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UNIVERSITY OF CALIFORNIA
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The Social Psychophysics of Cooperation in Groups

A Dissertation submitted in partial satisfaction of
the requirements for the degree of

Doctor of Philosophy

in

Psychology

by

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December, 1998

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ACKNOWLEDGMENT

Although a number of people are responsible for whatever merit is to be found in this work, my most profound debt is to my parents, Stan and Nina Kurzban, for, in a very real sense, everything that is my world.

DEDICATION

This work is dedicated to the men and women throughout our species' brief history who have fought and died that others might live free.

VITA

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Evolutionary Psychology
Coalitional Psychology/Group Behavior
Experimental Economics/Game Theory
Categorization
Spatial Cognition
Object Recognition

ABSTRACT

A consistent finding in experimental economics games is that players cooperate with one another more than would be predicted by a standard game theoretical analysis. One approach to understanding when and why players cooperate in these games is to consider the adaptive problems faced by human ancestors and the systems designed to solve these problems. This analysis suggests that these systems should be sensitive to particular features of the environment that activate decision rules that cause one to incur costs to benefit one's group. It is hypothesized that due to the extremely computationally complex problems associated with coordinating the actions of multiple individuals, these systems might be sensitive to cues that indicate that one is able to coordinate with other members of a group. Further, because the demands of "real-time" coordination are particularly strong for hunting and warfare, activities thought to have been predominantly in the domain of males, males might be more likely to be affected by the presence of these cues. Two experiments were conducted to test these hypotheses. In these studies, subjects in a public goods game were induced to engage in behaviors that were hypothesized to activate systems designed to detect the ability to coordinate. In particular, subjects matched eyegazes with one another, touched one another gently, and tapped out rhythms in synchrony. Contributions in these conditions were compared to contributions in a baseline condition as well as a condition in which communication was allowed, but only

through a virtual "chat room" generated on computers. Results indicated that matching eyegazes and touching one another did increase rates of contributions to the public good for male but not female subjects. Counter to hypotheses, the rhythm manipulation had no effect, and communication over the computer network did increase contributions for male but not female subjects. It is suggested that considering the nature of the adaptations for solving both the free rider problem and the coordination problem represents a potentially valuable direction for future research.

The Social Psychophysics of Cooperation in Groups

We share the same biology, regardless of ideology.

-- Sting, 1985

The Question of Altruism in Biology

To a casual observer it may seem as though economists and biologists have been obsessed with explaining the existence of cooperation for the last several decades At first, this might seem puzzling, since it is not obvious that cooperation needs any explanation. After all, it seems like a natural and common part of the world. However, to both biologists and economists, cooperation has represented an important puzzle, its existence seemingly in conflict with the principles underlying each discipline.

Trivers (1971), based on a discussion in Williams (1966), gave an early and classic account of the nature of the problem facing evolutionary biologists. He was looking not at cooperation per se, but altruism, which he defined (after Hamilton, 1964) as "behavior that benefits another organism, not closely related, while being apparently detrimental to the organism performing the behavior, benefit and detriment being defined in terms of contribution to inclusive fitness" (p. 35).[1] Given this definition, it is easy to see why altruism has been a problem

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[1] Two notes on this definition. First, Trivers included the condition that the organisms not be closely related because Hamilton's (1964) earlier theory of kin

for evolutionary biologists. All other things being equal, an organism that does not behave altruistically will, on average, enjoy greater fitness than one that does. In turn, it follows by the logic of the process of natural selection that genes that code for designs that increase the propensity to engage in altruistic acts will not increase in frequency in a population. The conflict between this logic, which indicates that altruism should not survive the process of natural selection, and observations of seemingly altruistic animal behavior[2] represented the core of the problem for biologists.

Addressing this problem, Trivers (1971) developed a model for how altruistic behavior can evolve, formalizing his account with the principles of game theory using the prisoner's dilemma (PD) (Luce & Raiffa, 1957). The prisoner's

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selection explained how altruistic behavior could evolve when the target of the altruistic behavior was a genetic relative of the organism delivering the benefit. Second, the hedge "apparently" should be eliminated. The problem of altruism does not exist if a behavior is "apparently" detrimental but "really" beneficial. Why Trivers places importance on an observer's construal of the cost of a behavior is an interesting and open psychological question, but is well beyond the scope of this discussion.

[2] Trivers (1971) points to symbiotic cleaning in fish and warning calls in birds as examples of altruism.

	C	D
C	5, 5	0, 8
D	8, 0	3, 3

Figure 1. Payoff structure for the Prisoner's Dilemma. Payoffs are listed Row, Column.

dilemma models a situation in which two individuals have the (symmetrical and simultaneous) opportunity to benefit one another at a cost to themselves. This situation can be thought of as one in which each organism faces a choice between cooperating (C) and defecting (D), where cooperating is interpreted as incurring a cost to benefit the other organism, and defecting is interpreted as choosing not to benefit the other organism. Each organism, or "player," receives a payoff depending on their own as well as the other individual's choice (see Figure 1). In the prisoner's dilemma, regardless of what the other player does, each individual always receives a better payoff by defecting than by cooperating. However, both are better off if both cooperate than if both defect. This is known as the "free rider" problem, and it represents a significant barrier to the evolution of cooperation. This analysis indicates that to the extent that the prisoner's dilemma models situations found in nature, organisms should be expected to defect, or refuse to be altruistic, on all such occasions.

However, this logic only applies if the players of the game interact for just a single round. Drawing on insights from developments in economic game theory on the nature of repeated games (Luce & Raiffa, 1957; Rapoport & Chammah, 1965), Trivers (1971) demonstrated that if organisms engaged in iterated interactions with a PD structure, under certain conditions those that behaved cooperatively with one another could be at a selective advantage relative to those that only defected. This model centered on the idea that decision rules that cause an organism to act altruistically – i.e., to incur costs in the process of benefiting others – can be selected for if there is a sufficiently high probability that these acts of "altruism" will be reciprocated. This idea formed the basis for Trivers' claim that this process of "reciprocal altruism" provides a route to the evolution of cooperation. Subsequent to Trivers, a number of researchers extended this approach, continuing to use game theory as a model for the evolution of cooperative strategies (Axelrod, 1984, 1986; Axelrod & Hamilton, 1981; Maynard Smith, 1982). Theoretical work was supplemented by the use of computer simulations in which the agents played repeated games such as the prisoner's dilemma (Axelrod, 1984). These agents were construed as organisms that contained genes that embodied particular strategies. A population consisted of a set of frequencies of genes with these strategies. The agents in each "generation" played games with one another in the model environment, and the frequency of each strategy in subsequent generations was a function of the payoffs that those strategies received in their interactions.

