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Identifying Chaos in Human Interactive Decision-Making

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Thesis Director

Second Reader

Third Reader

Director of the Carl Goodson Honors Program

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Running head: CHAOTIC INTERACTION

Abstract

Human subjects played two computer versions of the Prisoner's Dilemma (Poundstone, 1992). By varying the payoff scales and instructions, one version of the game encouraged competition whereas the other encouraged cooperation. The data were entered into a computer program capable of generating a Sierpiński carpet with strings of random variables. The completion percentage of the resulting carpets indicated the degree to which the game-specific interactions approached chaos. The Sierpiński carpets resulting from the cooperation games showed significantly higher completion percentages than the carpets resulting from the competition games. Because chaotic behavior is unpredictable in the stream of its occurrence, research is needed that identifies psychologically-related chaotic phenomena and the conditions under which chaos occur: This study contributes to both of these goals.

Identifying Chaos in Human Interactive Decision-Making

The realization that within randomness lies order, or chaos, has shaken science's comfortable conceptions of the world. With the advent of chaos theory, scientists in diverse fields have been surprised to discover patterns in data domains known to be unpredictable, random, chaotic. The experiment presented herein suggests that such patterns can be found among human interaction as well (see also Neuringer & Voss, 1993; Richards, 1990). Although human decision-making is not usually considered as being chaotic, aspects of it may fit the criteria defining chaotic phenomenon: unpredictability at the level of occurrence, sensitivity to initial conditions, and a robust chaotic structure (cf. Gleick, 1987; Neuringer & Voss, 1993).

Chaotic events generally conform to several basic guidelines. The first, and perhaps most obvious, is that they are unpredictable. At any given point within a given chaotic system, for example, a dripping faucet, the exact coordinates of the next point cannot be known. Similarly, it is generally impossible to predict with certainty what a particular person will do in the next instant. Although a pair of good friends—or good enemies for that matter—often believe they know what one another will do in a given situation, an erroneous prediction is always a possibility. Another person's actions remain in principle unknown and unknowable until the moment of performance. People may not even know with complete certainty how they themselves will behave: Their decision may change at the last minute, an observation which leads to the next characteristic of chaotic phenomena.

Chaotic events are highly susceptible to external influence. Any slight disturbance can alter the course of the entire system. For example, Lorenz (1963) discovered that the same nonlinear equation would produce two very different patterns even though the starting position for both patterns differed by only one-thousandth of a point. This phenomena is known as sensitivity to initial conditions, or "the butterfly effect." Human interaction clearly fits this description: The course of a short conversation, for example, is sensitive to any number of conditions, including something as seemingly insignificant as the temperature of the area in which the conversation takes place (Griffitt, 1970).

Chaotic systems—despite, or perhaps because of, their unpredictable, random behavior—will gravitate to a particular pattern, even when disturbed or altered. Chaotic systems are, therefore, deterministic in the long run. Although human interactions are, in principle, unpredictable when one is in the stream of their occurrence, psychologists can identify patterns, or systems, of occurrence. In other words, you may not know what a person is going to say next in a conversation, but you might well predict that the course of the conversation will include a greeting, a short exchange, and a closing. Sometimes a pattern itself is all one can know. Previous research demonstrates that strategic decision-making can be chaotic (Richards, 1990). Neuringer and Voss (1993) suggested that human are capable of approximating certain chaotic characteristics such as randomness and sensitivity to initial conditions. This experiment will demonstrate how closely certain human interaction approximate a chaotic pattern and the conditions under which such an approximation might occur.

I need to digress and comment on the concept of "approximating randomness." It seems necessary, in light of the data presented herein, to conceptualize randomness or chaos not as an all-or-nothing quality, but as a continuum. Perhaps research will one day reveal psychological phenomena that are completely chaotic. At present, the data, as what follows will demonstrate, necessitate positing a continuum of randomness in human behavior.

Assuming—for the moment—a continuum of randomness, what factors determine how closely a human interaction will approach chaos? The experiment that follows establishes the above assumption and explores the phenomenon's parameters. Reasoning that the best place to look for chaotic behavior in human interaction is a well-known strategic situation with limited possibilities, I adopted the Prisoner's Dilemma game as my domain of inquiry.

