Overcoming the Learning Barriers of Management Flight Simulators: Task Salience and the Dissociation between Performance and Learning

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Abstract

Recent experimental studies in management flight simulators showed a dissociation between task performance and learning: subjects' performance was significantly improved through practice, but very little deeper learning was detected. A theoretical framework is developed to explain the dissociation. That is, the cognitive strategies really used by subjects, e.g., *situation matching*, *feedback control* and *feedforward control*, are different from the normative cognitive strategy of *mental model simulation* expected by researchers. Methods to overcome the dissociation are suggested and demonstrated by two experimental studies. Based on the discussions and the experimental results, we found that the considerations of cognitive strategies and task salience are very important dimensions for designing effective learning environment of management flight simulators.

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Introduction

The tool of Management Flight Simulator (MFS) has become a significant focus in the system dynamics field. However, the popularity of these simulators has far outstripped the research on their effectiveness. A number of MFSs have been developed to propagate the thought of system dynamics (Sterman and Meadows, 1985), convey the understanding of specific systems (Meadows, 1989; Graham et al., 1992), cultivate CEO's systems thinking, and further, aid organizational learning in business(Senge and Sterman, 1992). Yet, there are little scientific evidences to support the superiority of MFS on the learning of systems. Academic effort on efficacy of MFS is now more important than to design new games.

Phenomenon of dissociation between performance and learning in MFS's has been found to be a problem to prove the effectiveness of MFS. The phenomenon demonstrates that practice improved subjects' performance significantly but had no effect on the inquiry of task knowledge (Berry and Broadbent, 1988; Berry and Diencs, 1991; Sanderson, 1989). Paich and Sterman (1992) found that subjects' performance were improved resulting from the familiarity to the task and the use of specific decision rule found when practicing but not the learning of task knowledge. Wang and Young (1992) had similar findings that performance was dissociate with task specific knowledge. These results demonstrate that to possess the ability to control a management game is not equal to learn the task system. Thus, finding the causes leading to the dissociation between performance and learning in MFS and their solutions is very important.

This study aimed at the investigation of the dissociation phenomenon, particularly focusing on the underlying cognitive processes behind the phenomenon, and on the methods to overcome the dissociation.

The findings by Berry and Broadbent

The findings by Berry and Broadbent are comprehensive to the understanding of dissociation phenomenon in MFS. A series of studies by Berry and Broadbent (e.g., Berry, 1991; Berry and Broadbent, 1984, 1987, 1988) have demonstrated a dissociation between task performance and associate verbalizable knowledge. They showed that practice significantly improved ability to control the task, but had no effect on ability to answer post-task written questions. In contrast, verbal instruction on how to reach and maintain the target value significantly improved ability to answer questions but had no effect on control performance. Moreover, there was an overall significant negative correlation between task performance and question answering. The findings were similar to those found by system dynamicists, except for the tasks used by system dynamicists were more complicated.

Two possible cognitive processes were adopted to explain the dissociations (for more detail, see Sanderson, 1989). The first lies in the distinction between explicit and implicit modes of learning. That conscious self-report task specific knowledge is not available, because some information processing is done unconsciously. This is related to the long-standing idea that cognitive activity takes place in parallel at multiple levels. Another explanation lies in the idea of production-system that verbal knowledge might decay in the process of cognitive skill acquisition (Neves and Anderson, 1981). As learning progresses, simple productions are replaced by more complex, inclusive productions through the knowledge-compilation process. However, the simple productions can support verbalizable knowledge about performance, but the more complex one can't, because the latter compresses a large number of initiating conditions and resulting actions. This explanation is similar to the idea that human cognitive capacity is limited, thus only the most salient information will be processed and reported.

Different cognitive strategies may be a cause to lead to the foregoing two cognitive processes. Broadbent, et al. (1986) proposed two kinds of cognitive strategies, namely, model manipulation and situation matching. When using model manipulation, subjects have known relations among variables so that they can forecast the performance of alternatives and choose the best one. when situation matching is used, subjects remember the relations among the situation, decision, and performance to make the best decision. Model manipulation strategy is based on task knowledge, then explicit learning occurred. Subjects can modify their task knowledge through the comparison between forecasts and outcomes. While the understanding about task systems is not necessary for situation matching, explicit learning does not occur. The situation matching process may be done unconsciously, so that conscious self-report of task specific knowledge is not available or the productions of situation matching become too complex to support verbalizable knowledge.

In short, the relations between performance and task knowledge depend on the cognitive strategy used. The argument is comprehensive to the dissociations in MFS and will be discussed later.

