A STUDY ON HUMAN CONTROL IN STOCK-ADJUSTMENT TASKS

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ABSTRACT. Results of an ongoing study investigating the effect of different task feedback characteristics on human performance are reported. In a computer-assisted experiment, subjects were asked to perform a dynamic stock-adjustment control. A subject's control action enters the system in two ways: it effects the stock to be adjusted and it feeds back on the disturbance that impinges on the system. The latter effect is varied with respect to its strength and its delay. The major finding that emerges from the experiment is that increasing strength in the feedback link (in either a positive or negative direction) worsens performance. An effect of delay length on performance could not be shown.

INTRODUCTION

Developing a theory that relates complexity of decision situations to the likelihood of dysfunction in human decision strategies is a major research challenge in behavioral decision theory (Hogarth 1981, Kleinmuntz 1985). One obstacle in meeting the challenge is to find a framework that permits the comparison of different decision tasks with respect to their complexity. I believe that feedback theory can provide such a framework (Mackinnon and Wearing 1985). Following this approach the challenge can then be reformulated as to determine what particular characteristics in feedback structures lead people to perform poorly or well.

The feedback structure of dynamic decision situations can be characterized along various dimensions: number of feedback links, number of states present, degree of non-linearity, degree of uncertainty, strength of feedback, delay of feedback, system stability, eigenvalues and eigenvectors of the system, etc. Each of these dimensions could conceivably have an influence on how people perceive the consequences of the feedback structure and on what decision strategies they employ. What is ultimately needed is a systematic effort to determine how the

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various dimensions of the feedback structure interact and influence peoples behavior.

A possible starting point for such a systematic effort is to investigate decision making in basic feedback structures. Once behavior in simple systems is understood, the groundwork is laid to investigate how people perform in more complex feedback structures that are composed of several basic systems. One structure that is of particular interest is the class of stock-adjustment tasks. A vast number of human activities can be characterized as attempts to adjust the actual state of a variable to a desired value. How is stock-adjustment control effected by changes in the characteristics of the underlying feedback structure? Finding an answer to this question is the motivation behind the experiment reported in this study.

PRIOR EXPERIMENTAL WORK IN BEHAVIORAL DECISION THEORY

Stimulated by papers by Edwards(1962) and Toda(1962) a literature known as dynamic decision theory developed in the 60's and early 70's. See Rapoport and Wallsten(1972) and Rapoport(1975) for an overview. Of particular interest for the current study are the experiments on multistage control problems. Rapoport(1966a,1966b) examines how people perform control on an unstable process of the kind $x(k+1)=a*x(k)$ where $a>1$. Rapoport(1967) and Ebert (1972) report on experiments on stock-adjustment problems. Most of the studies focus on the effects of varying time horizons and uncertainty on performance.

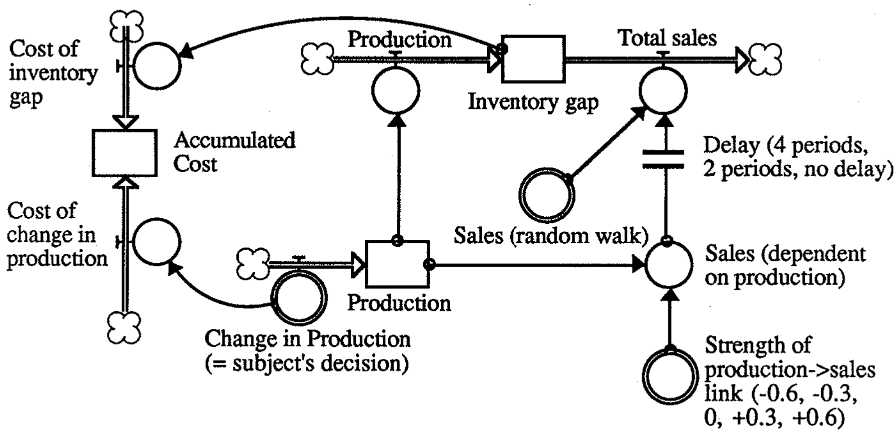
Although interest in dynamic decision theory has continued through the 70's until today (Broadbent and Aston 1978, Mackinnon andd Wearing 1980, Hogarth and Makridakis 1981, Kleinmuntz and Thomas 1987; Brehmer 1987 for an overview), dynamic decision theory has not been a very active research area. Slovich et al (1977) suggest that the mathematical sophistication of dynamic decision problems and the need for time consuming computer programs might be some of the reasons behind the decline in interest among psychologists.