Method

Subjects

Seventeen pairs of general psychology students were given extra credit for participating in this experiment. The students played a computer version of the Prisoner's Dilemma under two different sets of instructions. In one set, the players were told to cooperate with each other by keeping their scores as even as possible; in the second, they were told to compete by trying to get more points than the other player. In neither case were they allowed to communicate with one another about their strategy or decisions. Each pair played both versions of the game; version presentation was counterbalanced; 150 iterations of the Prisoner's Dilemma constituted one game.

Design and Procedure

I used two different Prisoner's Dilemma programs (one for the competition scenario and one for the cooperation scenario), written in BASIC, that assigned points rather than years in prison depending on a player's decision (Rhoads, 1993). The program asked the players to make a decision to either C (cooperate) or D (defect) with an individual joystick and waited for both responses; it then displayed that interaction's responses, the resulting scores from the preceding iteration, and the players' cumulative scores. Players always viewed a table representing possible choices and the version-dependent outcomes. Table 1 depicts the competition scale wherein the leading competitor receives the most points. Table 2 depicts the cooperation scale wherein matched scores represent cooperation. In order to cooperate, one subject often had to take a loss in points to equalize the scores.

Insert Tables 1 & 2 about here

I used another BASIC program that analyzed input strings of joint decisions (CD, DD, DC, CC) to determine the level of chaos in the games played (Rhoads & Rhoads, 1993). The program simulated the "chaos game" (Glieck, 1987), which produces a pattern called a Sierpiński Carpet. In the chaos game, a carpet is generated with a string of random numbers. The starting point is any random point within a square. Each vertex of the square is labeled with two numbers that correspond to the random rolls of a die (see Figure 1). After establishing a starting point, the die is cast and another point is placed at one-half the distance from the starting point to the vertex on the square corresponding to the number on the rolled die. From this new point the whole process is repeated. After several hundred points have been established in this manner, a pattern becomes evident.

Insert Figure 1 about here.

In this experiment, the vertices corresponded to the four possible choices in the prisoner's dilemma. The strings of joint decisions produced by each subject pair during a game were entered in place of the random numbers. Thus, the closer the strings of decisions approximated chaos, the more complete the carpet (for those who want to check the mathematical validity of the program, see the appendix). Carpet-completeness was tabulated by dividing the number of points in a complete carpet by the number filled-in by carpets generated via the Prisoner's Dilemma games, thereby producing a percentage of completeness. The number of points filled in by the different carpets differs—even though all carpets go through the same number of iterations—because, in a less complete carpet, more points will be placed in the same spot on the screen (i.e., on top of one another). The program counts the number of filled in pixels on the computer screen: A more complete carpet will have more filled-in pixels because the points would spread throughout the square; a less complete carpet would have the same number of points but fewer filled-in pixels because the points would concentrate in certain areas. The degree to which subject-pair games generated a Sierpiński Carpet is the degree to which their behavior approaches randomness, or, if you will, chaos within human decision-making.

Results

Overall the Sierpiński Carpets for the cooperation games showed a much higher percentage of completion than did the carpets for the competition game. The mean percentage of completion for the competition and cooperation games were 10.14 and 44.19, respectively. A t-test revealed a significant difference between the two groups, $t(16) = -8.60$, $p < .000$. Figure 2 displays the Sierpiński Carpets and percentages of completion for each subject pair resulting from each game.

Insert Figure 2 about here

Discussion

These data demonstrate that systems governed by different rules produce different degrees of chaos. The Prisoner's Dilemma game emphasizing cooperation produced higher degrees of chaos because it conformed more nearly to the three criteria for chaos mentioned in the introduction: unpredictability at the level of occurrence, sensitivity to initial conditions, and a robust chaotic structure. In the competition game, although the same number of choices were available, it was much more likely that each subject would make the only response that could result in winning the game. In the cooperation game, with exactly the same number of choices, a set response was a much less adaptive strategy. Though the cooperation game did not approach complete unpredictability at the level of occurrence, the probability of correctly predicting the next response was much more complicated than in the competition game. In the cooperation game, each decision was dependent on the decisions directly preceding it—an observation suggesting the second criterion of chaos, sensitivity to initial conditions.

