CHAPTER 9

Regularities from the Laboratory
and Possible Explanations

Our experiments have generated a series of empirical regularities. Let us briefly review these findings.

1. In the baseline experiments, the Nash equilibrium is the best predictor of aggregated outcomes for low-endowment experiments. In the high-endowment setting, aggregate behavior is far from Nash in early rounds but begins to approach Nash in later rounds. However, Nash is not a good predictor of individual strategies in either design. Further, subjects told us in debriefing interviews that they were investing more (less) in the CPR when the average rate of return on the previous round exceeded (fell below) the return from their other option. This type of heuristic helps to explain the pulsing patterns observed in baseline experiments, but is not consistent with predictions derived from noncooperative game theory.

2. The theoretically predicted outcomes are the same in low- and high-endowment environments. However, empirical results in the high-endowment design exhibited greater instability, less effective communication, lower joint outcomes, and higher defection rates.

3. Contrary to the theoretical prediction, subjects used the sanctioning mechanism even when they could not communicate. Subjects directed most of their sanctions toward those who overinvested in the CPR.

4. According to subgame consistency, past experience should not affect the decision whether or not to adopt a sanctioning mechanism. However, in our experimental designs with endogenous choice of a sanctioning mechanism, past experience affected subjects' choice. Two of the six groups presented with the choice to adopt sanctions decided against it. A high percentage of subjects in these two groups had experienced an environment in which a low cost, punitive sanctioning mechanism was imposed and used extensively.
One of the major questions left open by the series of communication experiments reported in chapters 7 and 8 is: Why is there so much cooperation in CPR dilemmas where subjects can communicate face to face? This question is of special importance given the findings from chapters 5 and 6. In experiments where subjects are not able to communicate, behavior at the aggregate level is consistent with predictions of suboptimality. Empirical regularities related to these communication experiments are as follows:

1. Subjects in repeated, high-endowment, CPR constituent games, with one and only one opportunity to communicate, obtained an average percentage of net yield above that which was obtained in baseline experiments in the same decision rounds without communication (55 percent compared to 21 percent—see table 9.1.).

2. Subjects in repeated, high-endowment, CPR constituent games, with repeated opportunities to communicate, obtained an average percentage of net yield that was substantially above that obtained in baseline experiments without communication (73 percent compared to 21 percent). In low-endowment games, the average net yield was 99 percent as compared to 34 percent.

<table>
<thead>
<tr>
<th>Experimental Design</th>
<th>Average Percent Net Yield in Experimental CPR after Round 10</th>
<th>Average Percent Net Yield in Experimental CPR (minus fees and fines)</th>
<th>Defection Rate</th>
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<td>36</td>
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<td>Baseline 25 tokens</td>
<td>21</td>
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<td>5</td>
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<td>Repeated Communication 25 tokens</td>
<td>73</td>
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<td>13</td>
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<td>One-Shot Communication 25 tokens No Sanction Chosen</td>
<td>56</td>
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<td>42</td>
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</table>

*Note: All computations are for rounds in which the treatment was in effect. Nash equilibrium for all designs is 39 percent net CPR yield.*
3. Repeated communication opportunities in high-endowment games led to higher joint outcomes (73 percent) than one-shot communication (55 percent), as well as lower defection rates (13 percent compared to 25 percent).

4. In no experiment where one or more subjects deviated from an agreed-upon joint strategy did the other subjects then follow a grim trigger strategy of substantially increasing their investments in the CPR.

5. Although communication agreements often came very close to near optimal yield, the subjects in these experiments frequently debated which strategy to adopt. Even with the high levels of information that we gave to subjects, it is obvious that subjects found the task of determining optimal strategies to be challenging. The agreements they adopted were frequently easy to remember and implement.

Assuming that individuals perceive the game as we have operationalized it in the laboratory setting, the subgame consistent equilibrium prediction for one-shot and repeated communication is the same as that for a finitely repeated constituent game without communication. Communication in any form should not make a difference, but it does. Repeating the opportunity for "mere jawboning" should not yield different results than one-shot communication, but it does. If communication were simply being used to agree upon a joint strategy, then one round of communication should suffice. Once individuals have made an agreement in the lab, much of the time spent communicating is devoted to establishing trust and verbally chastising unknown individuals if agreements are broken. These activities, when not backed up by enforceable agreements, do not yet play a theoretical role in explaining results within noncooperative game theory. These findings on the effects of face-to-face communication are supported by other experimental research (see discussion in chap. 7).¹

For those who base predictions of higher levels of cooperation in repeated settings on the presumption that individuals will adopt grim trigger strategies, our evidence is contrary. Surprisingly, when one or more subjects deviated from an agreed-upon joint strategy in some experiments, a few subjects subsequently reduced their investments in the CPR. In all discussions of how to respond to individuals who broke agreements, subjects always rejected any proposal that they should invest all of their tokens in the CPR so as to punish the defector.

Thus, behavior of subjects in both communication and noncommunication experiments was inconsistent in a variety of ways with behavior predicted from the theoretical perspective of complete rationality. In the remain-

¹. We focus on face-to-face communication. This institution may be quite different in both strategy space and behavior in comparison to highly limited nonverbal communication.
ing sections of this chapter, we explore possible explanations for the results obtained in our communication experiments.