System dynamics practitioners have only recently begun to conduct studies into how people solve dynamic decision tasks (Bakken 1988, Diehl 1988, Sterman 1987). Sterman's work (Sterman 1989a, 1989b) strongly dynamic decision-making. It is not clear, however, if these misperceptions are due to a lack of information about the environment, due to a lack of understanding of the basic task or due to a lack of understanding of the connections between decision and outcomes.

EXPERIMENTAL DESIGN

The stock-adjustment task is formulated as an inventory-production system with a quadratic cost function. Over a 30-step decision period, subjects are charged with adjusting production in the presence of varying sales. Figure 1 displays the stock-flow diagram of the system. The subjects' objective is to minimize total accumulated cost. Changes in production are twice as costly as a deviation of inventory from its setting point (=0).

Figure 1: Stock-flow diagram of the task



Sales consist of two parts: sales independent from a subject's production decision and sales directly influenced by a subject's decision. Independent sales follow a random path. Subjects are informed that their best bet is to expect that independent sales next round will be the same as independent sales in the current round, but that the actual value can differ anywhere between +20 and -20. The link between production and dependent sales varies from trial to trial along two dimensions: strength of the link and delay length of the link. The subjects are informed about the conditons for each trial.

A two-factorial, within-subject design is chosen for the experiment. Strength of the production-sales link can take on five values (+0.6, +0.3, 0, -0.3, -0.6), delay of the link can take on three values (4 periods, 2 periods, no delay). Since length of delay is undefined for a link strength of 0, the conditions can be combined in 13 different ways (5*3-2). Each subject received the thirteen treatments in a different, randomized order. The overall sequence order was balanced.

Thirteen subjects participated in the experiment. Ten of the subjects are undergraduates at M.I.T., three of the subjects are enrolled in a masters program at M.I.T. The subjects performed the 13 trials in 4 sessions (2-3-4-4). It took about 25 min. to complete a trial. Subjects received detailed instructions at the beginning of the first session and a short reminder of the rules at the beginning of each of the following sessions. Each subject received a base payment of $20 and additional payments based on performance. Subjects were informed that the expected average pay would be $40 and that performance would be computed on base of their ten best trials. Four subjects did not complete all four sessions. There did not appear to be a difference in performance of subjects who dropped out of the experiment and of subjects who completed the experiment. The results presented below are based solely on the nine subjects who completed the experiment.

EXPERIMENTAL RESULTS

To evaluate the subjects' performance, accumulated cost at the end of each trial is compared to the cost that would have resulted if the optimum control rule had been used. Figure 2 shows the performance ratios for the nine subjects. For each subject, performance in the median game is indicated by the black square. In addition, performance for the third best game and for the third worst game is shown. In 48 of the total 117 trials (41.0%), the actual cost did not deviate by more than %50 from the optimum cost. In 4 trials (3.4%) actual cost was more than 100 times higher than optimum cost.

Figure 2: Subjects' score (3rd, median, and 11th best)

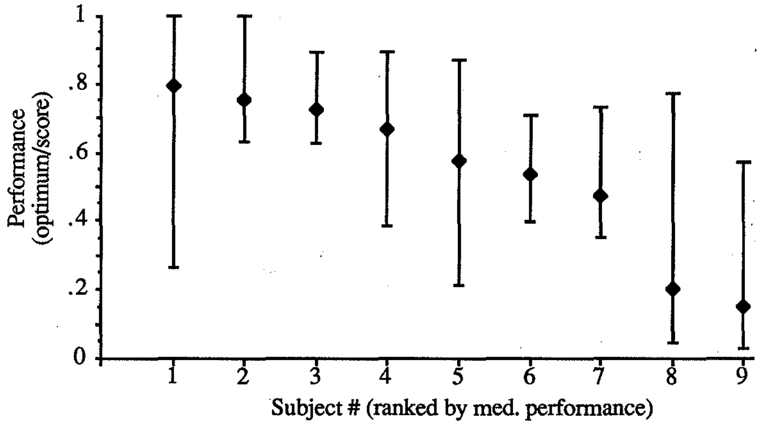


Figure 3 displays the average performance ratio achieved in the thirteen consecutive trials. The practice effect is statistically significant (F12/96=2.63; Prob.>0.99). For the statistical analysis presented below the practice effect was removed.