Subjects playing the cooperation game had to pay attention to the joint decision made previously and the points of both players in order to know whether to try to adjust the point total up or down with a subsequent decision. Although the cooperation game did require a little more thought and consideration the time it took to play either game was relatively equal. In the competition game the previous decision was unimportant. A winning choice would always keep the subject from losing points regardless of the other subject's decision. Neither the previous decision nor the other subject's points mattered: The competition game was sensitive to no initial conditions. In contrast, the cooperation game was sensitive to both the previous decision and the other player's choice.

Finally, the cooperation game displayed a robust chaotic structure; that is, the string of decisions conformed to a general strategy or structure. Also, slight changes or disturbances within the interaction did not disrupt the overall structure inherent in the strategy: Mistakes were made and subjects would experiment with the possible decisions; adjustments were made and the pair would again establish a system of cooperation. The competition game was far less robust in response to differences in responding pattern. If a subject made a mistake or chose to make a decision alternate to a winning strategy, the course of the game was more or less decided from that instant. This is because once a player made a losing decision, in other words once one player chose D and the other chose C, the player that chose C was going to win if he stuck with that choice because there was no way for the player that chose D to regain lost points.

The cooperation games, compared to the competition games, met the chaos criteria and thus exhibited a greater degree of chaos. Models of human interaction that reflect these criteria more closely than the model presented here would, theoretically, produce closer approximations of chaotic patterns and thus reveal increasingly accurate behavioral structures. Although the very nature of chaos theory precludes prediction and control in the traditional sense, it is possible to describe chaotic psychological phenomena and the circumstances under which such phenomena may emerge. Specifically, knowing the limits of psychological insight into interactive situations could be just as important to psychology as the Heisenberg Uncertainty Principle to physics.

References

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Appendix

```
100 CLS: DIM A$(301)
104 SCREEN 1,0
106  COLOR 4,3
110 FOR R = 1 TO 60
120 FOR N = 1 TO 150
130 IF N = 150 THEN 415
190  READ A$(N)
210 IF A$(N) = "cd" THEN 270
220 IF A$(N) = "dd" THEN 280
230 IF A$(N) = "dc" THEN 290
240 IF A$(N) = "cc" THEN 260
260 G = RND(1)
262 IF G <.5 GOTO 360
264 GOTO 365
270 G = RND(1)
272 IF G <.5 GOTO 370
274 GOTO 375
280 G = RND(1)
282 IF G <.5 GOTO 380
284 GOTO 385
290 G = RND(1)
292 IF G< .5 GOTO 390
294 GOTO 395
360 H = H/3: V = V/3 : GOTO 400
365 H = (140+H)/3: V = V/3: GOTO 400
370 H = (280+H)/3: V = V/3: GOTO 400
375 H = (280+H)/3: V = (120+V)/3: GOTO 400
380 H = (280+H)/3: V = (240+V)/3: GOTO 400
385 H = (140+H)/3: V = (240+V)/3: GOTO 400
390 H = H/3: V = (240+V)/3: GOTO 400
395 H = H/3: V = (120+V)/3: GOTO 400
400 PSET (H,V)
410 NEXT N
415 RESTORE
430 IF R = 60 GOTO 1000
431 NEXT R
550 DATA dd,cc,dd,cd,cd,dd,cc,cd,dc,cd,cd,dd,dd,cd,cd,dc,dd,cc,cd,cc,dd,dd,dd,dd
,cc,cd,cc,dd,dd,dd,cc,cc,cd,cd,dd,dc,dd,dd,cc,dd,dc,dd,dc,dc,dc,dc,dc,dd,dc,dc,d
c,dd,dc,dc,dc,dd,dc,dc,dc,dc,dd,dc,dc,dc,dc,dc,dc
560 DATA dd,dd,dc,dc,dc,dc,dc,dc,dc,dc,dd,dc,dc,dd,dc,dc,dc,dc,dc,dd,dc,dc,dc,dc
,dc,dc,dd,dc,dd,dc,dc,dc,dc,dc,dc,dd,dc,dc,dc,dd,dc,dc,dc,dc,dd,dc,dc,dc,dc,dd,d
c,dc,dc,dc,dd,dc,dc,dc,dd,dc,dc,dc,dc,dd,dc,dc,dc,dc
570 DATA dc,dc,dc,dd,dd,dd,dc,dc,dc,dc,dc,dc,dc,dc
580 DATA
590 DATA
1000 FOR G =1 TO 20
1001 PRINT
1002 NEXT G
1003 PRINT "done"
1004 REM
1010 A = 1: B = A: D = 0
1020 FOR A = 1 TO 150
1030 FOR B = 1 TO 120
1040 IF POINT (A,B) <>0 THEN D=D+1 ELSE D=D+0
1100 IF B=120 THEN 1200
1110 NEXT B
1200 B=1
1210 IF A =150 GOTO 1300
1220 NEXT A
1300 PRINT "total=  "D
1400 E=D/4500
1405 E=E*100
1410 PRINT"percentage=  "E"%"
```