Rather than simply demonstrating dissociations, an alternative approach has been to look at conditions that give rise to either implicit or explicit learning. Berry and Broadbent (1988) propounded that "salience" of task could affect the used cognitive strategy. They found low salience led to implicit learning, and the relation between performance and task knowledge is vague or even negative, vice versa. Task salience, defined by Berry and Broadbent, is the probability that, if a person learns by the explicit rather than the implicit mode, the key variable will be chosen. There are three ways to increase level of task salience as follow:

(1) To reduce irrelevant factors in situation (Broadbent, et al., 1986); For example, to reduce the number of relations of variables to be processed in a decision.

(2) To make the key events act in accordance with general knowledge from outside the task; For example, to remove the delay between actions and outcomes (Berry, 1991; Berry and Broadbent, 1988), or to add a positive feedback loop to increase the impact of actions on outcomes (Broadbent, et al., 1986)

(3) To give an explicit verbal direction as to which are the key variables; For example, to instruct subjects what kind of variables are relevant (Berry and Broadbent, 1988)

Accordingly, for system dynamicists, it is possible to lead subjects to use the expected cognitive strategy through the manipulation of task property in order to overcome the dissociations in MFS. Nevertheless, the manipulation of task salience should be modified, because task properties in MFS are different from those in the research by Berry and Broadbent.

Cognitive strategies in dynamic complexity task

The difference between tasks used by Berry and Broadbent and MFS research lies in task property and learning objectives. The typical tasks used by Berry and Broadbent are combined by a set of linear equations. The task knowledge to be learned is the relations of polarity and quantity between decision variables and objective variables. Tasks of MFS are characterized with nonlinearity, delay, and multiple causal feedback loops, and are more complex than the former. Furthermore, the polarity and quantity relations between variables are generally provided in MFS. A holistic understanding about system structure is the objective in MFS.

For the *situation matching* strategy, since the interdependence and the shift of dominance loops in MFSs' dynamic complexity task, using the situation matching strategy in MFSs task is not so effective than used in Berry and Broadbent's task. However, we still find that the existence of the situation matching strategy in our recent experiment.

Feedback and feedforward control were found to be used often in MFS tasks (e.g., Paich and Sterman, 1992; Wang and Young, 1992). For the *feedback control* strategy, system structure is treated as a black box when subjects use feedback control. While using feedback control, no more than the knowledge of polarity relations between decision and objective variables is needed to approach the goal. The pattern of decision behavior in the use of feedback control is similar to a goal directed negative feedback loop. The efficacy of feedback control strategy depends on whether the decision negative feedback loop can dominate the system.

Feedforward control is similar to feedback control that system structure is treated as a black box. To use feedforward control, forecasting based on historical data, theory, or expert's experience is the base to make decision rather than on outcomes in feedback control. For example, the pattern of production life cycle was used by subjects in Paich and Sterman's study (1992); Books' law was used by subjects in the study of Abdel-Hamid (1993); forecasting by experience in Wang and Young's study (1992). These ways of control need lower level of cognitive effort comparing to mental simulation where understanding about system structure is necessary (Brehmer, 1990).

Although these three cognitive strategies (situation matching, feedback, and feedforward control) are preferred by subjects and advantageous for the improvement of performance, they are not helpful for learning in MFS.

In contrast, the expected cognitive strategy by system dynamicist is *mental model simulation* for its theoretical effectiveness for learning. When using mental model simulation, subjects produce a mental model to represent the task system based on their information and knowledge. Subjects formulate decision policy from the model and test it on the MFS, and they can modify their mental model based on decision outcomes (Isaace and Senge, 1992). Then, the learning about the task system occurs.

To use *model manipulation* strategy is difficult in MFS. The distinction between model manipulation and mental model simulation lies in the representation of task where the former represents task with mathematical type, the latter with a way which is comparable with rule of human thinking. Subjects can simulate policies for a long-term period with mental simulation but just one period decisions with model manipulation in MFS because of the complexity of task. In fact, subjects could hardly use model manipulation in MFS because subjects can not compute the high order and nonlinear equations in MFS. Therefore, model manipulation is ignored in the following discussion.

The foregoing discussions demonstrate that dissociations in MFS resulted from the cognitive strategies chosen by subjects are not the expected ones by system dynamicists. There are two reasons for subjects tend <u>not</u> to use mental model simulation. First, it needs more cognitive inputs to use mental model simulation than situation matching, feedback and feedforward control. Second, human beings have poor ability to represent dynamic feedback systems (Brehmer and Dorner, 1993; Forrester, 1975; Senge, 1990; Sterman, 1989a, 1989b). Therefore, how to evoke subjects to use the expected cognitive strategy is the proposition to improve the effectiveness of MFS.