**Why So Much Cooperation in Communication Experiments?**

We are not the first to observe high levels of cooperation in experimental social dilemmas with communication. The theory of infinitely repeated games is one explanation offered for this finding. In infinitely repeated games, some of the many possible equilibria are fully efficient (Friedman 1990). In chapter 7, we discussed two alternative approaches for explaining observed patterns of cooperation, both of which rely on notions of incomplete information.

One of these approaches interprets the game as if it were infinitely repeated. This approach relies on incomplete information surrounding the termination point for the experiment. For example, suppose the subjects approach the game as if it were repeated, but with only a vague notion of the number of repetitions. Further suppose that the subjects think the termination of the experiment is due to randomness, and that the probability of termination in any round is small. In these circumstances, subjects may recognize more than one sensible way of playing the game, some of which increase group gains. That is, not knowing exactly when it ends, the subjects act as though the game might last forever. If this were the case, there are many other equilibria available to them. All of these equilibria have efficiencies at least as great as that of the subgame perfect equilibrium of the finitely repeated game. Our data are not inconsistent with such an interpretation. Given the plethora of equilibria available to the subjects (if they were to perceive the game as infinite), they face a difficult coordination problem. We are, however, skeptical of this interpretation as being the sole explanation for these findings. For instance, it is well documented in public-goods experiments that even when the termination point is made explicit to the subjects, the results are strikingly parallel to those observed here (see for instance Isaac and Walker 1988a, 1991, and discussion in appendix 5.1). Also, in recent CPR experiments with an explicit termination point, our findings are strongly supported (Hackett, Schlager, and Walker 1993).

A second approach relying on incomplete information concerns other subjects’ types. For example, face-to-face communication (and resulting verbal commitments) may change a subject’s expectations of other players’ responses. In particular, if a subject believes that other subjects are of a cooperative type (that is, will cooperate in response to cooperative play), that subject

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2. If a game were to be repeated infinitely, there would be no last period and the logic of backward induction no longer applies in this form.

3. As mentioned in chapter 5, subjects are told that the experiment will last up to two hours and have already experienced training experiments that lasted no more than 20 rounds.
may play cooperatively to induce cooperation from others. In this case, cooperating can be sustained as rational play in the framework of incomplete information regarding player types. The cost of this approach is the incredible calculation processes involved in determining an equilibrium under incomplete information.

Given our reluctance to rely on these two approaches, we propose two principles based on the evidence we have gathered. The first principle is that agents use communication to reach an agreement. The second principle is that agents will find and adopt a simple agreement. In a communication session, our subjects tend to do two things: (1) focus on an agreement approximating the group maximum and (2) formulate a simple symmetric plan of play for the repeated game. The principle of simplicity in the one-shot case carries over to the repeated case. Interestingly enough, these two principles are also consistent with arguments of bounded rationality.

Game theory based on complete rationality requires that players have a strategy—a complete plan of play for every contingency. Selten, Mitzkewitz, and Uhlich (1988) argue that players are basically reactive in nature. Suppose that players in a communication phase have reached agreement on how play should proceed. As long as play proceeds according to the agreement, there is no need to react. Reaction is only called for when something unexpected happens, in particular, a defection from the agreement. The first principle that subjects use when communicating about equilibrium selection—find a simple symmetric solution—gives the subjects a reference point, their agreement, for reactions. The second principle—simplicity—reinforces the agreement as a reference point and suggests the form that reactions may take to deviations from the agreement. One possible type of “simple” reaction is a measured reaction. There are other possible reactions, some of which we briefly discuss below.

Measured Reactions

In a measured reaction, a player reacts mildly (if at all) to a small deviation from an agreement. Defections trigger mild reactions instead of harsh punish-

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4. This point is made forcefully by Banks and Calvert 1992a, 1992b.
5. Colleagues working with Reinhard Selten in the Department of Economics at the University of Bonn have developed and tested a series of behavioral strategies related to various types of games. See Rockenbach and Uhlich 1989 on two-person characteristic function games; Mitzkewitz and Nagel 1991 on ultimatum games with incomplete information; and Keser 1992.
6. Our use of this term was inspired by the concept of “measure-for-measure” introduced by Selten, Mitzkewitz, and Uhlich 1988. However, there are important differences in our application relative to theirs. Namely, their subjects do not have a communication phase, and they model their subjects using Selten’s three-stage theory of bounded rationality. Our application makes use of only one of these three stages and substitutes communication for another stage.
ments. If defections continue over time, the measured response slowly moves from the point of agreement toward the Nash equilibrium. Thus, a measured reaction is very different from a grim trigger strategy. The intuition behind measured reactions is that, by keeping play near the agreement, it is easier to restore the agreement. Further, the risk of a complete unraveling toward the one-shot game equilibrium is reduced when players do not overreact to deviations. Since the payoff achieved from an agreement (or, play close to the agreement) dominates one-shot game payoffs, measured reactions represent a useful response to the problem of equilibrium selection.