Author Notes

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Table 1

Prisoner's Dilemma Payoff Scale Encouraging Competition

	Subject B	
	Cooperate	Defect
Subject A	A, B	A, B
Cooperate	2, 2	0, -3
Defect	-3, 0	0, 0

Table 2

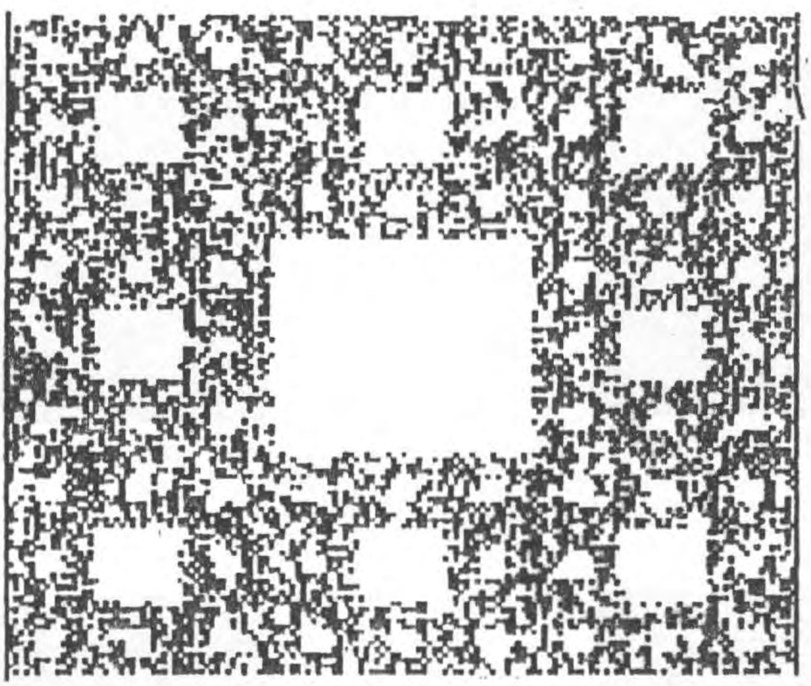
Prisoner's Dilemma Payoff Scale Encouraging Cooperation

	Subject B	
	Cooperate	Defect
Subject A	A, B	A, B
Cooperate	-1, 2	5, 1
Defect	0, -.5	1, -1

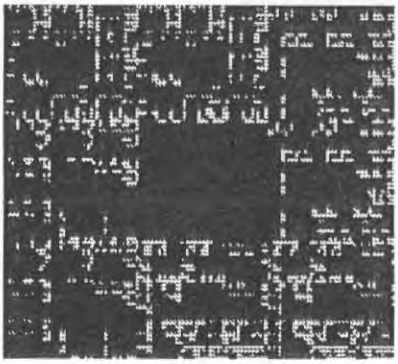
Figure Captions

Figure 1. Example of a complete Sierpiński carpet.

