Using Mental Schemata: An Experimental Analysis of Computer Skill Acquisition

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Abstract

Although mental schemata are central to many contemporary learning theories, the precise relationship between such schemata and specific types of learning remains vague. This paper describes an analysis of subjects learning basic computer skills when presented with four different kinds of elaborations that should influence subjects' schemata: (1) a simple description with no model; (2) a redundant elaborated text also with no explicit model; (3) a functional model; (4) a descriptive analogy. Subjects were tested on procedures, general command concepts, and system questions. Models and analogies were shown to improve initial performance on all types of questions. However only system questions showed this advantage after a delay. It is argued that the utility of building a mental model through elaboration depends on the specific tasks that are analyzed.

Although there is consensus concerning the general utility of mental models, there is relatively little agreement concerning the ways in which these models are formed and used in specific tasks. These more detailed relationships are necessary both for a general theory of learning and for designing improved instruction. This paper provides one instance of specific model-task analysis, by investigating the use of models during the acquisition of basic computer (operating system and editor) skills. There are three questions that this research is designed to address: (1) Do explicit attempts to modify the subjects' schemata by providing elaborations influence performance? (2) Are the effects of such manipulations specific to particular kinds of tasks or do they generalize to a range of tasks? (3) What underlying mechanisms can account for these effects?

In order to evaluate the effectiveness of explicit models, we manipulated the kinds of information (models) presented to subjects. Specifically, the study investigated functional models of the underlying

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system operations, analogies describing system performance, and specific examples of commands. The question of the influences of models on different tasks was addressed by a series of tests assessing knowledge of specific procedures, knowledge of the general principles behind the procedures, and knowledge about the general functioning of the system.

Method

Subjects and Materials

Eight students who had some computer experience but no prior experience with UNIX served as subjects.

Instructions. The experimental materials consisted of a set of four booklets, each describing a subset of UNIX commands. Each booklet presented a general description of a particular aspect of the system followed by a description of the procedure for using four UNIX commands.

Eight versions were written for each of the booklets, reflecting four different types of elaboration combined orthogonally with two formats of command examples. The four elaboration conditions consisted of the following: (1) The Simple version stated the relevant concepts, but provided no elaboration of their meaning. (2) The Elaborated version contained an extended statement of the simple concepts, while avoiding explanatory material insofar as possible. (3) The Model version provided a functional model describing certain properties of the system. (4) The Analogy version provided an analogy from a familiar domain.

For each elaboration condition, there were two types of example format. The abstract format included a general description of the procedure together with an abstract statement of the form of the command (e.g. "mv NAME1 NAME2<cr>"). The concrete example format described a specific instance of command use and indicated the way in which that particular command would be written (e.g. "mv george harry<cr>").

Questions. For each set of concepts and commands (each booklet), a set of related questions was developed. These questions were divided into three groups: procedural questions testing knowledge of specific procedures: "true-false" declarative questions, testing general knowledge of command usage; and system questions, testing knowledge of overall system structure or function.

Procedure

Each subject was run individually on three consecutive days. On each of the first two days, subjects were presented with two of the four instruction booklets, each followed by a related set of questions. On the third day they were presented with all of the questions from the first two days in quasi-random order. For each booklet of instructions and each set of questions, the subject was asked to read aloud the material and to say whatever came to mind while reading or while answering questions.

Results

Elaboration Condition. The effect of elaboration condition for the three types of questions immediately after training (initial performance) is shown in Figure 1. In general, performance was better in the model and analogy conditions than in the simple and elaborated conditions. Procedural and declarative questions showed reliable effects of elaboration condition ($F(3,9) = 9.20$, $p < .01$). Models and analogies were best for procedural questions, whereas the elaborated condition was worst. For the declarative questions, analogies were better than the other three elaborations. The greatest effects of type of elaboration were evidenced on the system questions ($F(3,9) = 4.03$, $p < .05$). Responses in the model and analogy conditions indicate 76% correct, whereas the responses in the simple and elaborated conditions were at 50%.