Consider our designs with one-shot or repeated communication, where agents have agreed to contribute 6 tokens each to the CPR (this is the agreement reached in several of our experiments). Then a typical measured reaction would look as shown in the left panel of figure 9.1. The reaction shown in this figure has on the x-axis the average decision of all other players in the previous round \((t - 1)\), and on the y-axis the decision of a given player in the current round \((t)\). The measured reaction passes through the agreement: if all others kept to the agreement in \(t - 1\), then this player keeps to it in round \(t\). Moreover, if others invest less than the agreed amount, this player sticks to the agreement. Finally, if others invest more than the agreement calls for, this player responds in a measured fashion by investing somewhat more or by sticking to the agreement in the hopes of getting others to return to the agreement. Measured reactions continue until the one-shot equilibrium is reached. At this point, no further reactions are called for. Play has now reached the one-shot equilibrium, and any further deviations reduce a player’s payoff. If investments were to exceed the Nash equilibrium, eventually a player would do best to leave the CPR entirely and invest all tokens in the safe alternative.

The linear reaction shown in the left panel of figure 9.1 is simple but ignores the restriction that decisions have to be integer valued. We call any reaction function passing through the agreement point and the one-shot equilibrium a measured reaction. The right panel of figure 9.1 graphically presents the measured reaction box, which shows the limits within which all such reactions must be found. Note that the lower-left and upper-right corners of this box are defined by the agreement reached in an experiment, AGREEMENT, and the symmetric one-shot equilibrium \((8,8)\), NASH. All integer-valued step functions lie within this box.

Besides measured reactions, there are many alternative reactions subjects might exhibit in our decision situation. At one extreme, they may make the same decision under all circumstances, constant play. We have observed behavior consistent with other possibilities as well. For instance, a subject who invests at a maximal rate while other subjects hold back their investment level to an agreed-upon level is playing "never give a sucker an even break." A
variation on this strategy is observed when a subject convinces the others to invest at low levels and then proceeds to invest at a maximal level. This could be called "sandbagging the suckers."

Measured reactions appear to have improved cooperation in our communication experiments without sanctioning. There are 18 such experiments where subjects had at least one opportunity (15 costless, 3 costly) to communicate but no opportunity to use fines. In all these experiments, the anonymity of the subjects was maintained. In some of these experiments (all 25-token, one-shot communication and half of all 25-token repeated communication), subjects had information about the individual investments of each player. This information was anonymous, however, in respect to the actual identity of each player. An analysis of the responses made by subjects in these experiments is summarized in table 9.2 and discussed below.

**High-Endowment Experiments with One-Shot Communication**

After the first 10 rounds of experiment 19, first reported in table 7.1, the subjects were given a single opportunity to communicate. In their discussions, they stressed that they wanted to obtain a fair outcome where everyone received the same outcome. The subjects agreed upon a strategy of investing 6 tokens each in the CPR. While the agreement was not at the optimum, if all participants followed this agreement, they earned 89 percent of the optimum yield. The experiment lasted 22 rounds after the communication round, leaving 21 rounds × 8 decisions to seek evidence of measured reactions.
<table>
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<tr>
<th>Type of Communication Experimental Design</th>
<th>First Reported in Table</th>
<th>Percentage Agreement</th>
<th>Percentage Extended Agreement</th>
<th>Percentage in the Box</th>
<th>Percentage Total Measured Reactions</th>
<th>Percentage Large Deviations</th>
<th>Average Percentage of Yield after Agreement</th>
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<td>96</td>
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</table>

<sup>a</sup>In the 10-token design, a bounded investment decision of 10 tokens is considered as a large deviation.

<sup>b</sup>Subjects received information on Market 2 decisions for each individual subject by an anonymous identification number.
Figure 9.2. Measured reactions (experiment 19)

Figure 9.2 shows how the reactions appear in reaction space. In 53 percent of all decisions (89/168), a subject invested at the agreement in round $t$ in response to an average investment equal to the agreement in $t - 1$. This can be interpreted to mean that the individual knows that on average the others kept to the agreement in $t - 1$, and so the individual keeps to the agreement in $t$. This 53 percent is represented in figure 9.2 in parentheses next to the word AGREEMENT.

Besides the 53 percent of all reactions at the agreement point, there were an additional 29 percent inside the measured reaction box. This is depicted in figure 9.2 by the number 82 percent within the measured reaction box, which includes the reactions at the agreement point, the Nash point, and interior to the box. There were no observations of one-shot Nash. This is represented by the 0 percent in parentheses next to NASH on the figure. Measured reactions are only defined between the AGREEMENT and one-shot NASH. In this experiment, and as we shall see in most one-shot communication experiments, a noticeable percentage of players stick to the agreement when the group average is less than the amount agreed upon. In this experiment, for
example, 7 percent of all responses were of the form where "i's reaction is 6 in round t, when the other's average in t - 1 was less than 6." This is represented by the number 7 percent above the line extending leftward from the agreement point.

There are two other types of reactions worth emphasizing. One is the optimum. The second is what we refer to as a large reaction. In this experiment, we observed no reactions where the individual invested at the optimum in response to an investment in the previous round that averaged at the optimum. We define a large reaction as any reaction greater than or equal to the one-shot best response to the agreement. For instance, the one-shot best response to the agreement at 6 tokens is 15 tokens by the player breaking the agreement. In this experiment, there is only one large reaction (rounded to 1 percent), displayed next to LARGE REACTIONS. In this experiment, the measured reaction is very much in evidence.