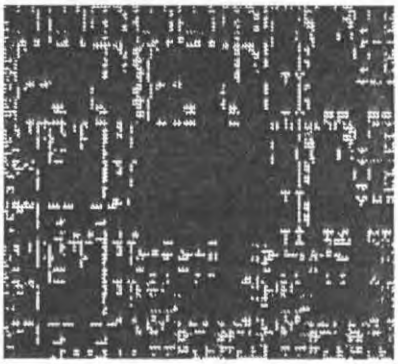
Figure 2. Percentage of Sierpiński carpets completed by subject pairs as a function of prisoner's dilemma instructions.



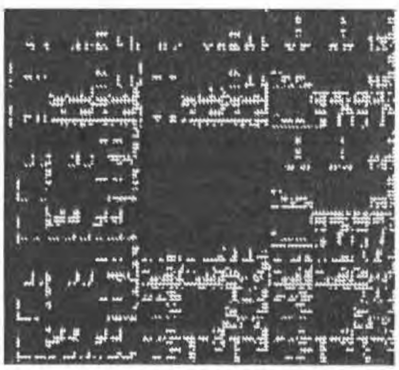
Cooperation Game



Pair 1 (52.40%)



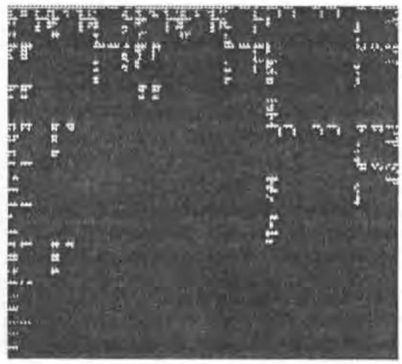
Pair 2 (49.11%)



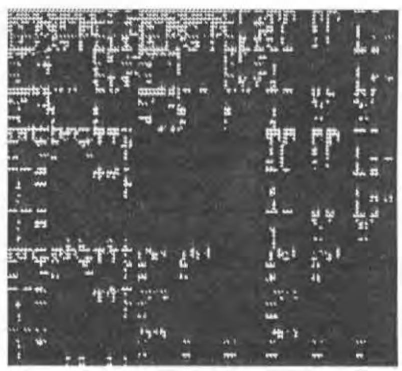
Pair 3 (52.49%)

Competition Game

Pair 1 (7.76%)

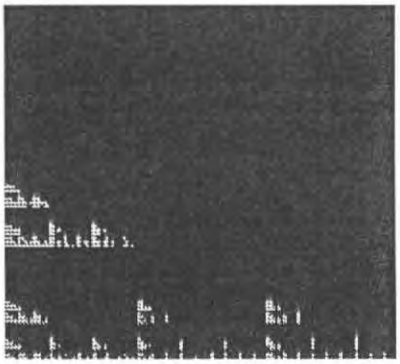


Pair 2 (15.04%)

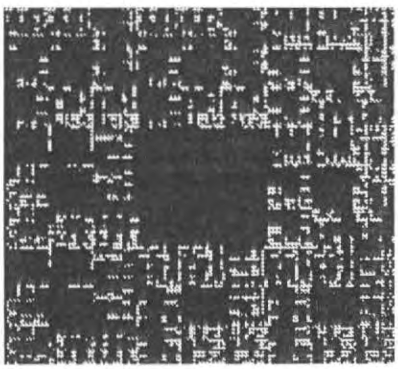


Pair 3 (40.60%)

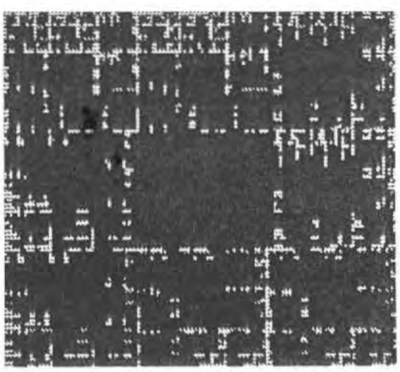
Cooperation Game



Pair 4 (9.64%)



