SIMULATION AND INFORMATION ORDER AS INFLUENCES IN THE DEVELOPMENT OF MENTAL MODELS

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BACKGROUND

Research in the area of mental models (Coovert, 1987; 1990; Coovert, LaLomia, & Salas, 1989) has suggested that training individuals about a procedural device can be enhanced by providing learners with a conceptual model of the device. A conceptual model conveys the underlying structure of the device, and aids the user in inferring the procedures necessary for its operation. Such models are intended to give the learner a better understanding of how the device functions, as well as assisting the learner formulate a more useful mental model. The end result is a more capable individual.

The present study examined two characteristics which are thought to influence the development of an effective mental model. These characteristics are: 1) the order of presentation of a conceptual model, and 2) the use of simulation (we use the terms simulation and animation interchangeably). It was hypothesized that presenting a conceptual model of a computer's operating environment, before any procedural instructions, would facilitate development of an individual's mental model. We also hypothesized that simulation would lead to the development of an enriched mental model. Thus, receiving a conceptual model of the system and seeing aspects of it animated would facilitate learning and lead to improved performance both during training as well as later.

METHOD

Independent variables. The independent variables manipulated in the study were: a) conceptual model order (first versus last) and b) simulation (simulation versus no simulation). Subjects were presented with a conceptual model of the system either before or after being provided with explicit instructions for operating the system. Figure 1 presents the conceptual model of the computer systems operating environment. The figure represents the state of the system part way through the training process. Here, a program is in the active file, the results of the program are in the output file, and a copy of the program is in the library. In the simulation condition, entities such as programs and program output are shown moving between various components of the system (e.g., a file traverses the arc between the active file and the library after the "save" command is issued). In a non-simulation condition, the objects did not move, but merely appeared in the destination.

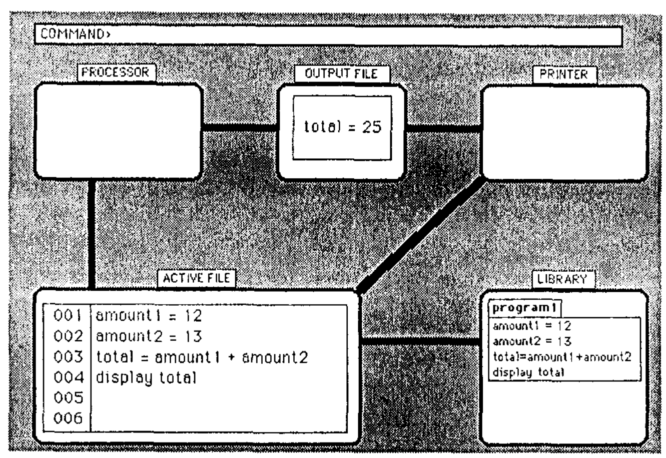


Figure 1. Conceptual model of the operating environment.

Dependent variables. The dependent variables of interest here included: the time to complete the assigned tasks, the number of tasks completed, the number of conceptual errors committed, and performance on three tests which varied in difficulty level.

Subjects. Research participants were 64 undergraduate students at the University of South Florida. Prior to the experiment, potential subjects filled out a questionnaire assessing computer experience. Only individuals reporting no computer experience were selected for participation.

Design. The experimental design is a 2 (simulation: simulation, no simulation) by 2 (conceptual model order: before procedural information, after procedural information) by 2 (performance time: initial training, one week later). Simulation and conceptual model order are between subject factors and performance time is a within subjects factor.

Procedure

All individuals completed training one at a time. The experimenter provided each research participant with a brief introduction and overview of the experiment and then seated him/her in front of a Macintosh computer. The computer presented the instructions for operating the system and presented all training information and stimulus information according to the subject's condition. Upon finishing the instruction phase, subjects were given a list of tasks to perform on the system and subsequently performance tests. One week after the initial session, subjects returned and completed parallel forms of the dependent measures.