In experiment 20, the participants again had only one opportunity to talk. After a short discussion, they agreed to invest 5 tokens each. They saw on their screens that one player had invested 25 tokens in each of the first 10 rounds. Only one player speculated about the payoffs that the all-25 player had obtained and mused that this player "could be coming up with real money if everyone else is pulling back." Unfortunately for the others, this player could make twice the money the others made by persisting in his behavior and was perfectly willing to exploit the reaction. He had actively promoted the decision to select 5 rather than 6 tokens as their agreement. As his parting shot at the end of the round, he told the others, "So we all need to stick to it."

This player did not follow the same heuristic as the others. He adopted something closer to "never give a sucker an even break." With no further communication, the other seven players could see on their screens round after round that the same player invested 25 tokens. As shown in figure 9.3, 31 percent of the reactions were in the measured reaction box, while 15 percent were large reactions—most of which were the actions of this one player.

Let us examine in more detail what the others did. In figure 9.4, we have plotted the number of players who followed an almost measured reaction (investing at the agreement point, below the agreement, or 1 token above the agreement) for rounds 11 through 32. As shown, all of the other players kept close to the agreement in the first few rounds after discovering the blatant violation of their agreement. Over time, the number of individuals keeping to

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7. When the other players contributed 5 tokens each, someone contributing 25 tokens could make 8 "experimental cents" on each token in the CPR and only 5 "cents" on the same tokens in the alternative investment. That meant that the individual investing 25 tokens made a total of 200 "cents" on any round when the others invested no more than 35 tokens in total. The others made 140 "cents." If everyone had followed the agreement, all would have made 185 "cents." Subjects were paid one half of the "experimental cents" they earned in the 25-token experiments.
the agreement slowly dropped. In the last 3 rounds, one-half of the participants continued to invest very near the agreement or somewhat less while the other half invested 7 or above. It appears that seven of the individuals wanted to adopt measured reactions and adhered to them as long as they felt there was any chance to keep their payoffs in Market 2 above those in Market 1. Absent one recalcitrant individual, the group would have followed a measured reaction and achieved a much higher joint return.

In experiment 21, the subjects disagreed on what the optimal investment was. They finally decided to invest 3 tokens each in round 11, 4 tokens each in round 12, 5 tokens each in round 13, 6 tokens each in round 14, and then to pick the best (independently). During this trial phase, there were two large deviations as well as one reaction out of sequence. Once the trial phase was completed, the modal subject choice from then on was 6 tokens. From this we infer that an implicit agreement at 6 had been reached. Since the group never had another chance to communicate, there is no way to check this inference. Clearly, the lack of a clear agreement point at the end of the communication period jeopardized the performance of any heuristic, such as measured reac-
tions. As shown in figure 9.5, 41 percent of the reactions were in the measured reaction box, while 10 percent were large reactions.

In addition to these three one-shot communication experiments, there are two additional experiments with a comparable structure. As discussed in chapter 8, we ran six experiments in which groups had an opportunity to decide whether to impose a sanctioning mechanism on themselves or not. Two of the groups decided against adopting a sanctioning mechanism. These two experiments constituted a one-shot opportunity to communicate followed by a series of rounds without a sanctioning mechanism or any further opportunity to communicate. These subjects were very experienced players. To be in this experiment, they had to have had a prior experience with a sanctioning mechanism. Many of the individuals in these two experiments had been in sanctioning experiments where we had used a 20-cent fee to impose an 80-cent fine. The fining rate in these 20–80 experiments was much higher and more erratic than in the other sanctioning experiments. Many of the subjects expressed a strong aversion to the use of a sanctioning mechanism.

In experiment 54, the subjects did not come to a clear, explicit agreement as to the number of tokens they should invest. They said they wanted to continue doing the same as before. Since the average individual investment in the first ten rounds was 5.8 tokens, we interpret this desire as an implicit agreement to 6 tokens each. This group did not maintain the status quo,
however. In the 15 rounds following communication, there was a substantial decay of returns, as two subjects averaged over 10 tokens invested each. By the end of the experiment, this group was close to the one-shot Nash equilibrium, and its implicit agreement had collapsed. As shown in figure 9.6, 31 percent of the reactions were in the measured reaction box, while 4 percent were large reactions.

In experiment 55, the subjects clearly agreed on an investment of all 4s. The first few infractions were small and so were the reactions. Beginning in round 17, one player consistently invested 20 or higher tokens in each round until the end. The other players used great restraint for 3 rounds, at which time two players increased their individual investments beyond the Nash equilibrium. In round 22, a total of 110 tokens was invested and the group earned -322 percent of total yield. Four players still continued to use measured reactions throughout. Their efforts were futile, since the group earned only 36 percent of total yield after the communication round, but their measured reactions did help make performance after communication quite a bit better than it had been before (positive vs. negative yield). As shown in figure...
9.7, 55 percent of the reactions were in the measured reaction box, while 15 percent were large reactions.