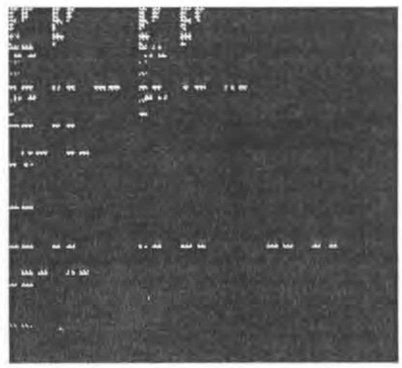
Pair 5 (59.07%)



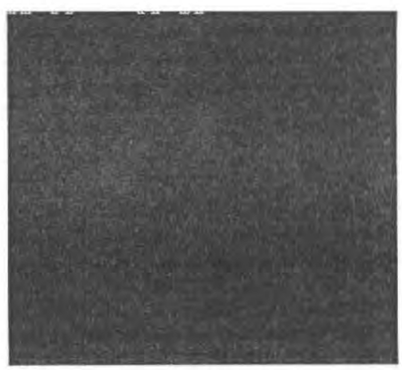
Pair 6 (39.98%)

Competition Game

Pair 4 (6.87%)

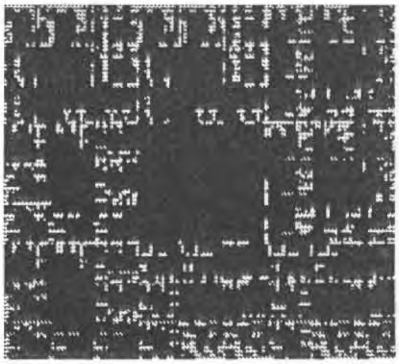


Pair 5 (1.36%)

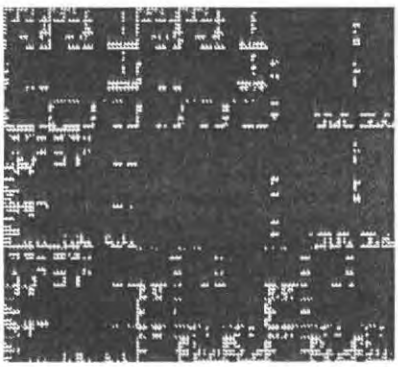


Pair 6 (0.00%)

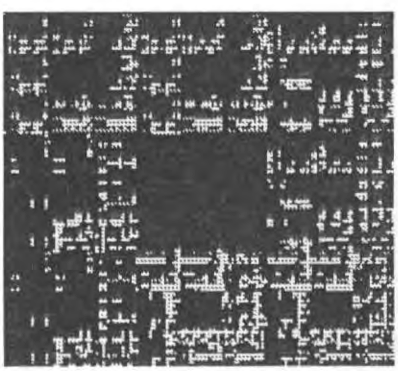
Cooperation Game



Pair 7 (49.38%)

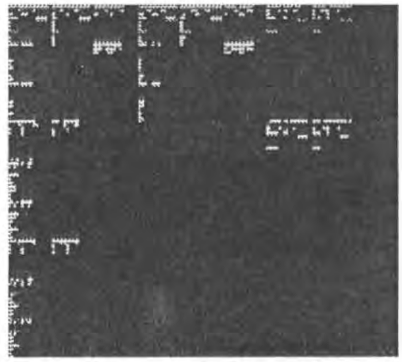


Pair 8 (37.56%)

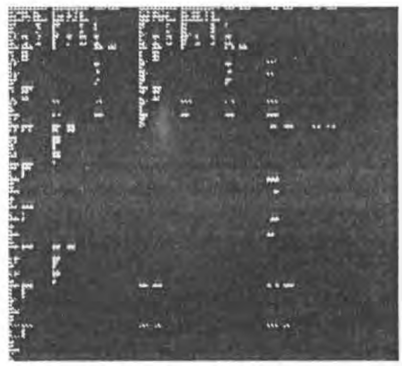


Pair 9 (56.89%)