Figure 3: Practice effect

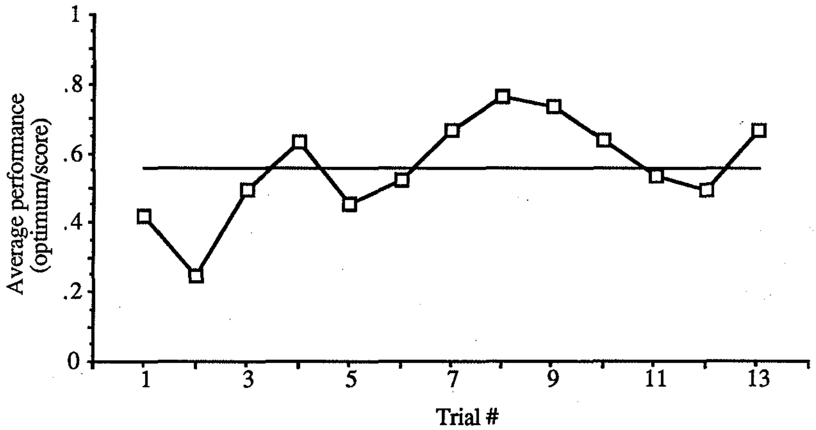


Figure 4 shows the influence of the feedback characteristics on performance. Each of the 13 cells contains the average score that the subjects achieved under that cell condition. The cell values are adjusted for the practice effect. Scores are computed as optimum cost divided by actual cost. The average score for all 13 conditions combined is 0.558. Cell values above 0.558 indicate that performance is improved with respect to the cell condition. Cell values below 0.558 indicate that performance is worsened.

Figure 4: Average score for each of the 13 conditions

		Strength of feedback link				
		-0.6	**-0.3**	**0**	**+0.3**	**+0.6**
Length of delay	**0**	0.558	0.571	0.703	0.640	0.435
	2	0.450	0.666		0.566	0.529
	4	0.438	0.546		0.662	0.493

For a statistical analysis of the effects, positive and negative feedback conditions were separated. Performance worsens both with increasing negative feedback and with increasing positive feedback, as Figure 5 shows. Delay length does not influence performance.

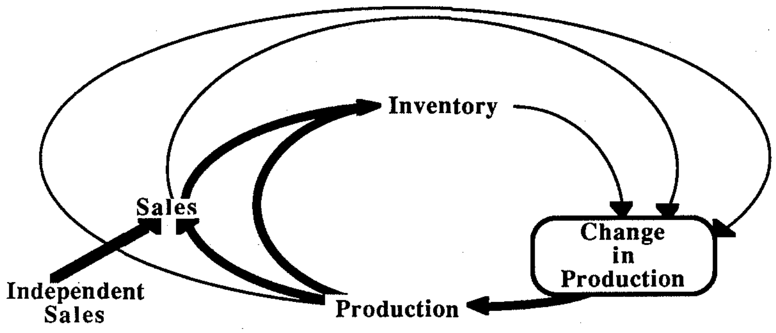
Figure 5: Statistical analysis of the main effects

	F	Prob.
Increasing positive feedback	3.440	> 0.90
Increasing negative feedback	4.889	> 0.95
Increasing delay length	0.046	no effect

CONCLUSIONS AND FURTHER RESEARCH

The results seem to indicate that decision makers insufficiently adjust their decision rules to increasing feedback strength in stock-adjustment tasks. To corroborate this conclusion, a detailed statistical analysis of the decision rules used is indicated. The research task ahead can be illustrated with help of Figure 6.

Figure 6: Feedback structure of the stock-adjustment task



The bold links between variables represent the physical structure of the system, the other links represent the assumed information structure that is used in the decision process. The research task ahead can then be formulated as: What information structure is used by the decision maker to accomplish a task, given a specific physical structure and a specific objective? In the experiment reported in this study, the physical link between production and sales was varied systematically along the two dimensions link strength and link delay. An analysis of the decision rules used should reveal how decision makers adjust the information links in response. The adjustment used by the decision makers can then be compared to the adjustment suggested by the normative model.

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