Task Salience for dynamic complexity task

The analysis of task-induced cognitive strategy is helpful for the prediction of what kinds of design of MFS is advantageous to learning rather than performance only. The effect of Sengupta and Abdel-Hamid's (1993) design was ambiguous from the point of induced cognitive strategy, though they claimed cognitive feedback provided in their study has induced mental model simulation strategy. It is possible that subjects use feedback control strategy to approach decision goal based on the provided "indicated workforce level" which was an indicator of experts' knowledge. For induced cognitive strategy was not measured in Sengupta and Abdel-Hamid's (1993) study, it is hard to make conclusion.

The manipulation of task salience to induce mental model simulation strategy in MFS is possible. First, to provide subjects reference mode of the task system can increase task salience, because key variables and their pattern of behavior are given. Second, to provide causal loop diagram can eliminate redundant information and hint subjects the polarity relations and delay between those key variables. Furthermore, causal loop diagram can instruct subjects how to represent a complex dynamic system, and decrease the barrier of using mental model simulation. Third, partial model test proposed by Morecroft (1985) divides a whole complex system into several controllable parts, and then increase the salience of task. This design is similar to that in the study by Broadbent, et al. (1986) where subjects were instructed to test the relations.between variables one a time.

Examples to manipulate task salience

Two examples of manipulating task salience are given as follow. They are all tested by experimental methods. The details of the experimental results can be found in Young, Wang and Yang (1992).

Example 1: assignment as manipulation

The first example used assignment to manipulate task salience in the task of People Express Management Flight Simulator (Sterman, 1988). Task salience was manipulated by the aids of *reference mode, partial model test* , and *causal feedback diagram.* For the aid of *reference mode*, it was manipulated in the following question, wherein three reference modes (customer growth rate, turnover rate and service quality) were announced.

> **Q1**...Using the following policies until quarter 4 of 1984: (a) Fare=0.09, (b) Target service scope=0.6, and (c) Aircraft annual growth rate = 100%. Your aircraft must be more than 72. Please answer the following questions:
> (1) Why the customer growth rate decreased after dramatic growth?
> (2) Why more hiring induced higher turnover rate?.
> (3) Why did high service quality gradually decline?

For the aid of *partial model test*, it was manipulated in the second question of the assignment, wherein subjects were asked to solve three problems. Moreover, subjects were asked to treat the problems one by one, that is, one problem a time .

> **Q2** ...Using the policies in **Q1** until quarter 4 of 1984, then solve the problems of declining customer growth rate, high turnover rate, and declining service quality. Please treat the problems one by one, that is, one problem a time . Records every policy and associated outcomes which you have tried, then explain "why".

Finally, for the aid of *causal feedback diagram*, subjects acquired the causal feedback diagram of PE constructed by Sterman and Kim (1988) without verbal description.

The experimental results show that, the treatment of task salience not only have positive effect for decision performance, but also for the learning of the underlying structure (for more details, see Young, et al., 1992).

Example 2: screen design

The second example demonstrated methods to manipulate task salience in MFS's computer screen. There were three kinds of simulator's screen design including causal-loop, hierarchical, and departmental in the experiment (Young, et al., 1992). As shown in Figure 1, the causal-loop type of screen was designed like the causal loop diagram used by system dynamicists. The hierarchical type of simulator's screen was designed like a hierarchical causal-tree diagram, as shown in Figure 2. Both the screen diagrams (causal-loop and hierarchical) have offered the on-line causal relationships among variables. However, the departmental type of screen, as shown in Fgure 3, only represented variables without relationships.

The experimental results show that subjects provided with the causal-loop type screen have best performance and best learning effects, followed by those provided with the hierarchical type. Subjects provided with departmental type have worst performance and worst learning effects, although the effects were not statistically significant. Moreover, in the analysis of subjects' cognitive strategies, it is found that the causal-loop type screen induced a more analytical cognitive type compared with the departmental design. However, the hierarchical screen design induced more intuitive cognitive type than the departmental condition (for more details, see Young, et al., 1992).