In this way, successful strategies – i.e., ones that received payoffs higher than those of other strategies – became more frequent. By letting populations play games across many generations, successful strategies could be distinguished from less successful ones. This approach provided a powerful tool for determining what types of strategies could compete well with others in particular kinds of game theoretic environments. The result of this body of work is that the free rider problem has, at least in part, been solved, and it is now well understood how genes that code for mechanisms that deliver benefits to others at a cost to themselves can nonetheless be selected for.

From Altruism to Cooperation

While Trivers wanted to understand the evolution of altruism, he nonetheless maintained the terminology of the prisoner's dilemma (Luce & Raiffa, 1957), labeling the decision to deliver benefits at a cost to the self as "cooperative" rather than altruistic. Looking again at Figure 1, consider what "Cooperation" means. In terms of payoffs, a C move means that the player incurs a cost of three units to benefit the other player by five units, regardless of what the other player does.[3] If the Row player chooses C and the Column player chooses

[3] This is true for the payoffs in Figure 1, but it is possible to assign payoffs such that the formal properties of the prisoner's dilemma are maintained but the magnitude of the costs incurred and the benefits delivered change depending on the other players' choice. This is irrelevant to the present discussion, because as

D, it is true that Row has benefited Column, but it seems dubious to say that Row has *cooperated* with Column. Column has done nothing more than passively accept the benefits conferred by Row.

Cooperation, at least intuitively, should refer to joint efforts to achieve a common goal. If agent A does some act X and is better off, and agent B does some act Y and is better off, this is not cooperation; A and B must interact in some way. So, cooperation can be defined as *coordinated action by multiple agents for the purpose of realizing a goal (or state of the world) that results in benefits to the agents engaging in the action.* Note two important features of this definition. First, it includes the idea that the action of the two parties be coordinated. This excludes cases of "unilateral" altruism. Second, it omits the idea that there must be a cost incurred by the acting agents. The reason for this is that the definition of cooperation should capture cases in which two agents can mutually benefit one another without either one needing to incur a cost to do so (Tooby & Cosmides, 1996).

For example, Tooby and Cosmides (1996) in their discussion of "engagement models" pointed out a pathway whereby adaptations for conferring benefits on others can evolve that takes advantage of the fact that by

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long as the prisoner's dilemma structure is in place, a C choice delivers benefits to the other player at a cost to self.

accomplishing their own goals, organisms generate a vast array of "externalities," outcomes that are the result of a mechanism's function that are incidental to the performance of that function (analogous to "by-products" in the language of evolutionary biology). The generation of externalities is a consequence of the interrelationships inherent in any complex ecosystem (or social system). By virtue of any biological design's normal activities, it makes a number of changes to the world that are relevant (positively or negatively) to other sets of genes' interests (probability of replication). Crucially, there are any number of ways in which any particular task can be accomplished, many of which might be functionally equivalent for the behaving organism. Of course, performing a task in one way as opposed to another will generate a different set of externalities.

Imagine that there is some task that organism A needs to carry out. Further suppose that because of the associated externalities, some ways that organism A might accomplish the task would be better than others (with respect to fitness outcomes) for some organism B. If organism B could develop a system such that it contingently rewarded organism A for operating in one of the ways that benefited it as opposed to one of the ways that hurt it, by the same logic as reciprocal altruism, selection could favor a systematic switch on the part of organism A to perform the task so that it received the contingent benefit. In this way, organism A has delivered benefits to organism B and incurred no costs in doing so.

Game Theory and Economic Predictions of Human Behavior

Reciprocal altruism, kin selection, and engagement models have helped to solve the problem of altruism and cooperation in evolutionary biology. However, in the same way that biologists have been forced to grapple with the existence of altruism and cooperation, economists have had to do so as well, and for similar reasons. Where biologists used game theory to consider the evolution of strategies embodied by genes, economists have typically envisioned the agents in game theoretical accounts to be humans.[4] The analysis, and therefore the problem, remains largely unchanged.

Consider applying game theory to human decision-making in the context of a one-move prisoner's dilemma game. The game theoretical prediction is identical to the prediction in the context of evolutionary biology: everyone will defect because each agent does best in the one-move prisoner's dilemma by choosing D, the *equilibrium* strategy.[5] To the extent that humans do not choose equilibrium strategies, modeling people as game theoretic rational actors is

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[4] Indeed, game theory was designed to model human economic behavior, even though it has proven invaluable in evolutionary biology (Maynard Smith, 1982).

[5] An equilibrium strategy is one such that an agent can not do any better by switching to a different strategy, assuming that all other agents are similarly playing their own best strategy.

problematic. There is a great deal of evidence that people do indeed often deviate from equilibrium behavior.

In the real world, people face the same decision as a hypothetical player in a one-shot game with some frequency. For instance, when a traveling restaurant patron must decide whether or not to tip the server, they are in a situation in which they can choose to be altruistic (choose to tip) or defect (leave no tip).[6] Assuming the patron prefers having more money to less money (an assumption generally made by economists,[7] and one which seems to be extremely good), the patron should choose not to tip, keeping the money for him or herself.[8] This prediction is, of course, at odds with what is actually observed. Not only do people tip, but they also routinely choose to donate their time or money to charity, support public radio, and engage in a wide variety of other acts counter to their game theoretic best financial move (e.g., Andreoni, 1995).

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[6] I add that the patron be traveling because a patron who is a "regular" can be construed as being in a multi-round game.

[7] To clarify, this assumption is applied to all agents in an economy, not just restaurant patrons.