**15-Token Experiments with Costly Communication**
Chapter 7 describes three experiments (35–37) where subjects were given an opportunity to communicate if five out of eight of them contributed to the provision of the communication round. In two of these experiments (35 and 37), agreements were reached as soon as the provision of a communication round was accomplished and either 100 percent or 99 percent of the responses were in the measured reaction box. The average percentage of yield in both experiments also came close to optimal. In the second experiment of this series (36), the subjects immediately paid the cost of a communications round and agreed to invest 5 tokens in the CPR. After only 1 round of full agreement, one player invested all 15 tokens in the CPR and continued to do so until the game ended. The reaction of the other players in the next round was measured, to say the least. Five players kept with the agreement and the other two invested 1 token more than the agreement. When a second player began to invest all 15 tokens in the CPR, the other six players were indeed faced
with a puzzle. Over the life of the experiment, 22 percent of the responses were large reactions (in this case, all were 15 tokens). No one invested more than the Nash equilibrium, however, for the next 4 rounds. In fact, there were only three investments that exceeded the Nash equilibrium other than those of the two players who invested 15 tokens each round. With only 45 percent of the reactions on the agreement point and only 67 percent in the measured reaction box, the group achieved only 67 percent of total yield after their agreement, as contrasted to the two other costly experiments where a near-optimal response was sustained.

Low-Endowment Experiments with Repeated Communication
In all four of the repeated communication, 10-token experiments, subjects followed their agreements with a high level of fidelity and responded to the few deviations in such a manner that one could safely argue that the subjects used measured reactions in these experiments (reported in table 9.2). The reactions diagrams for these four experiments all have higher than 97 percent of the reactions in the measured reaction box, and almost all of these are at the
agreement point. For this reason, we have not reproduced these reaction

High-Endowment Experiments with
Repeate Communication

As discussed earlier, the 25-token design is behaviorally a far more difficult
situation than the 10-token design. We conduct six experiments with high
endowments and repeated opportunities to communicate (from table 7.3). In
all six experiments, subjects reacted consistently with measured reactions,
with at least 75 percent of all reactions in the box. We now consider each
experiment in some detail. In experiment 26, subjects agreed to invest 6
tokens each. Thus, the agreement point in reaction strategy space is the point
(6,6). The big difference between this experiment and the previous ones is that
not a single reaction of the form (6,6) was ever observed. This group was
literally never at the agreed-upon point. Nevertheless, the group did achieve a
reasonable net yield (70 percent), and stayed in the vicinity of the agreement.
In the 12 rounds where reactions could be observed following the initial
communication round, 93 percent (89/96) of the reactions lay within the
measured reaction box (see fig. 9.8). There were only 7 reactions lying
outside the box, and none of these were large. This is especially impressive
given that there are no observations at (6,6).

The transcript of this experiment provides evidence about the expressed
thoughts of the subjects as they coped with the continuing problem of defecting
members. In the first rounds, seven subjects invested at the agreement and
the eighth subject (player C) invested two tokens over the agreement. After
considerable discussion about what to do, they finally agreed that “staying
with 6 is the best.” The last two comments made before they returned to their
terminals were:

Player B: Let’s not get greedy. We’ve just got to start trusting.
Player H: Let’s everyone do 6.

In the next round, the 12th, player C increased investments in the CPR from 8
tokens, invested in round 11, to 19 tokens. This constituted a real challenge to
their agreement and an affront to the other players. Player A invested 7 rather
than 6 tokens (consistent with a measured reaction). All the others stayed with
the agreement and invested 6 tokens. After this round, the discussion opened
with

Player B: This should be our last meeting—if we can’t get some trust,
we might as well go back and screw each other over. We could all
make more money if we could stick together, but if some are going to
do the others in, then, we just should go. Does everyone agree to do the same thing?
Player D: If there is any objection to this, can we just plain hear why not?
Player H: Well, it is obvious that someone is making a little more money.
Player B: Well, they know that they are going to make more money, they could probably make all of two bucks, but still, I mean, if we go back to the way we were, none of us will make as much.
Player E: Let’s try it one more time.
Player H: No, let’s go back to the way we were doing it.
Player D: If you do, you sure lose!
Player G: If you don’t work together, you lose.
Player E: That person will do it, whatever we agree to.
Player H: Does anyone want to confess?
Player D: Let’s try one more time.
Player G: If this doesn’t work, then forget all about it.
Player H: Want to try to invest 6? Let’s try it.
Player B: Let's go for 6. [Player B then looks at each and every one of the other 7, points to each one, and looks at each one directly in the eye.] It shouldn't take very long for anyone to put in 6 in Market 2!

After this dramatic close, player C dropped back to the agreed-upon 6 tokens in round 13, but player A invested 8. In the discussion following round 13, the players were so glad to be close to their agreement that they simply congratulated themselves on getting closer and asked to return to their terminals early. They had similarly short discussions from then on. After the fifteenth round, for example, they had the following exchange:

Player H: Not everyone is investing 6.
Player B: Evidently not.
Player C: Unless everyone keeps to it, it starts to get away from us.
Player H: Let's say we invest 6 again. Obviously somebody is cheating, but what can we do? But the rest of us can just continue to invest 6.

