than 40 characters to be
                      removed or if a line of fewer than
                      20 characters to be completed
                      or if...
                    USE_CHANGE_METHOD if . . .
                     . ISSUE_CHANGE_COMMAND
                     . SPECIFY_DELIMITER
                     . GOAL:  SPECIFY_OLDSTRING
                     .  .select  WORD_METHOD
                                 LETTER_METHOD
                                 MINIMAL_STRING_METHOD
                                 TARGET_WORD_METHOD
                     .  REPEAT_DELIMITER
                     .  SPECIFY_NEWSTRING
                     .  REPEAT_DELIMITER
                     .  SPECIFY_LINE
                    USE_MULTILINE-CHANGE_METHOD if . . .
   .   .   .GOAL:  VERIFY_UNIT_TASK
   .   .   .   .   GOAL:  RECTIFY_ERROR until no error
   .   .   .   .    .EXECUTE_UNIT_TASK
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Fig. 1. Generic Goal-Operator-Method-Select (GOMS) model for editing performance

the task, and were consistent across individuals. Individual differences were reflected in the METHODS that were selected and when they were used; those in which there were substantial differences are indicated by an incomplete conditional (*if...*). The selection rules inferred from the protocols of skilled individuals were strikingly different from those of less skilled, but age differences were minimal. Skilled individuals used the change command (CHANGE_METHOD) except when the change involved more than about 15-20 characters. Less skilled individuals either replaced whole lines or shifted unsystematically between replacing and changing, making frequent errors when using the change command. There were consistent individual differences in whether a replacement was done by deleting the old line and inserting a new one (DELETE/INSERT_METHOD) or by specifying the replace command (REPLACE_METHOD), but the differences were not related to skill level. Skilled individuals were more likely to make multiline changes (MULTILINE-CHANGE_METHOD), though this was somewhat more

likely in younger than in older adults. When skilled individuals used the change command to make a correction, they were most likely to specify the smallest string logically possible or one a few letters longer (average length was four characters); less skilled individuals specified one or more surrounding words. When an entire word was to be replaced, all users tended to specify the target word.

The principal difference between skilled and less skilled individuals was in the use of the powerful but syntactically complex change command. During learning, skilled individuals may have achieved sufficient mastery that the syntax could be handled automatically and attention could be directed to locating strings that would specify changes efficiently. Nonetheless, few skilled individuals escaped syntax errors in using the change command. An alternative is that less skilled individuals brought lower levels of cognitive resources to bear on the task, so both the syntax and string specification imposed significant burdens. Support for this alternative was found in two observations. First, skilled individuals were more likely to scan the manuscript to locate repeated changes, consistent with the interpretation that they had more resources available. Second, correlation of the measure of working memory capacity with both recall and performance measures suggests that limitations in processing resources are important in both declarative and procedural knowledge acquisition.

ACKNOWLEDGEMENTS

This research was supported by a grant from the Spencer Foundation, and by the Scholarly and Creative Activities Committee of California State University at Long Beach.

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