Subjects were better with the editor questions (procedural 62%; declarative: 76%) than with the other command subsets (procedural: 39%; declarative 63%). This is probably due to subjects having had more previous experience with editors than with other types of commands.

INITIAL PERFORMANCE BY ELABORATION

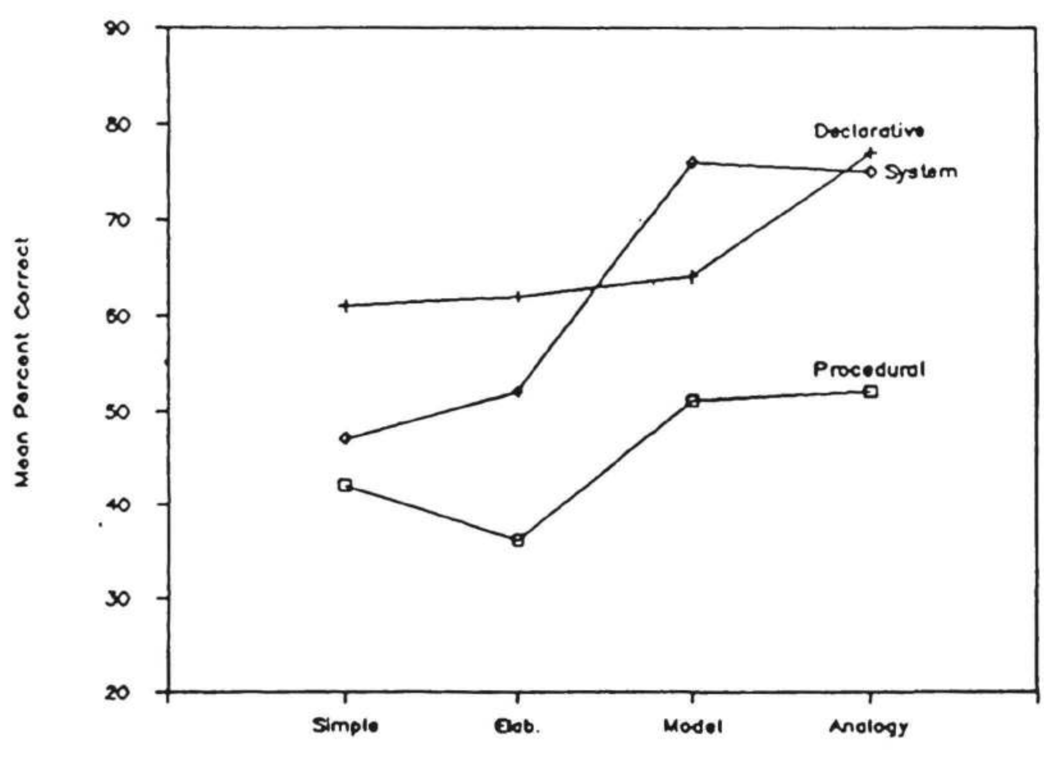

Figure 1

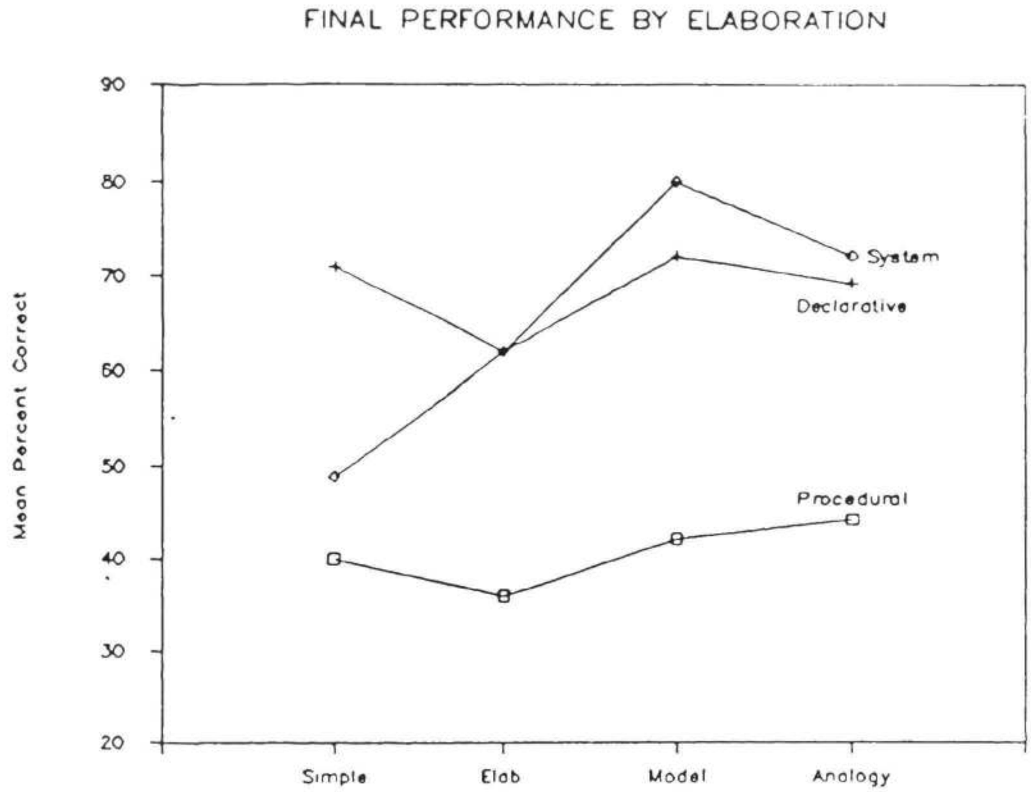

Figure 2

Changes in the effects of elaboration over time were measured by a final test after the completion of all training. The results for this performance are shown in Figure 2. The model and analogy conditions continued to show a performance advantage for system questions which required general knowledge of concepts rather than individual procedures. The rank order effects for procedural questions remained the same, but differences among elaboration conditions were no longer reliable. Presumably the models and analogies provided relatively little help in retaining specific aspects of individual commands.

Examples. As can be seen in Figure 3, the primary effect of examples was in the procedural case. Those using concrete examples got 51% of the procedures correct, whereas those using an abstract format got only 39% correct. Presumably the specific examples provide a concrete instance that is easier to assimilate than the general statements. These specific syntactic components, however, did not seem to have general utility for either the more general command information in the declarative questions, or for the system questions. At the same time, it is important to note that abstract formats did not improve responses to general command (declarative) questions. A single concrete example appears to be as useful in this case as the more abstract statement.

