

Chapter 8

Some models of control

Turn now to a few examples of model-building. The models I will describe will be neither flesh-and-blood nor Tinkertoy; they will be models built in computers. The computers used are not supercomputers; they are the PC sort owned by millions of people nowadays. You can do this sort of thing yourself. It takes some study, of course. But if you can read well, if you are willing to learn some not-very-advanced mathematics, and if you can be patient with computing manuals, you can do the sort of thing you will read about here. I say again that these are tangible, operating models, not verbal arguments about how things might work. Furthermore, these models are built to work in unpredictable environments, just as do living creatures. I begin with a study showing the dependability of this kind of research.

ACCURACY AND RELIABILITY

Bourbon, Copeland, Dyer, Harman, and Mosley (1990) undertook to demonstrate the accuracy and reliability of predictions of tracking made with PCT. I recount here some parts of their project.

Bourbon and eight of his students performed a task of tracking a target on a computer screen. Every person performed the task more than once; all told, the nine persons replicated the task 104 times. And here I must pause to make sure you do not pass lightly over that statement—that the task was replicated 104 times. In psychological literature, replications are hard to find. Most experiments in the literature are never replicated; there are dozens of reasons, and I will not go into them here. Some experiments have been replicated once or a few times, almost never with results that could be shown quantitatively to be close to previous trials. (And in the methods of traditional psychological research, experiments

called “replications” typically differ so much from the original that they might better be called “somewhat similar” experiments.) A few experiments, chiefly psychophysical experiments, have been replicated (so to speak) some dozens of times. I had never heard of an experiment, until I came upon PCT, that had been replicated 100 times. So please reach for your yellow highlighting pen and highlight “104 times.”

Procedure

Figure 8–1 (from Bourbon and others, 1990) shows the experimental arrangement. The larger oval on the right side represents the computer. The oval at the top represents the computer screen; you see there three short lines labeled T, C, and T. The two lines labeled T were, together, the target; they were moved up and down in unison by the program in the computer. The task of the participant was to move a Handle (symbolized by the letter H underneath the ovals) forward and backward so as to keep the short line labeled C (the Cursor) as accurately between the Target lines as possible. Each replication (or “run”) of the task contained two parts. In the first part, the Handle was the sole cause of the position of the Cursor between the Target lines; when the Handle was moved, the Cursor moved a proportionate distance. In the second part, a random disturbance was added by the computer program to the effect of the Handle. The effect of that, when the Handle was moved, was to cause the Cursor to move at an unpredictable speed, and even sometimes in an unexpected direction.

The duration of each part was one minute. The first part was used to determine the idiosyncratic performance characteristics (but not the particular acts) of the participant. I will explain what I mean by an individual’s performance characteristics below under “The Model,” and I will clarify some features

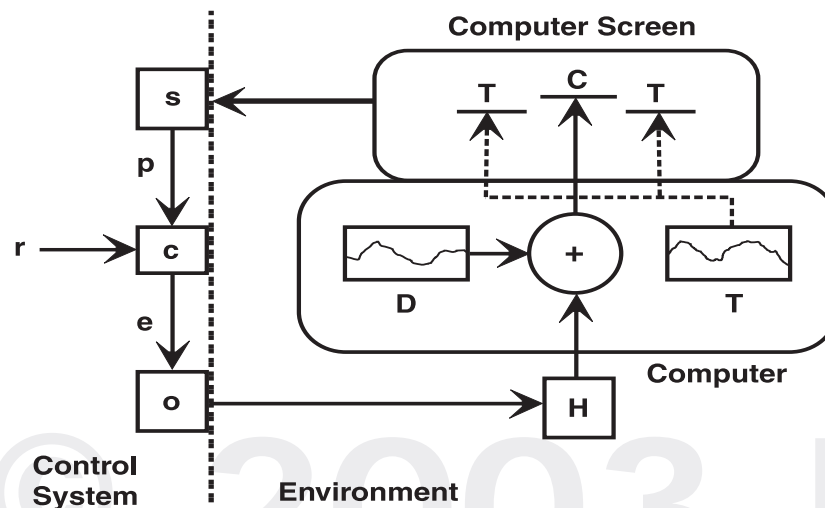


Figure 8-1.

Relations among variables in the environment and in the model.

In the environment, T=Target, C=Cursor, H=Handle, and D=Disturbance. In the model, the functions are s=sensor, c=comparator, and o=output; the signals are p=perceptual, r=reference (internal standard), and e=error.

of procedure there, too. The second part was the test of the theory; in it, the numbers characterizing the participant were inserted into the computer's model, the performance of which would be compared to the human participant's performance.