[8] Hereafter I use the male pronoun for brevity, as well as to avoid awkward constructions, of which this is one.

This discrepancy between the game theoretic prediction and observed behavior is obtained in the more controlled setting of the economics laboratory as well (e.g., Hoffman, McCabe, & Smith, 1996). In addition to the prisoner's dilemma, a number of games have been used to test game theoretical predictions of human behavior. One popular game has been the so-called "ultimatum" game. In this game, a prize (often cash) is to be divided between two subjects. One subject, the "proposer," is instructed to suggest a division of the prize between the two subjects. The other subject, the "responder," can either accept the proposal, in which case the prize is divided as the proposer has selected, or can reject the proposal, in which case both subjects receive nothing. It is easy to show that the equilibrium outcome is for the proposer to offer the responder only the smallest fraction of the prize and for the responder to accept the offer.[9] This is because the responder, faced with a vastly unequal proposal, still does better by accepting the proposal; accepting results in at least a small payoff for himself whereas declining leaves the responder with nothing. The proposer, reasoning backward from the responder's choice, can assume that any non-zero offer will be accepted and is therefore best off proposing to keep the lion's share of the prize for himself.

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[9] If the proposer offers zero, the responder should be indifferent between accepting and rejecting, and so select an option at random. This is why the proposer should offer the smallest unit of account, rather than zero.

In contrast to the equilibrium prediction, proposers routinely offer more than the smallest possible unit (Bolton & Zwick, 1995; Güth, 1995; Güth & Tietz, 1986; Hoffman, McCabe, Shachat, & Smith, 1994; Hoffman, McCabe, & Smith, 1995, 1996; Suleiman, 1996). For example, in Güth, Schmittberger and Schwarze's (1982) studies, proposers offered on average 35% of the prize to the responder, keeping only 65% for themselves. More recently, Weg and Smith (1993) have obtained similar results, with proposers offering between 36% and 45% of the prize, depending on the experimental condition. Perhaps even more surprising, responders occasionally reject positive offers, accepting a payoff of zero instead of something.

Results similarly incompatible with game theory are obtained in what are referred to as "extensive form bargaining" games. In these experiments, subjects are presented with a decision tree consisting of decision nodes and payoffs. Players alternately make decisions at each node, and each player's payoff depends on the final node reached. These games are similar to a prisoner's dilemma game in the sense that there is often a non-cooperative equilibrium (analogous to the D-D box in the prisoner's dilemma matrix). That is, if each subject chooses at each node to maximize his payoff, and knows that the other will play similarly, both will be worse off than if each player made more cooperative choices. The game theoretic prediction is that players will move along the pathway to the non-cooperative equilibrium payoff, even though there is another path on the tree that leads to a Pareto superior outcome.[10]

As in the ultimatum game, results are at odds with this prediction (Hoffman, McCabe, & Smith, 1995; McCabe, Rassenti, & Smith, 1998; Rutherford, Kurzban, Tooby, & Cosmides, 1997). For example, McCabe, Rassenti, and Smith (1996) found that people made cooperative moves that left them vulnerable to exploitation (and therefore a smaller payoff) if the other player made his best response to these moves. In addition, they found that people often failed to exploit cooperative moves made by others. In general, these results support the conclusion that people make more cooperative moves than would be predicted by game theory.[11]

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[10] A Pareto improvement occurs when an allocation or outcome is changed so that at least one agent has an increase in payoff by virtue of the reallocation, while no agent is any worse off.

[11] This is technically only true on the purest form of *non-cooperative* game theory. Because players that "trust" other players and move toward the Pareto superior outcome at the risk of exploitation actually do better (that is, leave the experiment with more money) than those who don't (since the desired outcome is actually often reached), it is odd to say that these decisions are "irrational." If players' knowledge of human nature is taken into account, and it is assumed that players

Evidence from the ultimatum game and the extensive form bargaining game suggests that pure game theoretic principles are inadequate to predict actual human behavior in economic games and illustrates why economists are concerned with the prevalence of cooperation. Note that reciprocal altruism does not solve the problem for economists in the way that it does for biologists for a number of reasons, including the fact that games are often one-shot, leaving no possibility of reciprocity.

The ultimatum game and the extensive form bargaining game have been used to look at cooperation in the context of dyadic interactions, and nicely illustrate how there is "too much" cooperation in the context of traditional game theory. However, because my focus is on interactions with more than two individuals, it is important to look in some detail at the experimental literature investigating cooperation in groups.

Public Goods: A Review

Overview of public goods experiments. By far the most common paradigm for studying issues of cooperation in groups is the public goods game. As defined by economists, a public good is a good or service that has two essential

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use this knowledge to update their priors, there is a sense in which these results are consistent with a game theoretical account that incorporates knowledge that subjects bring to the lab.

properties. First, the good must be non-rivalrous,[12] meaning that the consumption of the good by one agent does not decrease the amount that other agents may consume the good. Second, the good must be non-excludable, meaning that once the good is produced, it is not possible (or perhaps practical) to exclude others from enjoying it. These "others" would include, of course, those who did not contribute to the good's production. Because rational choice models predict that people should be unwilling to "pay" for public goods (since they can enjoy their benefits without paying their cost), the fact that people are willing to do so (and, therefore, cooperating) has made public good provisioning an important research question, and one relatively well-suited to experimental exploration.

In a typical experiment, a small number of subjects, generally three to six, are brought into a laboratory and seated in individual cubicles. They are each told that they will be given an allocation of tokens (an endowment) and that these tokens are worth actual cash. They are further told that they will be given an opportunity (or multiple opportunities) to put these tokens into one of two accounts, the "personal account," and the "joint (or public) account." Subjects are instructed that for each token they place in the personal account, they will receive the value of that token at the end of the experiment. However, each token they contribute to the joint account will increase in value according to the interest rate

[12] The term "jointness of supply" is also used for this concept.

(always positive), the resulting sum distributed equally (in most experiments) among all subjects.