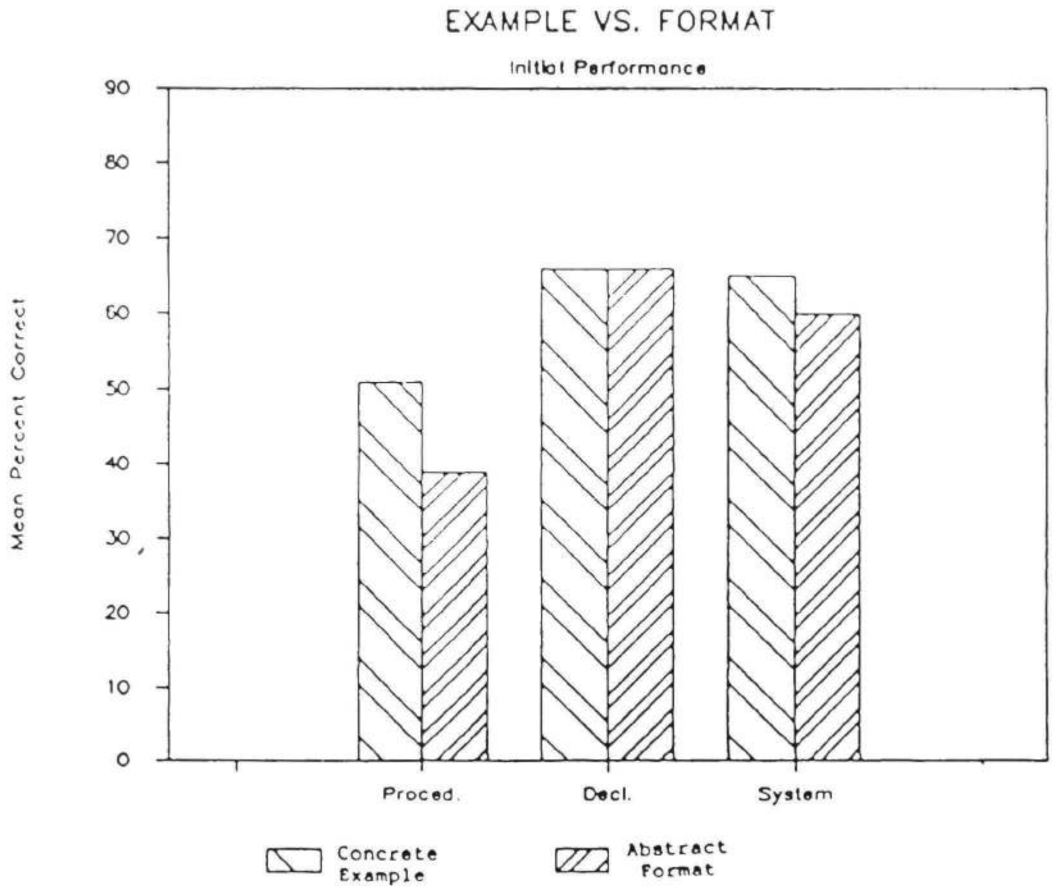

Figure 3

The effect of examples is largely eliminated during final testing. Unlike the model information, examples appeared to be encoded as separate instances. Individual retrieval of these items required in initial performance is fairly straightforward: however, such individual instances apparently do not provide the kind of schema that is necessary to distinguish among a set of commands as required during final performance.

Learning and Forgetting. Changes in schemata over time were assessed by analyzing response changes between initial and final testing. Learning was assessed by determining the percentage of wrong answers on initial performance that were correct on final performance. Forgetting was measured by determining the percentage of questions that were initially correct, but which were wrong on the final performance test. The results of this analysis are shown in Figure 4. In general, there is more forgetting than learning on the procedural questions, whereas there is more learning than forgetting on both the declarative and system questions.

These results are consistent with the notion that subjects are actively integrating information during initial testing as well as during study whenever it is available. The procedural questions require specific sequences of steps, and there is relatively little information about those sequences outside of the specific commands. The declarative and system questions, on the other hand, do not require specific syntactic knowledge. Information from other commands can be informative about the kinds of constraints imposed or about possible generalizations. As a consequence, to the extent that the material from the different booklets is actively integrated, subjects may actually be learning or improving their understanding of new concepts.

This kind of integrative learning, however, can also hurt performance. If subjects are actively assimilating information they may take false statements as true. In fact, we found that our subjects tended to change almost twice as many of their responses on declarative questions from false to true (32%) as from true to false (17%).

