# Probability matching in the Prisoner's Dilemma[1]

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*An attempt is made to relate the findings of probability matching studies to more complex human behavior. The general result is that the PM finding is not directly applicable to situations which are more complex, i.e., where the subject has additional cues available on which to base his prediction.*

The recurring finding in two-choice experiments is that Ss will come to select the more frequently rewarded alternative with a frequency asymptotically equal to the frequency with which that alternative occurs. While there is some doubt about the meaning of this probability matching (PM) result and its bearing on the validity of the various assumptions underlying mathematical learning theories, the consistency of the finding makes it interesting in its own right.

One potential value of the PM finding would be to use this as a model of human choice behavior in complex situations. Such a model could be applied, for example, to Gullahorn-type computer simulations with the PM model used as a decision rule at various choice points in the simulated interactions (Gullahorn & Gullahorn, 1963). Prior to such an application, however, it is necessary to ascertain whether PM behavior does appear in situations more complex than the average PM study.

The typical attempt to introduce greater complexity into the PM situation has involved increasing the number of alternatives (Gardner, 1958). However, others have introduced complexity by adding *meaning* to the choices or predictions. Mandler, Cowan, & Gold (1964) found that concept attainment followed a pattern comparable to probability matching, and Hokanson & Doerr (1964) found that, in the absence of other cues, Ss predicted interpersonal events in a fashion consistent with the PM data from simpler studies. The present study follows this approach in introducing greater complexity to the PM situation, looking at predictions made in the context of a Prisoner's Dilemma (PD) game.

In the Prisoner's Dilemma, a "mixed-motive" game, two Ss each have two possible choices, sometimes labeled Cooperation and Defection (see Matrix 1). If both Ss take the C choice on a given trial, they both earn some amount of money or other reward. If both take the D choice, they both lose some amount. If, however, only one chooses D, then that player gains more than he would in the C-C situation, and the Other loses more than he would in the D-D situation. With an individual's gain thus dependent in part on Other's behavior, it is to his advantage to be able to predict this behavior on each trial. In this study the PD was modified so that this normally implicit prediction was made explicit. A second modification consisted of giving all Ss identical false feedback.

## Method

Ss were seated in booths arranged so that they could see neither E nor the other Ss. In front of each S was a small box bearing two switches and two lights. The lights were controlled by E, and the switches were connected to lights on E's panel. Ss were run in groups of one to six with an average size of four. The total sample of sixty[2] was split into three groups of 10 males and 10 females each with one group being run in each of the following conditions:

(1) PM Alone—Ss were presented with a series of 200 lights, 138 "C's" and 62 "D's" in a sequence which had been derived from a random number table with the only constraint having been a desire to achieve an over-all distribution of approximately 70% "C's" and 30% "D's." The sequence was described to Ss as being "pre-set and controlled by E on the basis of the output from a 7094 program." They gained/lost one penny for each correct/incorrect prediction; these earnings were added to a base salary of one dollar.

(2) Game with "Real" Other—Ss were presented with the same sequence of lights as in condition 1, but here they were told that the lights were controlled by one of the other Ss (same sex) and that they themselves were controlling Other's lights. Payoffs were determined by a PD matrix (see Matrix 1), a copy of which was given to each S. In addition to this payoff which was dependent on their own and Other's choices, there was a one penny gain/loss on each trial for a correct/incorrect prediction of "Other's behavior" as in the first condition where prediction of the "computer produced sequence" was the only task.

(3) Game with "Computer"—This condition was identical to condition 2 except that the sequence of lights was now said to be pre-set on the basis of a 7094 program designed to produce the "best" strategy for this kind of task.

## Results

Over the last 100 trials there were 72 occurrences of the "C" light. The overall mean number of predictions of "C" in the last 100 trials was 74.45. For

Matrix 1. Entries represent payoffs to S contingent on their own and Other's choice.

| Own Choice | | C | D |
|---|---|---|---|
| Other's Choice | C | 2¢ | 4¢ |
| | D | –4¢ | –2¢ |

Groups 1 (PM Alone) and 3 (Game with "Computer") the mean number of predictions was very close to the actual number of "C" occurrences (Group 1 had a mean of 71.4 "C" predictions; Group 3 had 71.3) while for Group 2 (Game with "Real" Other) there was a greater discrepancy (Group 2 had 80.65 "C" predictions). However, an analysis of variance on the number of "C" predictions made in the last 100 trials showed no significant difference among conditions ($F = 2.61$, $df = 2/54$). In other words, Ss' prediction levels were not significantly different despite the difference in the supposed source of the feedback, the "meaning" of the sequence. Over the last 100 trials, however, there was a significant sex difference; males predicted "C" much more often than females, who were closer to probability matching. (Across conditions males had a mean of 78.6 "C" predictions; females had 70.3, $F = 4.60$, $df = 1/54$, $p < .05$.)

If we use as our variable the number of "C" predictions made over all 200 trials, there is a difference among conditions significant at the .01 level ($F = 7.19$, $df = 2/54$, $p < .01$). Those Ss who believed they were predicting the behavior of another S behaved quite differently from those who believed they were predicting some sort of computer output (Group 2 had a mean of 154.6 "C" predictions; Groups 1 and 3 had 129.4 and 129.0, respectively). There was no significant sex difference over all 200 trials ($F = 2.99$, $df = 2/54$; males had a mean of 143.1 "C" predictions and females had 132.2).

## Discussion

The difference among conditions over all trials indicates that Ss are utilizing cues not contained in the sequence. Those Ss who were told they were paired with another S apparently had certain preconceptions about Other's probable behavior which interfered with their adjustment to the situation. However, the fact that the feedback was not contingent on their behavior insured that most Ss would eventually realize that Other was not behaving as expected. With their preconceptions no longer useful, these Ss then fell back on the probability learning strategy of prediction based on properties of the sequence which had been utilized from the beginning by those predicting what they thought was the output from a computer program. In other words, to the degree that the situation was complex (other cues were "available") PM alone did not account for predictive behavior.

One interesting feature of this readjustment process is the differential reaction of males and females. There was no significant difference between sexes over all 200 trials, but over the last 100 trials there was a difference between sexes significant at the .05 level in the number of "C" predictions made. The inflexibility of Other, mentioned in the instructions for those paired "with computer output" and readily apparent to those paired with "another S," was differentially utilized by the males. They were more liable to realize that the optimal strategy was to predict "C" on all trials. (They were also more liable to play the game as though Other was always going to choose "C"). Females were less likely to make use of "Other's inflexibility" as a cue for prediction. This difference would appear to be related to sex differences in quantitative (strategic) abilities rather than to differential perceptions of the feedback. Having detected the randomness of the pattern of stimuli, the males were better able to calculate the response which provided them with greater payoff.

Summary

In the absence of other "cues," Ss will utilize a probability matching strategy as an aid to prediction or choice. The addition of more cues (greater complexity) leads to deviations from PM; the deviation in this study is greater for males than for females. "Cues" which may be utilized when present include preconceptions about the probable pattern of the sequence being predicted and the sensitivity of the feedback to S's own actions.

## References

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## Notes

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2. An additional 40 subjects were run in two conditions not relevant to the present discussion.