RESULTS

For all of the results presented here, analysis of variance revealed a significant main effect for simulation, no main effect for conceptual model order, and no conceptual model order by simulation interactions.

Time to complete tasks. The presence of simulation had a significant effect on the amount of time to complete the assigned tasks $F(1,60) = 8.27$, $p < .01$. Subjects in the simulation condition took less time to complete the tasks than subjects in the no simulation condition. Means for the two groups during the initial session and one week later are shown in Figure 2.

Number of tasks completed. Simulation had a significant effect on the number of tasks completed $F(1,60) = 12.27$, $p < .001$, with individuals in the simulation condition completing more tasks than individuals not in a simulation condition. This is true at both points in time. Figure 3 depicts this effect.

Number of conceptual errors. Simulation also facilitated the development of the correctness of an individual's mental model. Those subjects in the simulation conditions committed fewer conceptual errors (e.g., trying to print an empty file) than subjects in the non-simulation conditions $F(1,60) = 8.12$, $p < .001$. Means for the two sessions are presented in Figure 4.

Performance tests. Three different performance tests were developed. The first test required subjects to recall

Figure 2
Time Taken to Complete Tasks
By Trial

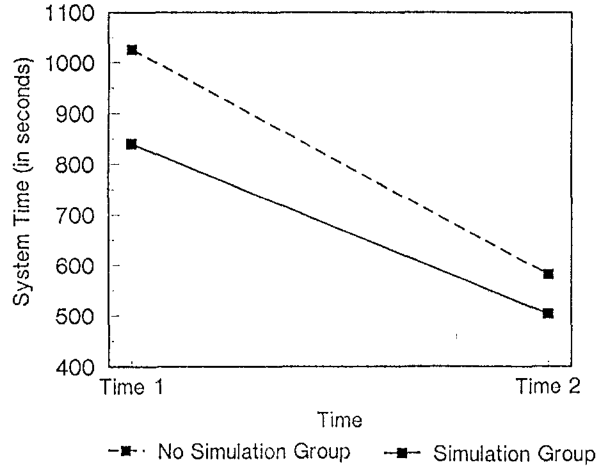


Figure 3
Number of Tasks Completed
By Trial

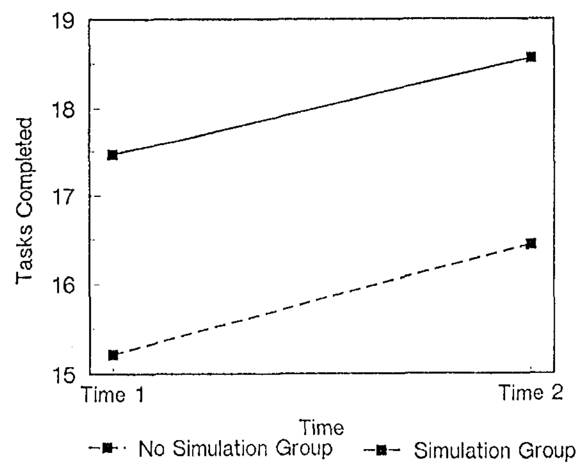