The random disturbance of the effect of the Handle is a feature of all tests of PCT with a computer simulation; the random disturbance simulates the unpredictable occurrences that interfere with the effects of our acts in non-laboratory environments. An example is the effect of unexpected gusts of wind when we point an automobile down the highway. Another is the distraction of an interruption from a third person when we are carrying on a conversation.

There were two forms of task (each run in each form containing the two parts so far described). Four students and Bourbon (five persons in all) carried out the first form. In this form, the Target moved up and down at an unchanging rate. Each person ran through both parts of each run ten times, with a few minutes between the first and second parts while the idiosyncratic constants were inserted into the computer model. The disturbance to the effect

of the Handle added to the second part was different for every replication and every participant. When I say that the disturbances followed different patterns, I am not thereby saying that the replications were different in a substantive way. The unpredictability of the precise effects of the Handle is necessary to test the theory. If you want to know whether a person (or a mechanical substitute) is capable of driving an automobile from here to there, you will want to see the journey succeed more than once despite changing winds that affect the course of the automobile. Using this same task, Bourbon, acting only as a participant, ran four more replications of the first part, but then waited a year before running the second part.

Four more students and Bourbon participated in the second form of the task. This form was the same as the first except that the Target did not move at a regular rate; now, the Target moved according to a table of random numbers. This was presumably a more difficult task than the first form. Again, as in the first form, the Target paths in the first and second parts were different in every replication. Here again, each participant ran through ten replications.

Table 8–1.

Mean correlations between indicated pairs of variables calculated over fifty replications of the task with both target and handle randomly disturbed. Data from five participants, each giving ten replications with 1800 data-pairs calculated within each replication.

	By the participant	In the model
Between Cursor and Target	.984	.993
Between Handle and Cursor	.701	.707
Between Handle and Target	.710	.708
Between Handle and disturbance	-.682	-.696
Between Cursor and disturbance	.032	-.001
Between Handles of participant and model		.996
Between Cursors of participant and model		.992

Figures 8-1, 8-2 and Table 8-1 reproduced with permission of authors and publisher from: Bourbon, W.T., Copeland, K.E., Dyer, V.R., Harman, W.K., and Mosley, B.L. *On the accuracy and reliability of predictions by control-system theory. Perceptual and Motor Skills, 1990, 71, 1331–1338. Copyright Perceptual and Motor Skills, 1990.*

Results

Table 8–1 shows some mean correlations among positions of Cursor, Target, Handle, and disturbance produced by the five participants in the later form of the task in which both the Target and the Handle were randomly disturbed.

To keep this narration simple, I am omitting the data from the simpler task performed earlier; those data (which you can see in the original article) tell much the same story as these later data. Figure 8–2 shows graphically the performance of one of the participants who contributed data to Table 8–1.

In the left graph, labeled “Person,” you can see how very closely the participant was able to cause the Cursor C to track the Target T. You can see that same accuracy when you look at the first line of Table 8–1 under “By the participant.” The correlation you see there between Cursor and Target is .984, only .016 away from a perfect score of 1.000. The participants achieved correlations like that despite the unpredictable disturbances given the Target and Handle. Since the mean is only .016 away from the maximum possible, it is obvious that all five participants gave very accurate performances. Those performances should not, however, surprise us. A lion chasing a gazelle must do that well or go hungry. The sailor

of a sloop does that well to keep the sail full of wind. The driver of an automobile does that well or runs off the road. If a psychological theory is to be tested quantitatively, the theory should be able to mimic action that is as accurate as the action we see here. Indeed, in Table 8–1 under “In the model,” we see the number .993, which is the average of the correlations between Cursor and Target produced by the model in the computer. The model’s average correlation of .993 is very close to the mean of .984 among the live persons. Looking at the upper part of the graph labeled “Model” in Figure 8–2, we see that the records for C and T are so close together that it is difficult to tell that there are two records there. It is easy to see, too, that the records at the right, produced by the model, are similar indeed to the records at the left, produced by the human.

You can easily infer from Figure 8–2 that the correlation is somewhat positive between the Handle and either the Cursor or the Target, because some of the larger ups and downs go somewhat together. But you cannot pick up the record of the Handle and fit it perfectly to the record of Cursor or Target. The correlations between the Handle and the other records were not zero or negative; as you see in Table 8–1 in the second and third lines, those correlations