Across all variants of the public goods game, a subject maximizes his payoff by contributing zero to the joint account and putting his total endowment in the personal account (this is the equilibrium outcome).[13] Of course, if everyone were to contribute his endowment to the joint account, all would be better off than if everyone contributed their endowment to the personal account. That is, a rational choice model predicts that people will contribute everything to the personal account, thus failing to achieve the efficient outcome. So, the extent to which individuals are cooperating with one another can be indexed by the number of tokens contributed to the joint account.

A description of a public goods experiment requires the specification of a number of important parameters. These include: 1) the number of players, 2) the players' sex, 3) the social context (face-to-face, over computer terminals, etc.), 4) the players' endowments, and whether endowments are equal for all players, 5) the presence and form of communication, 6) the amount of information about others' endowments and/or decisions that players have access to, 7) the interest

[13] This is true for the games as described here. When the public good is "step-level," as described below, games may have complex equilibria, or no equilibrium.

rate in the public account and the rules for the provisioning of the public good, and 8) the number of iterations of the game and if this number is known to players (adapted from Ledyard, 1996).

Parameter seven, the interest rate, requires some additional comment. The interest rate directly affects the incentive for defection (i.e., contributing to the private account). If, for example, there are six subjects, and tokens in the joint account are doubled (100% interest rate), then for each token a subject puts in the joint account, that subject receives the value of one third of a token (1 token, doubled, divided by six subjects). This number is referred to as the marginal per capita return (MPCR) (Isaac, Walker, & Thomas, 1984) and is an index of the incentive to behave selfishly. The lower the MPCR, the larger the incentive to defect.

Second, the rule for provisioning the good can either be continuous or discrete. A continuous good is provisioned as described above. For a discrete good, also referred to as a "step-level" good (Rapoport, 1988), the public good is like a bonus, conferred only if some minimum threshold of aggregate contributions to the public account is reached. If this threshold is not reached, the good is not provided, and any contributions to the good are lost.[14] This distinction

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[14] A bridge that reaches 90% of the way across a river is a real life example of a step-level good that was not quite provisioned.

is important, because it can change the incentive structures for cooperation, sometimes in complex ways (Marwell & Ames, 1980). So, for example, if a player has information that their contribution to the public account is both necessary and sufficient to provision the public good, their rational choice will be to contribute (assuming the bonus from the public good is larger than their endowment).

In general, as with the ultimatum and extensive form bargaining games, results in public goods games are at odds with the game theoretical prediction. Depending on the experiment, contributions range from zero (equilibrium play) in later rounds of some games (Isaac, McCue, & Plott, 1985) to 90% or more in others (Yamagishi, 1986). In a typical ten-round game, contributions begin at roughly 50% and drop off over time toward zero. No doubt because these results are so discrepant from the game theoretical prediction, there has been a vast amount of research on the public goods game.

It is possible to classify the perspectives of researchers who have tried to explain the over-provisioning of public goods into four general categories of theories. The first is *classical game theory*, which holds that contribution decisions are based on calculation of monetary benefits to the players. These models are essentially rational choice theories, and point to changes in the cost/benefit structure of the game as mediating variables in subjects' decisions. The second is *expectation models*, which hold that subjects' decisions are based on what they expect other subjects to do. A third set of models can be roughly classified as *social psychological* ones, in which social factors such as one's identification with a group play important roles in contribution decisions. A fourth and last perspective is one based on *individual differences*. This approach attempts to account for variance in public good provisioning based on differences between subjects.[15]

Note that there is a significant amount of overlap among these theories. That is, two different theories may make roughly the same prediction in certain experiments. Indeed, in some instances, researchers using different theories manipulate the same independent variable as part of a test of different hypotheses. For example, many experiments use communication as an important independent variable. On theories about expectations, communication can be relevant because

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[15] There is a possible fifth perspective, one that emphasizes "fear" and "greed" as key theoretical components (see e.g., Insko et al., 1990). This typically means that a player might expect that others might not contribute, and therefore "fear" that they will be exploited, and so choose not to contribute, or that a player might expect that others will contribute, and therefore, due to "greed," choose not to contribute in order to reap the benefits of free riding. I do not treat this as a separate theory, but do discuss the results of experiments motivated from this perspective in the context of this four-part classification.

it might change expectations though promises or pledges. However, social identity theory (Tajfel & Turner, 1986), a social psychological account, might similarly predict that communication will increase contribution, but because it enhances the extent to which a subject comes to identify with a group. Although multiple theories make similar predictions (a problem hardly unique to the PG literature), it is still possible to make meaningful distinctions among the various approaches.

Pure game theoretic accounts. By "pure game theoretic accounts," I mean models that assume that (1) all players are rational, (2) every player assumes that all other players are rational, and (3) each player's interests lie only in the monetary outcomes. These theories have a large obstacle to overcome: they must be able to account for the sizable contribution to public goods in a vast number of experiments because the game theoretic equilibrium outcome prediction for these games is that contributions should be zero for all subjects. This type of account generates two distinct hypotheses with concurrent predictions: 1) Contribution in public goods games are due to confusion on the part of the subjects. As subjects learn about the game, they will converge on equilibrium play. 2) Contributions in public goods games are sensitive to the cost/benefit parameters of the game. As the incentive to defect increases, contributions will decrease. Similarly, as information becomes available that contribution will lead to higher payoffs for a player than withholding contribution, rates of provisioning the public good will increase.

Proponents of he first hypothesis have argued that to the extent that subjects do not fully understand the public goods games, the rational choice model does not apply. On this line of reasoning, if every player understood the game, they would contribute zero tokens. Andreoni (1995) argues confusion is more likely to drive results off of the equilibrium prediction in the public goods game than in other games. Because the equilibrium outcome of public goods studies is zero contributions, the only way that subjects can make an error is to over-contribute. Thus, unlike games in which interior equilibria exist, in the public goods game, aggregate errors will look extreme, rather than averaging out to the equilibrium outcome.

Andreoni (1995) designed an experiment to distinguish the hypothesis that contributions in public goods games were due to confusion from the hypothesis that these contributions were due to "kindness."[16] To do this, he compared results in a standard 10-round public goods game with results in a game in which the aggregate group monetary payments were fixed and each person's share of this fixed amount depended only on their ordinal position when the payoffs to all the players were ranked. Under this condition, contributing to the public good is no

[16] This is the term that Andreoni (1995) uses.

longer “cooperating” – the aggregate group benefit is fixed, and so there can be no Pareto improvement in aggregate benefits. Contributions in this condition are purely altruistic, benefiting others at a cost to the self.