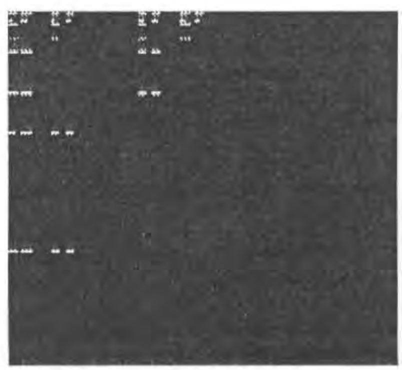
Competition Game



Pair 7 (11.56%)

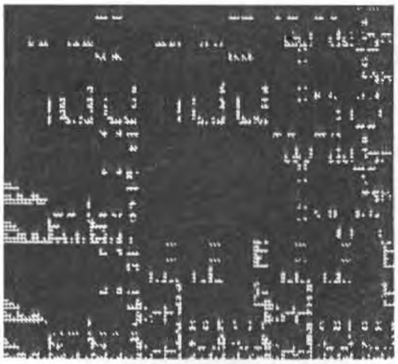


Pair 8 (13.98%)

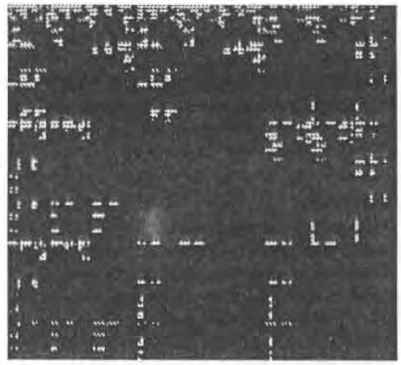


Pair 9 (2.53%)

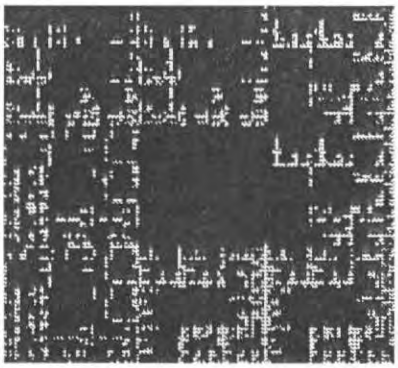
Cooperation Game **Competition Game**



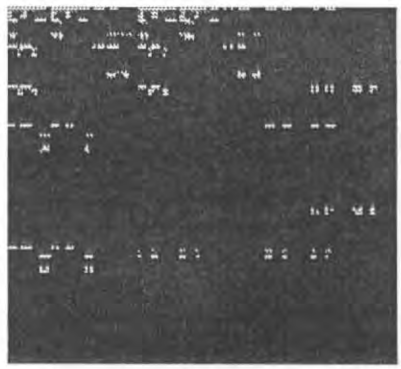
Pair 10 (29.31%)



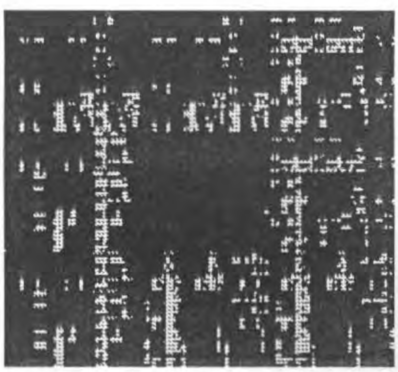
Pair 10 (19.96%)



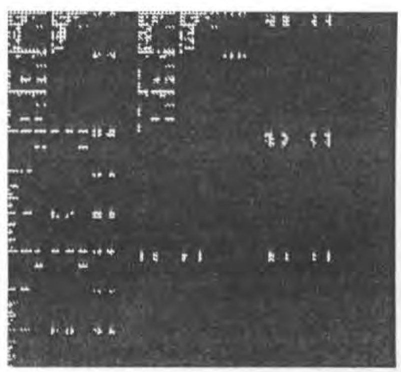
Pair 11 (53.84%)