At a still later point, player E suggested that they dump whatever they wanted into Market 2. Player H disagreed and pointed out that "we screw ourselves too."

The transcript reflects a group of subjects trying to grapple with a situation on the brink of disaster. Instead of going over the brink, their measured reactions to the provocation sustained behavior close to their agreement, even though they never achieved perfect compliance.

In experiment 27, the participants miscalculated the optimum at 50 tokens (instead of 36) and devised a rotation scheme whereby six individuals invested 6 tokens and two individuals invested 7 tokens. They had perfect compliance to their rotation system through round 20, when one subject invested 11 rather than 6 tokens. Given past experience in experiments with 20 rounds, this may have been an "end effect." The discussion after round 20, reproduced in chapter 7, reflects individuals who are puzzled why someone would break their agreement. They resolved to return to their rotation scheme. They did return to their terminals and continued with perfect compliance from there on. They achieved 84 percent of the potential yield, rather than a higher percentage, because they had miscalculated the optimum and not because they had difficulty keeping to their agreement.

In experiment 28, the players again overestimated the number of tokens that was optimal and agreed to invest 50 each round for four rounds (with a rotation system) and then 49 tokens each round. They faced only three defections during the course of their experiment. In the discussion following these defections, the players stressed the importance of not "messing it up"
by small deviations and never discussed the possibility of punishing those who deviated. The central focus was on keeping the agreement going still further.

In experiment 29, the subjects initially miscalculated the optimal investment level, but used their discussion to improve their agreement. By the last 5 rounds, they obtained 99 percent of the yield. Since they never faced a defection throughout the experiment, they never discussed a response for coping with this problem.

Experiment 30 was unique in one crucial respect. These subjects agreed to invest 1 token each in the CPR. This represents by far the worst agreement ever reached, with a potential group yield of only 40 percent. This agreement at the point (1,1) further implies the largest measured reaction box, with corners at (1,1) and (8,8). A large box is really easy to hit; indeed, 75 percent of all reactions in the 13 periods following the agreement landed in the box (see fig. 9.9). Despite this poor agreement, subjects held to it for 7 rounds. Then the same player who had suggested the agreement in the first place made the largest possible Market 2 investment, 25 tokens.8 A lively discussion ensued, as reported in chapter 7. In the last 5 rounds of the experiment, there were 17 double-digit reactions, and the agreement clearly unraveled. The combination of poor agreement and unraveling meant an overall average yield of only 37 percent, by far the lowest of the set of repeated communication, 25-token experiments.

Experiment 31 also helps illuminate how individuals who use a measured reaction avoid the complete unraveling of an agreement when presented with small infractions by one or two individuals. In this experiment, the group agreed to invest 6 tokens each. While they did achieve some rounds of perfect compliance, they frequently faced rounds in which one or two persons invested 7 or 8 tokens rather than the agreed-upon 6. At several points in their discussions, the participants discussed the possibility of strategies that mimic trigger responses and always rejected the idea. Here is one exchange:

Player D: What can we do to lose the most?
Player A: Lose the most?
Player D: Yeah, to get back at her—points at E (who was suspected of having overinvested).
Player A: But that hurts us all as well.
Player D: We probably don't have that many rounds left to really worry about this stuff of putting one more penny than we have agreed on.

8. The heuristic this player may have been playing could be described as: "Set the suckers up for a preemptive strike."

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Let's just keep on putting in those 6s—and let them have the benefits of their stupid penny.

At a later juncture, one player commented that the set of reliable players is even smaller (while only two people had defected, one of those individuals had never defected before). This was followed with:

Player E: What are we going to do, are we going to go for a free-for-all?
Player B: Go for a free-for-all? Shucks no, we all lose.
Player D: No, we all lose.

The discussion rounds in this experiment were quite heated, but by stressing the fact that they would all lose if they moved too far away from the agreement point, the group was able to gain 84 percent of net yield even when facing the problem of repeated but small defections.

Summarizing the results of the six repeated-communication, 25-token experiments, we find high rates of measured reactions, at least 75 percent in...
all cases and at least 93 percent in five cases. We find very low rates of large deviations, never higher than 3 percent, with no large deviations whatsoever in four cases. In the five experiments where the initial agreement promised a high average yield (at least 90 percent), measured reactions enabled groups to obtain on average 78 percent yield in a very challenging situation. Of course, measured reactions cannot salvage a very deficient agreement.

Bounded Rationality and Behavioral Heuristics

The above discussion of measured reactions provides part of an explanation of "Why so much cooperation in communication experiments?" but only part. Communication allows individuals to agree on a joint strategy and to begin a process of building trust in others to abide by that agreement. When sanctioning is not available, trust has to be built through communication and consequent changes in patterns of behavior. When behavior is relatively close to the agreed-upon level, most individuals respond to deviations in a very measured fashion. When most individuals use a measured reaction, even in challenging situations, they are able to gain joint returns close to the level agreed upon. Their closeness to optimality depends both on the yield potential of their agreement and on their rate of compliance. Individuals who exhibit measured reactions are able to sustain cooperation for an extended period and reap the benefits of doing so.