Andreoni takes this condition to remove the potential for kindness, leaving confusion as the only possible explanation for contributions. He acknowledges, however, that pure altruistic motives would still lead to contributions. Contributions in this condition started at 32.7% and declined to 5.4% in round ten, compared with the standard condition, in which contributions started at 56.0% and declined to 26.5%. From these data, Andreoni (1995) concludes that “kindness and confusion are *equally important* in generating cooperative moves in public goods experiments” (p. 14, emphasis added).

This conclusion might be somewhat premature. The results obtained suggest that in the modified version of the public goods games, subjects contribute even when these contributions are not “cooperative” in the traditional sense, but rather altruistic. Whether this is due to confusion or altruism can not be determined. Indeed, verbal protocols indicate that very few subjects (at least at the end of the study) failed to understand the incentive structure, implicating altruism rather than confusion. In addition, it may be that the modified game is in fact harder to understand because of the pragmatics of experiments. In a traditional public goods game, the subject is faced with a trade-off between the group interest in aggregate and individual interests, something that is likely easily understood. In the modified version, the trade-off is between individual interests and the aggregate of *everyone else's* interests, a very different type of dilemma, one which it is possible that subjects do not expect to be faced with, possibly making it harder to understand. In any case, this result does not necessarily speak at all to the extent to which contributions in the conventional public goods game are due to confusion.

If confusion is a major factor in these studies, then we should expect to find that contributions tend to decrease over the course of repeated rounds as subjects learn what optimal play is (Davis & Holt, 1993). Such a result would not necessarily mean that learning was responsible for decreasing contributions, but if it were not the case, this would damage the learning/confusion hypothesis. Indeed, across a wide variety of experiments, contributions do decrease over time (e.g., Andreoni, 1988, 1995; Isaac & Walker, 1988; Rapoport, 1988; Wilson & Sell, 1997).

Bornstein, Erev and Goren (1994) lend additional credence to the learning interpretation by comparing results from two different public goods style games. In one of these games, the equilibrium was for subjects not to contribute anything, as is the case in the standard public goods game. In a second condition, there were two symmetrical internal (mixed-strategy) equilibria.[17] Over the course of 20 rounds, subjects' average contributions between the two games diverged, suggesting that subjects were learning rather than playing reciprocal strategies, which would make average contributions between games converge. The authors take this as evidence for a behaviorist-like learning model, and reject the hypothesis that decisions in these games are a function of outcomes in previous rounds.

However, there is reason to question the learning account. First, there is evidence that even when play converges to the equilibrium in public goods games (no contributions), subjects have not necessarily "learned" that the equilibrium strategy is the best one to play – indeed, when subjects start a new set of rounds in the public goods game having "learned" equilibrium play in the previous set of rounds, subjects often return to non-equilibrium play (Andreoni, 1988; Isaac & Walker, 1988). Additionally, Marwell and Ames (1980) found that experienced players in their public goods game played similarly to those who were inexperienced. Note that they considered "experienced" players to be ones that had participated in an earlier study, which was only a one-shot public goods game.

[17] A "mixed strategy" equilibrium means that the best play is a probability distribution, rather than a particular single move every time, which is referred to as a "pure strategy."

In contrast, Isaac, Walker, and Thomas (1984) used experienced subjects who had played considerably more than just one round, and found more profound differences in their comparison of experienced and inexperienced players. Lastly, studies in which high levels of contributions are maintained are not unknown, and are particularly problematic for a confusion/learning approach (see, e.g., Sell, 1997, and Yamagishi, 1986, the "high sanctioning" condition).

Game theoretic models also predict that subjects' contribution decisions will change if the structural incentives change (Komorita, 1976; Rapoport, 1967). Rapoport (1988) formalizes this idea in his model of the provision of step-level goods. His model says that a player *i*'s decision to contribute will be a positive linear function of the magnitude of the public good (if provided) multiplied by the subjective probability that player *i*'s contribution will be critical to the public good, and a negative linear function of the player's endowment (the "cost" of contributing). He provides support for this model, showing that players' contributions are related to their reported estimation of the probability that their contribution will be critical to the production of the good. It is interesting to note that Rapoport includes a parameter in his model that is an index of the player's altruism. He concludes that such a parameter is important to the model, but makes no effort to explore it.

There is a significant amount of evidence to support Rapoport's claim that contribution decisions are mediated by the parameters in his model that represent the structural features of the game environment. For instance, players in N-person prisoner's dilemma games[18] are responsive to incentives, cooperating more as the reward for mutual cooperation increases relative to the reward for defection (Komorita, Chan, & Parks, 1993; Komorita & Ellis, 1995; Komorita, Sweeney, & Kravitz, 1980)

Similarly, Isaac and Walker (1988) demonstrated that subjects were sensitive to the MPCR, contributing more as the cost of doing so decreased. Lastly, Marwell and Ames (1979) found support for what can be considered a degenerate case of Rapoport's model – when one player can contribute enough to be certain the provisioning threshold is reached. Under these circumstances, Rapoport's model predicts that this player will contribute,[19] a prediction borne out by the data. However, interestingly, other players in these groups also contribute

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[18] An N-player prisoner's dilemma game gives N players a binary choice between defecting and cooperating. The payoffs are structured so that each player is in essence playing a normal PD game with the other N-1 players simultaneously, but forced to make the same move in each game. The game is basically a binary choice public goods game with a continuous public good.

[19] This makes the player's subjective probability one, presumably, and therefore predicts that as long as the public good benefit is larger than the player's endowment and the altruism parameter is non-negative, the player will contribute.

to the public good, a finding difficult for a game theoretic account and Rapoport's model: these players should expect that the player with the large endowment will provision the good regardless of what the other players do, making the probability that their contributions will be critical zero.