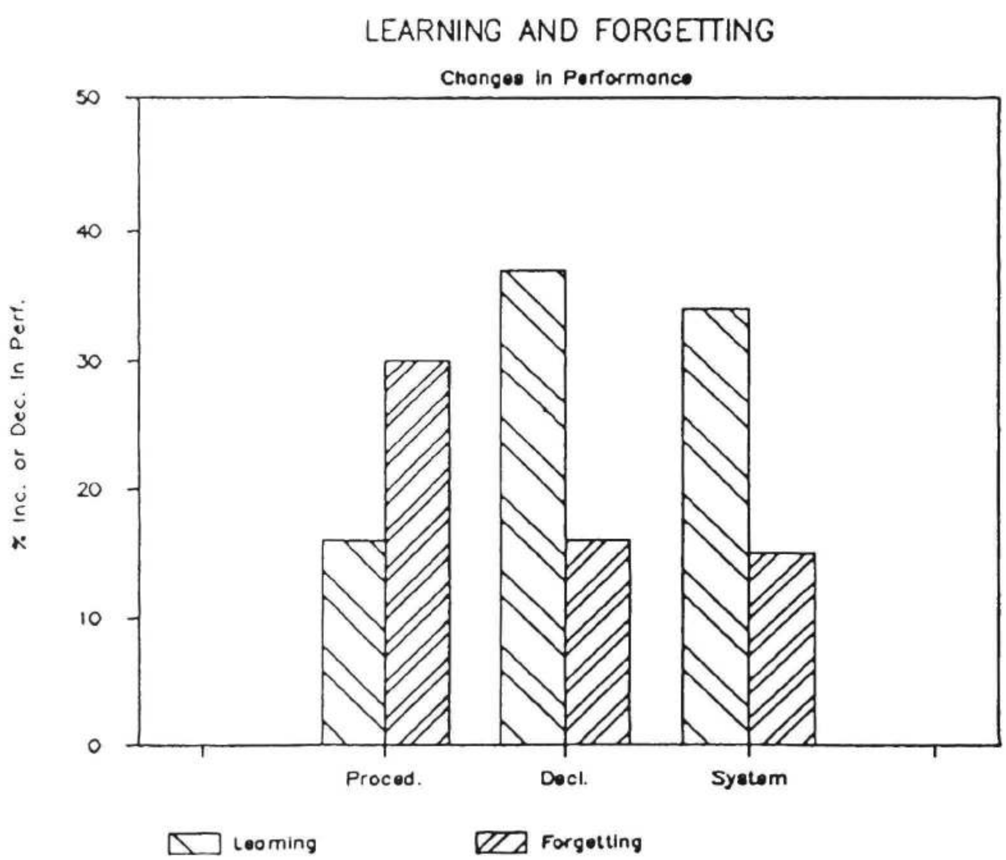

Figure 4

Discussion

The results reported here indicate that certain types of elaboration can in fact improve performance. The most dramatic effects of models and analogies were found on system questions which tapped general system knowledge. These results suggest that a model or analogy can provide a framework to which new information is assimilated. Improved performance was evident during both initial and final tests, suggesting that the elaborations provided a useful schema for retention. These results are consistent with those reported for basic text editing (Bott, 1979) and simple programming tasks (Mayer, 1975).

Models and analogies also showed improvement on procedural and declarative questions, suggesting that elaborations can influence different types of information. An analysis of errors indicated that improved performance was not restricted to particular questions. It is likely that the additional information provided by models and analogies improved performance through multiple access routes activated in memory (Anderson & Reder, 1979; Reder, 1979). These effects, however, are largely eliminated during final performance. This seems to be due to two factors. First, the model information is not specifically linked to individual procedures. Second, the information about command use is being integrated across the various commands. This amounts to a type of self elaboration in which subjects organize individual commands according to their own models, thus minimizing differences among the elaboration conditions.

Although there is some evidence of assimilation, our data suggest that much of the information is stored as individual facts or small clusters of knowledge rather than as general schemata. This type of encoding is perhaps most evident in the use of specific procedures and examples. Concrete examples did improve performance on procedures, even in the absence of general models. By storing a specific instance, subjects could apparently retrieve that individual instance at the time of test with a related example. The importance of this effect of individual instances was noted by Ross (1984) in a study on reminding. He found that during the acquisition of text-editing skills, subjects retrieved procedures by being reminded of superficial resemblances of the examples. Thus subjects would often use specific instances rather than any general model.

This approach seemed useful to our subjects when the number of commands was very restricted as in initial testing. However, the advantage of examples was not present during final testing when subjects were required to remember numerous instances. Presumably the examples are useful only as long as they provide sufficient information to discriminate among different procedures.

Changes in performance suggested that subjects were continuing to integrate information during the course of the study. For experts in any domain, assimilation of new information is often sufficient since they already have highly elaborated models of a domain. In the present study, some of our subjects appeared to perform like experts with respect to editing information, a domain which was quite familiar. In general, however, our subjects schemata were either missing or distorted. The data suggest that providing explicit models can help in the task of restructuring schemata (Rumelhart & Norman, 1978) or in constructing new ones. That process, however, is complex; although providing specific types of elaborations can improve performance by providing an explicit framework for integration of knowledge, subjects also introduce their own strategies for developing a representation of the domain.

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