On the other hand, when one or a few individuals do not respond consistently with measured reactions and are able to deviate in an extreme manner from an agreement (by having sufficient resources to be very disruptive to attempts by others to form near optimal agreements), measured reactions are not very effective. Dealing with extreme deviations is especially problematic when players communicate only once. To prevent agreements from unraveling, the ability to chastise offenders verbally on a repeated basis is essential in laboratory experiments without sanctions. In the 12 experiments where individuals reacted in a measured fashion by sticking to their agreements or by keeping deviations small (greater than 85 percent in the box), yields averaged 89 percent of optimum. In the 6 experiments where this was not the case, yields averaged only 43 percent of optimum.

Even if measured reactions work, this still leaves unanswered why some groups exhibit them and others do not. Where do such reactions come from? One answer to this question starts with Selten's dictum that complete rationality is the limiting case of bounded or incomplete rationality (1975, 35). From this perspective, a behavioral response like measured reactions are heuristics used by individuals as problem-solving tools when complete analysis is difficult and short-term self-interest dictates unsatisfactory long-term outcomes, such as the case where the cognitive task is beyond the immediate
scope of the individual, or game equilibria lead to suboptimal outcomes. Individuals learn to use a repertoire of heuristics depending upon their experience and their perception of the situation in which they find themselves, including the likely behavior of others.

In simple situations where short-term self-interest leads to near-optimal outcomes, individuals may very well exhibit behavior that closely parallels that predicted by a model of complete rationality. In simple situations where short-term self-interest leads to a highly suboptimal outcome, individuals may learn from experience or be taught by mentors that use of a heuristic may lead to better outcomes, as long as others follow similar behavior. In complex situations, individuals may adopt heuristics as a first approach to learning about the decision situation. Many terms are used for the concept of a heuristic including “rule of thumb,” “standard operating procedure,” and “standard of behavior.”

In a two-person, binary choice, repeated social dilemma where full information is available about the behavior of each person in the previous round, individuals who learn to play a tit-for-tat strategy, for example, can achieve high payoffs across many different encounters so long as there are a sufficient number of other individuals in the population prepared to play the same strategy (Axelrod 1984). Axelrod’s and Selten’s work on two-person decision settings shows that the best response depends not only on the game structure but also on the behavior of the other players (see also Taylor 1987; Bendor 1987; Bendor and Mookherjee 1987, 1990). Cooperating with those who cooperate enables individuals to obtain benefits not achievable by individuals following other strategies.

$N$-person situations are far more complex than 2-person situations. In a 2-person game of complete information, each person knows with certainty their own response and can infer the response of the other also with certainty. In an $N$-person setting, it is extremely hard to know whether a particular outcome is the result of many individuals cheating just a little or one person cheating a lot. No heuristic is as simple and straightforward as tit-for-tat in the 2-person situation.

Individuals who come to a situation with a complete preprogrammed strategy may miss out on opportunities for mutual gain that are available to those who can respond somewhat more adaptively. A bounded rationality approach enables the theory to make less severe assumptions about individuals’ calculation capabilities and shows that such individuals may do better in some environments than their completely rational counterparts. Instead of calculating all future contingencies and forming a complete plan of play, an individual uses rules of thumb sequentially as he or she learns about others’

patterns of play. If all of the players are using measured responses, the evolving pattern of play will lead them to much higher outcomes than other types of reactions.

Those following measured reactions, however, are no more likely than others to cope effectively with the problem presented by the presence of individuals who adopt entirely different types of heuristics—particularly some of the nastier ones involving either complete unconcern for keeping agreements, or even worse, luring others into an agreement where they are set up for a strike. Individuals who cannot draw on some form of sanction are all relatively exposed to the predatory actions of those who are perfectly willing to unilaterally take advantage of others.

In a situation without communication and with more than two individuals, it is extremely difficult to initiate a process by which individuals learn a measured heuristic. Similarly, if groups only communicate once, and if some individuals adopt less cooperative strategies than measured reactions, it is harder to sustain cooperation over time than when groups are able to discuss their joint behavior and outcomes continuously. As we see in our experiments, individuals who might use a measured reaction when communication is possible may not use it when communication is impossible.

But once individuals communicate (especially if they can communicate with one another repeatedly), they can build up trust through their discussions and through achieving better outcomes. If individuals come to these situations with a willingness to devise sharing rules and to follow a measured reaction, then communication facilitates agreement selection and the measured reaction facilitates agreement retention. The measured reaction heuristic prevents the full unraveling of an agreement when minor deviations first start to occur but is not effective when major deviations occur. In the latter event, no response other than a sanction directed at a large deviation is likely to be effective. In CPR situations, individuals come armed with an array of previously learned heuristics. With communication, these individuals have a chance to discover the approaches others are using to the game. Without communication, they do not know what to do in the situation they face and adopt strategies that vary tremendously.