Players' optimal strategies can also be changed in situations in which the experimenter provides a mechanism to bind players to pledged contributions. Consider the experimental conditions used by Chen and Komorita (1994). In these experiments, during an initial phase of the game, all subjects submitted a pledge (some fraction of their endowment) to contribute. In some conditions, the average pledged contribution was binding on all subjects. It is easy to show that with this mechanism in place, pledging the maximum possible contribution is a player's optimal strategy.[20] Indeed, in Chen and Komorita's three conditions in which pledges were binding and applied to all group members equally, contributions were very high, ranging from 51% to 73%,[21] a finding replicated by Chen (1996). Note that in the single condition in which each player's pledge

[20] In essence, pledges are extracting contributions from other players at a rate that exceeds the cost to the player of the contribution required by the pledge.

[21] This of course creates another problem for a pure game theoretic account: why don't players pledge 100%?

applied to only them and not the rest of the group, contributions were quite low (36%), a finding not terribly discrepant with rational choice predictions.

Pure game theoretic accounts also predict that players' decisions will vary as a function of the information available to them in the game. From the standpoint of game theory, information about others' moves should be divided into two types: certain and uncertain. Information that is certain is information that is reliable, and cannot be wrong in the context of the game. So, for example, in some experiments, before deciding whether or not to contribute, a player might receive information from the experimenter about how much a good has previously been provisioned. Even though this may be faked feedback, it is still certain in the sense that it can be taken as true for purposes of decision making. Similarly, if players make pledges that are enforced by the experimenter, this information should also be considered to be certain. To a close approximation, only information that is certain should affect play decisions.[22]

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[22] The "close approximation" hedge here is due to the fact that information that is less than certain can still update one's priors (Lopes, 1994), which can in turn change optimal play. Because the game theoretical prediction is clear in cases of certain information, I deal only with certain information in this section. A treatment of uncertain information effects is below in the subsection on player expectations.

Two situations in which the information structure should dictate changes in strategies have been extensively examined. The first is repeated games in which players do not know when the last game of repeated play will be (Chen & Komorita, 1994; Komorita, Chan, & Parks, 1993; Rapoport, 1990; Wilson & Sell, 1997). In this case, the Folk Theorem applies, and no game theoretic prediction can be made about the level of cooperation.[23] In a very weak sense then, we should expect more cooperation under these conditions than in the case where the game theoretic prediction is for zero contributions. There is not a great deal of support for this idea, and indeed, in Chen and Komorita's (1994) studies, in which the final round was unknown, contributions in two of their six conditions across two experiments were around 30%, quite low compared to other public goods experiments. In general, there does not seem to be evidence in any experiment that the existence of unknown endpoints increases contributions.

The second case in which information can change the game theoretic structure is games with provision points (or step-level games), in which knowing the contributions of others can change one's best play. If, by contributing, one

[23] The Folk Theorem says that there are an unrestricted set of equilibria in games with no known endpoints as long as certain other conditions are met, including that players place some value on future outcomes (Fundemberg & Maskin, 1986; see also Rasmusen, 1989, for a brief treatment).

can push total contributions over a threshold, contributing to the public good can become one's best move, an idea referred to as "criticality" (see, for example, Chen, Au, & Komorita, 1996; Sell, 1997; van de Kragt, Orbell, & Dawes, 1983). Partial evidence for the importance of criticality comes from experiments in which continuous games are compared with step-level games. In this case, the game theoretic prediction is that there should be more contributions in some step-level games, since players should rationally contribute if they believe that their contribution is necessary and sufficient to provisioning the good, a prediction borne out empirically (Bornstein, 1992, Experiment 1). Chen, Au, and Komorita (1996) also found that contributions increased in cases in which players had certain information that their contribution was either necessary or sufficient to provision a step-level good. These researchers found a direct correlation between subjects' perceptions that their contribution was critical and subjects' actual contribution decisions. In general, it does appear that "criticality" can play a role in mediating players' decisions under particular circumstances (but see Rapoport & Bornstein, 1989, and Rapoport, Bornstein, & Erev, 1989, for some counter-evidence).

Taken together, these data suggest that subjects are indeed sensitive to game theoretical parameters across a variety of experiments. Game theoretical principles seem to account for a large body of data under certain prescribed conditions, particularly when a mechanism for enforcing pledges is in place and when a player is able to detect that his contribution is necessary and sufficient to provision a step-level good (see Olson, 1965). The role of the Folk Theorem seems slight, while changes in the incentive structure, especially the size of the benefit of the public good with respect to the cost of contributing, seem to have important effects.

Expectation models. A second kind of model applied to public goods games holds that contributions are a function of players' expectations about other players' contribution decisions. Indeed, the relevance of the expectations of players has been acknowledged practically from the beginning of experiments using experimental games (Braver & Barnett, 1974; Garner & Deutsch, 1974). Note that the expectations in these models are to be distinguished from those discussed above in that these expectations are uncertain.

There are several possible sources of information that directly or indirectly afford inferences about what others' moves are likely to be. This information can be in the form of knowledge about the history of interaction of the players that the subject will be facing, such as what their contributions were in previous rounds if they are playing a multi-round game, or knowledge about how players have interacted in different games with different subjects. In some cases, experiments allow various types of non-binding signals that players can send to indicate their moves on subsequent rounds. However, by far the most popular source of information in the empirical literature is simple conversation among subjects before they make their decisions (Bornstein, 1992; Bornstein, Minglegrin, & Rutte, 1996; Bornstein & Rapoport, 1988; Braver & Wilson, 1984; Chen & Komorita, 1994; Dawes, McTavish, & Shaklee, 1977; Dawes, van de Kragt, & Orbell, 1987; Insko et al., 1993; Isaac & Walker, 1988; Kerr, Garst, Lewandowski, & Harris, 1997; Kerr & Kaufman-Gilliland, 1994; Orbell, van de Kragt, & Dawes, 1988; van de Kragt, Orbell, & Dawes, 1983), known as "cheap talk," referred to as "cheap" because what is said is not binding on the subjects. Expectation theories can loosely be classified into four categories: 1) *goal-expectation* models (Pruitt & Kimmell, 1977); 2) *promise/commitment/pledge* models (e.g., Chen & Komorita, 1994); 3) *signaling* models (e.g., Eckel, 1998); and 4) *norm* models (e.g., Kerr, 1995).