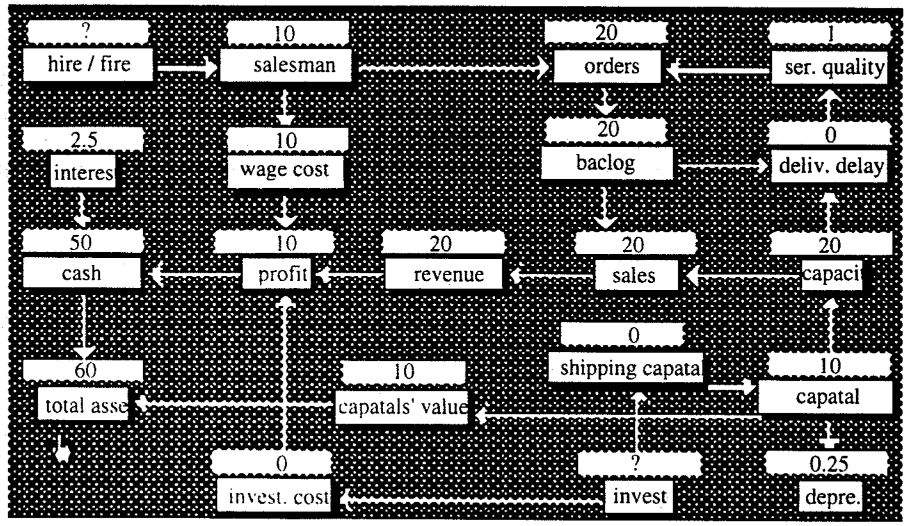

Figure 1: Causal-loop type screen design

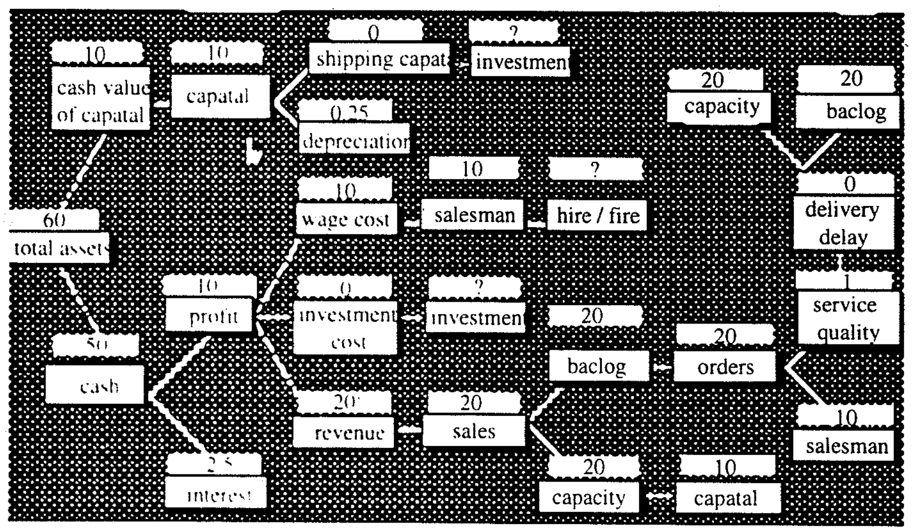

Figure 2: Hierarchical type screen design

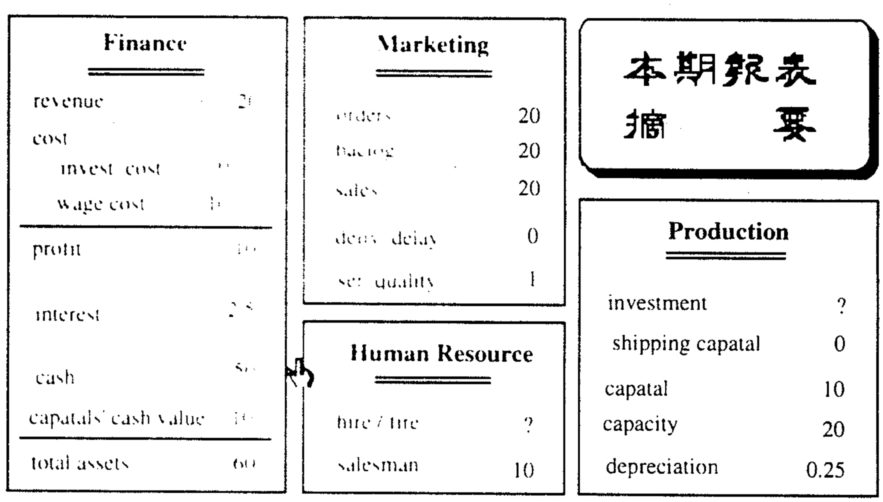

Figure 3: Departmental type screen design

Summary

The design and evaluation of the effects of management flight simulators is an important and challenging topic for the field of system dynamics. Recent experimental studies in management flight simulators showed a dissociation between task performance and learning: subjects' performance was significantly improved through practice, but very little deeper learning was detected. A theoretical framework is developed to explain the dissociation. Methods to overcome the dissociation are suggested and demonstrated by two experimental studies. Based on the discussion and the experimental results, we found that the considerations of cognitive strategies and task salience are very important dimensions for designing effective learning environment of management flight simulators.

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