Many individuals utilize heuristics learned from childhood experiences. On playgrounds around the world, children arguing about the allocation of toys, space, or the use of facilities are taught, depending on the situation, to use principles such as

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10. Piaget's theory of moral development is based on his observations of how children learn to play the game of marbles (Piaget [1932] 1969). The playground is where many individuals learn the heuristics that they will use for the rest of their lives in orienting themselves to diverse situations (V. Ostrom 1994).
Rules, Games, and Common-Pool Resources

• share and share alike (equal division);
• first in time, first in right;
• take turns;
• share on the basis of need; and
• flip a coin (use a randomizing device).\(^{11}\)

Most of the agreements developed in the lab setting were based on the first principle—share and share alike. The basic symmetry of the specific series of symmetric experiments apparently evoked this principle frequently.\(^{12}\) Once a sharing principle is devised (and a conception of the size of the joint good to be shared), individuals can agree to follow the sharing principle even without enforcement if they presume that most of the individuals with whom they are relating will reciprocate their trust. The adoption of a measured reaction heuristic enables individuals to start on a productive path toward higher joint outcomes without outside enforcers.

So long as the population of individuals sampled for laboratory experiments has a sufficient proportion of individuals who know and use a measured reaction heuristic, individuals can use this shared knowledge or social capital as a resource for gaining substantially better outcomes than they would otherwise have gained. Even when groups discover individuals within their midst playing entirely different strategies, the restraint shown by the remaining individuals keeps their joint returns higher than they were when pursuing completely independent strategies.

Conclusions

We have now addressed in some depth the first and second core questions that we posed in chapter 1. At the aggregate level, predictions derived from noncooperative game theory are given considerable measure of support in situations that most closely approximate a barren institutional setting involving no capacity to make binding agreements as well as no capacity to commu-

\(^{11}\) We are indebted to Vincent Ostrom for his persistent stress on these universal types of sharing principles. In chapter 4, we use several of these sharing principles as allocation rules and examine what difference they make in the structure of an assignment rule. Specifically, we compare a first in time, first in right, a priori announcement, and a rotation system with the default condition that fishers are permitted to take any amount of fish they would like.

\(^{12}\) In experiments where asymmetric endowments were distributed randomly or using an auction mechanism, Hackett, Schlager, and Walker (1993) found that subjects chose and successfully maintained allocation rules that were consistent with approximate rent maximization. In the treatment design in which token endowments were allocated randomly, subjects most frequently adopted rules that called for equal withdrawal. In the treatment design in which larger token endowments were purchased through an auction mechanism, subjects explicitly sought to adopt rules to achieve maximum rents and equalize payoffs net of auction prices.
nicate. Even in these environments, however, behavior at an individual level does not conform to theoretical predictions and does not appear to settle down to an equilibrium. The type of pulsing behavior that we observe is not predicted by any variant of noncooperative game theory. We do, however, find behavioral regularities that can initially be explained as a consequence of the type of heuristics that players adopt in these situations.

We now turn more overtly to the relationship of institutional variables to an explanation of the level of cooperation found in CPR dilemmas and begin to explore how these findings are related to the effect of rules on games. In the laboratory setting, the rules that govern situations are largely preset by the experimenters. Different experimental designs can be viewed as the imposition of different sets of rules or institutional arrangements. In our baseline experiments, for example, subjects were told that they could not verbally communicate and that the game would end if they tried to verbally communicate. In our one-shot communication experiments, subjects were told they had one and only one opportunity to communicate. The instructions given to the subjects and the way the experiments were programmed were, in essence, the rules of the game. In a one-shot communication experiment, subjects could develop a sharing agreement, but had no way to develop sanctioning mechanisms. In repeated communication experiments, subjects could agree on a sharing rule and could also use jawboning as a crude method of sanctioning those who did not keep to an agreement. Jawboning is most successful when most individuals want to cooperate—so long as others do. Jawboning alone is not very effective against those who do not care what others think. In most of our experiments, subjects were not given the opportunity to devise sanctioning mechanisms to be used against those who did not rely on measured responses.

In two experimental designs, however, subjects were given an opportunity to decide upon the fundamental rules they would use in organizing a future series of decision rounds. In one series, they could decide (using majority rule) whether they wanted to provide a communication arena. In the other, they could decide (again, using majority rule) whether they wanted to use a sanctioning mechanism in future rounds and how much they were willing to charge themselves to implement a fine on someone else. Of the three groups presented with the option of providing the communication institution, all three eventually chose the option. Of the six groups who were presented the opportunity to decide whether or not to have a sanctioning mechanism, four decided to change their operating rules and adopt a sanctioning mechanism.

13. For a subject who is interested in earning money, ending the game is a strong punishment. It is also a credible threat given two experimenters in the lab. While we were prepared to stop a game if someone started to communicate, we never had to do so.
ing mechanism. The groups that did opt to change their rules and impose a sanctioning system upon themselves were able to achieve the highest average net yield (93 percent) of all experimental groups facing the high-endowment situation. These groups used their one-shot communication opportunity to agree to a well-defined set of investments and backed this agreement with an agreed-upon sanctioning system.

The results from these experimental designs replicate a core part of our essential findings from the field. When substantial benefits can be gained by arriving at a joint plan of action for a series of future interactions, individuals may have in their repertoire of heuristics simple sharing rules to propose, backed up by a presumption that others will use something like a measured response. If in addition, individuals have learned how a monitoring and sanctioning system enhances the likelihood that agreements will be sustained, they are capable of setting up and operating their own enforcement mechanism. It is now time to turn to a discussion of our findings from the field.