Pruitt and Kimmel (1977) stressed the importance of expectancies more than twenty years ago in their review of the gaming literature and formalized their ideas about its role with their *goal-expectation* (GE) theory. They argued that while wanting to be cooperative was necessary for cooperation to emerge, this desire "must be accompanied by *an expectation that the other will cooperate* either immediately or in response to the actor's cooperation" (Pruitt & Kimmel, 1977, p. 375, emphasis original). Their model is a strategic one in that they see cooperative behavior as a way to further self-interest by inducing other individuals in the game to cooperate. In this sense, their model bears an intriguing resemblance to Trivers' (1971) model of reciprocal altruism.

The clearest prediction of the goal-expectation theory is that peoples' decisions to cooperate will be a function of their expectation that cooperating will induce others to do so. There is some intriguing evidence that this is the case.[24] When playing an iterated prisoner's dilemma game, subjects are more likely to cooperate if they are interacting with (real or simulated) counterparts who are playing a reciprocal strategy like Tit-For-Tat[25] (Komorita, Hilty, & Parks, 1991; Komorita, Parks, & Hulbert, 1992), rather than a strategy that is unresponsive to their plays, even if that strategy is "all cooperate" (Kahn, Hottes, & Davis, 1971; Parks & Vu, 1994 (American but not Vietnamese subjects); but see McClintock & Liebrand, 1998, as well as Bornstein, Erev, & Goren, 1994, for evidence weighing against the importance of reciprocal strategies). Komorita, Chan, and Parks (1993) obtain similar results in a public goods setting, concluding that "at least

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[24] Pruitt and Kimmel (1977) support their model by citing evidence that people are more likely to cooperate if they have information that the person with whom they are playing has cooperated with someone in the past (Braver & Barnett, 1976, cited in Pruitt & Kimmel, 1977). I do not consider this to support their theory per se, since it does not speak to the effect of cooperation on inducing further cooperation, the heart of their argument.

[25] Tit-For-Tat is a strategy that cooperates on the first round, and in subsequent rounds does whatever the other player did on the previous round (Axelrod, 1984).

50% of the group must use a reciprocal strategy to have a significant impact on the other members" (p. 264), although they note that this finding does not hold as groups get larger (see Sell, 1997, for a similar result as well as anecdotal evidence that people are using GE strategies).

Yamagishi (1986) suggests a modification to the goal-expectation approach to try to address what he perceives as weaknesses of the theory. He notes that large groups will be problematic for the GE model because individual acts of cooperation may be difficult to detect, limiting one's ability to induce cooperation among group members (presaging Komorita, Chan, & Parks', 1993, result). His *structural goal-expectation* approach adds the idea that individuals who have the goal of cooperating can generate structures (or institutions) that change incentives so that players' best moves become cooperation. He suggests the provisioning of a sanctioning system as one such mechanism, and demonstrates that when sanctioning is relatively cheap, cooperation can be sustained in a public goods environment. In these studies, groups achieve levels of contribution over 70% (Caldwell, 1976, obtained a similar result, eliciting a cooperation rate of 65%). It should be noted however that in this condition, the punishment mechanism was both intelligent and cheap. It was intelligent in the sense that it monitored contributions perfectly, inflicting punishment only on the lowest provisioner of the public good, and cheap in that each token contributed to the punishment account punished the lowest contributer two tokens. It is difficult to know what to make of such a punishment mechanism and the possibility of instantiating such a mechanism outside of the lab. Yamagishi's findings are suggestive, however, in that they show that players will make use of a punishment system if one is provided.

In sum, there do seem to be indications that players try to induce cooperation through their own cooperative moves in both prisoner's dilemma and public goods games, but the GE model is restricted in its scope: it does not do well in large groups, and it certainly cannot account for findings in one-shot games, where it is impossible to influence players' future moves (examples of experiments with one-shot games include: Bornstein, Mingelgrin, & Rutte, 1996; Bouas & Komorita, 1996; Braver & Wilson, 1986; Dawes, van de Kragt, & Orbell, 1988; Marwell & Ames, 1979, 1980; van de Kragt, Orbell, & Dawes, 1983; Wit & Wilke, 1992).

Other models based on expectancies involve the making of *promises, commitments, or pledges*.[26] Chen and Komorita (1994) speculated that pledges in and of themselves might lead to increased provisioning of public goods. They argued that "a pledge provides information about the intentions of other members and is likely to promote trust and positive attitudes" (p. 372). In their experiment

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[26] I consider here only non-binding pledges. Binding pledges can change the payoff structure of the game, and are discussed above.

testing this hypothesis, subjects in one condition were instructed to indicate how many tokens they would contribute in the subsequent public goods game. So doing in no way bound them to their stated contribution. Contributions in this non-binding pledge condition were no different from those in a condition in which no pledges were allowed, suggesting that, at least in this case, a pledge with no force behind it has no noticeable effect.[27]

Dawes, McTavish, and Shaklee (1977) had earlier speculated in a similar fashion, suggesting that the finding that pre-play communication increased contribution to public goods might stem from the fact that "group members' statements of their own intended decision could assure other members of their good intentions…" (p. 3). Indeed, this work, using a binary[28] public goods game, replicated the finding that pre-play communication enhanced contribution to public goods, increasing the proportion of contributors from 27% to 74% when ten minutes of unrestricted communication were allowed before subjects made their contribution decisions. In an additional condition, subjects were required to

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[27] A finding predicted by Hobbes (1651): "And covenants, without the sword, are but words and of no strength to secure a man at all."

[28] A binary game is one in which players have a choice of contributing their total endowment to the public account or none of it, rather than having a continuous choice.

indicate by a non-binding vote whether or not they were going to contribute. This condition had no significant effect on contribution decisions, casting doubt on the idea that conversation leads to increased cooperation because it makes intentions clear. Similar results have more recently been obtained by Chen (1996), who found that pledges have strong effects only when they were binding at a group level (see discussion above). Indeed, under this group binding pledge condition, in which face to face communication was not permitted, contribution rates were as high as when face to face communication was allowed.