Figure 4
Number of Conceptual Errors
By Trial

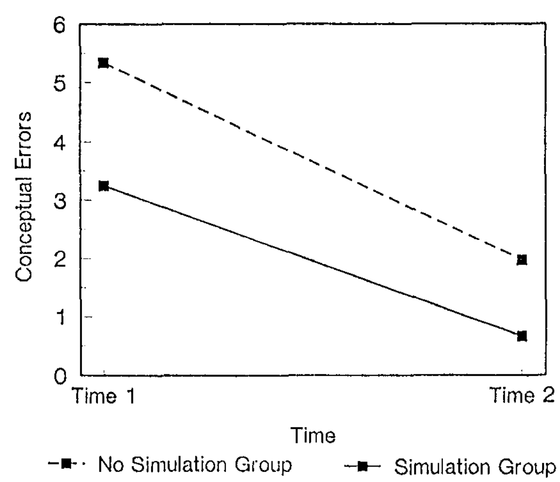


Figure 5
Performance Test - Individual Commands
By Trial

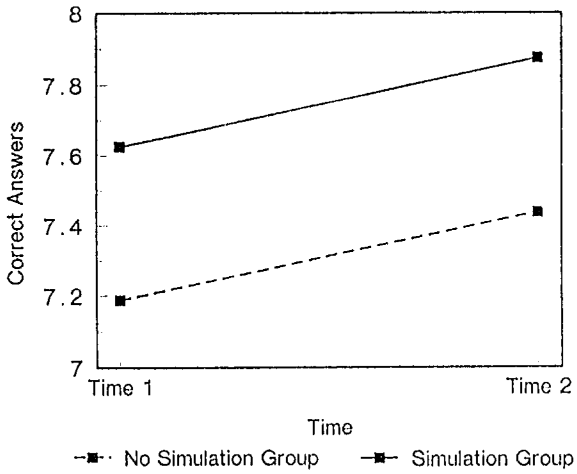


Figure 6
Performance Test - Chained Commands
By Trial

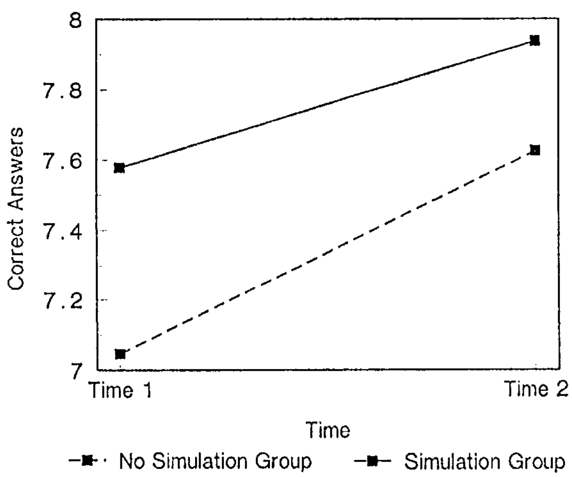
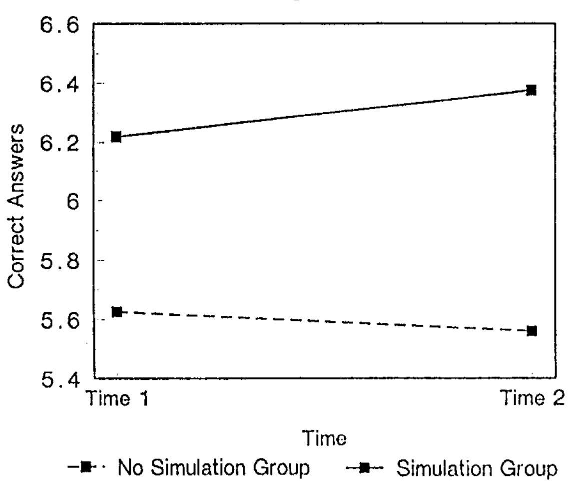


Figure 7
Performance Test - Problem Solving
By Trial



individual commands. The second type of test required subjects to chain commands together to perform a task. The third test type required individuals to reason about the system and predict its state after a series of commands (which the subject had not received training on) were issued. This test was termed problem solving. Once again, the influence of simulation is quite apparent. Subjects in the simulation conditions performed better on the tests of individual commands ($F(1,60) = 6.49$, $p < .01$), chained commands ($F(1,60) = 5.42$, $p < .05$), and problem solving ($F(1,60) = 3.92$, $p < .05$). Figures 5, 6, and 7 depict these results.

DISCUSSION

This study demonstrates the power of simulation in teaching individuals about the operating environment of a computer system. Simulation has a significant influence on each of the dependent measures employed in this research. It was surprising, however, that the order in which one receives a conceptual model did not have an influence. Future research should focus on the boundary conditions for the influence of simulation in learning.

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