Pair 11 (7.58%)

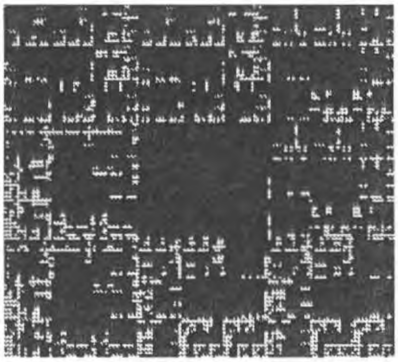


Pair 12 (40.13%)

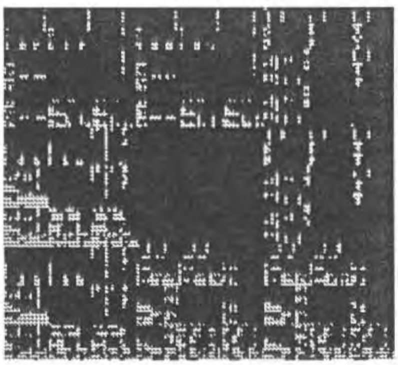


Pair 12 (12.49%)

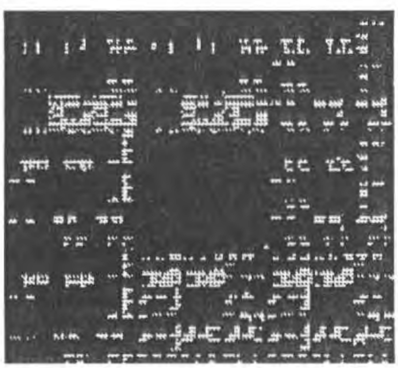
Cooperation Game



Pair 13 (55.24%)



Pair 14 (47.04%)

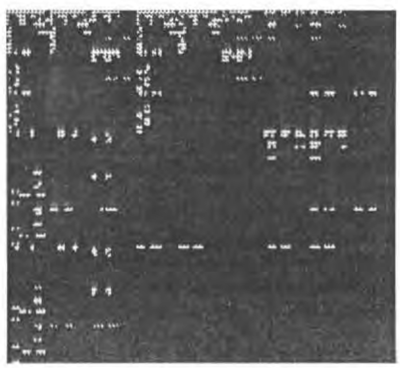


Pair 15 (40.49%)

Competition Game

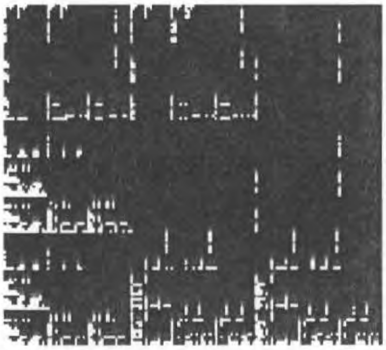
Pair 13 (4.71%)

Pair 14 (4.16%)



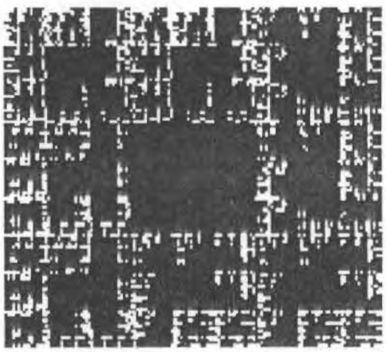
Pair 15 (14.62%)

Cooperation Game | **Competition Game**

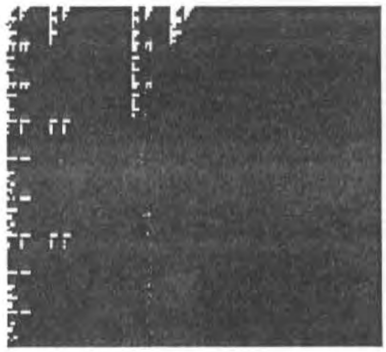


Pair 16 (25.16%)

Pair 16 (2.71%)



Pair 17 (56.69%)



Pair 17 (6.40%)