Orbell, van de Kragt, and Dawes (1988) provide slightly more encouraging data with respect to the influence of non-binding pledges. In addition to replicating the finding that allowing discussion increases contribution rates, through an analysis of the discussions among subjects they found that a vast majority of subjects promised to contribute their endowment during the ten-minute discussion phase of the experiment. More importantly, in those (seven-person) groups in which the decision to contribute was unanimous, roughly 90% of these subjects in fact followed through on their non-binding promise (but see Dawes, McTavish, & Shaklee, 1977, Experiment 1, for a case in which unanimous promising was considerably less successful; see also Bornstein, 1992, for evidence against the power of promises). In contrast, in the condition in which promises were not universal and less discussion was allowed, contribution rates were roughly 56%.

A final piece of evidence that adds some weight to the importance of commitments comes from an experiment by van de Kragt, Orbell, and Dawes (1983). In this study, seven subjects were presented with a one-shot public goods problem with a provision point (either three or five contributors necessary), and were either allowed discussion or not. Under these conditions, discussion led to nearly perfect provisioning of the good, with the only deviation from perfect efficiency being the *over*-provisioning of the good. The reason for the success of these groups seems to have been from their designation of the exact number of individuals to provision the good -- what the authors refer to as a "minimal contributing set." If a contributor assumed that the others would follow through on their commitment, their best move was to contribute, leading to the efficacy of the minimal contributing set solution.

Taken together, these results suggest that non-binding pledges are of limited value in solving public goods problems. They do seem to have an effect under two conditions: 1) when pledges are unanimous, although this does not always seem to hold, and 2) when pledges provide information that one's contribution will be "critical" to provisioning the good. The extreme limitations on the efficacy of non-binding pledges call into question both the argument that they play an important role in public good provisioning in general as well as the more specific claim that increases in contributions found in experiments in which conversation is allowed are due to the ability to make non-binding commitments (see Kerr & Kaufman-Gilliland, 1994, for a discussion and similar conclusion).

A third set of theories that suggests that decisions in public goods games depend on expectations emphasizes the role of *signals*. To an economist, signals are pieces of information that decision-makers can use to make inferences about others' future behavior. In a technical sense, signals are a superset of non-binding commitments, pledges, and promises. Psychologically, however, there seem to be important differences between promises and pledges, which connote a contract of some type, and other types of signals that do not seem contractual.

Signaling has typically been studied with respect to its utility in solving the coordination problem in game theoretic contexts, rather than the free rider problem, which is of concern in public goods environments. In games such as "chicken," there is a coordination problem because each player would rather choose the option that the other player does not choose (see Figure 2). Signals, non-binding information that indicates what move a player will make, can be effective in this kind of game (Bornstein, Budescu, & Azmir, 1997; Palfrey & Rosenthal, 1991; Ward, 1990; Wichman, 1970).

	X	Y
X	1, 1	4, 5
Y	5, 4	1, 1

Figure 2. Payoff structure for the Chicken game. Payoffs are listed Row, Column.

The research in public goods areas has shown signaling to be relevant as well. To begin with, there is a great deal of evidence that there is a relationship between peoples' expectation of other players' moves and their own decisions (Allison & Kerr, 1994; Bornstein, 1992; Bornstein & Ben-Yossef, 1994; Dawes, McTavish, & Shaklee, 1977; Komorita, Parks, & Hulbert, 1992; Rapoport, 1992; Wit & Wilke, 1992; Yamagishi & Sato, 1986). The existence of this correlation leaves open the possibility that this relationship is causal, and that contribution decisions are based in part on the expectations of what others will do (although see Dawes, McTavish, & Shaklee, 1977, and Braver & Wilson, 1986, for intriguing arguments that the causality goes the other way), making reputations and other types of signals an important research area.

In some cases, players are allowed to signal their intended plays explicitly through some medium of communication, although this tends to be ineffective if there is no way to enforce these signals (Wilson & Sell, 1997; see also the discussion of promises above). Another type of information available in some experimental contexts is the history of the interaction partners. Allison and Kerr (1994) hypothesized that history played an important role in mediating contribution decisions, proposing that "people will use a group's previous performance outcome in a social dilemma to generate judgments about the group's level of cooperativenes and its likelihood of resolving future social dilemmas successfully" (p. 689). In this case, subjects reported that they thought that previously successful groups were more likely to succeed in the future. Allison and Kerr's (1994) hypothesis was supported by evidence that under certain conditions, contributions increased when subjects were led to believe that the group in which they were making their decision had previously successfully provisioned a public good. Note that when provisioning the good required a small fraction of the subjects to contribute, information about past success actually decreased contributions, a result the authors explain by suggesting that players used this fact as a "justification" to free ride.

In some games, players have information about the history of the players in the form of an update of the amount of contribution in previous rounds. In general, providing this information decreases contributions over time (Andreoni, 1988; Isaac & Walker, 1988; Rapoport, 1988). Wilson and Sell (1997) have recently replicated this result, and shown that giving players no information about contribution in past rounds can lead to better (more efficient) outcomes than providing players with this information, although this does not hold if the information given to players indicates that others have been cooperative in the past (Braver & Barnett, 1974).

In some experiments, information other than a groups' history can act as a signal. Orbell and Dawes (1993) provide an intriguing example. In their study, players were presented with a standard prisoner's dilemma, but, in one condition, players were given the option of not playing the game at all, instead keeping their payment from a previous study (included to ensure that subjects did not end the experiment with a negative total). In this case, it could be that subjects interpreted other subjects' decisions to play instead of withdraw from the game as a signal of their willingness to cooperate. There is some evidence to support this conclusion. The data indicated that those who intended to cooperate were more likely to choose to play the game when they had the option, meaning that the signal of playing had some validity. Additionally, there were more cooperative choices in the condition in which not playing was an option compared to the condition in which subjects were obliged to play the prisoner's dilemma game. Taken together, although these two findings do not support a signaling model directly, they are nonetheless suggestive.

Finally, Eckel and Wilson (1998) have shown another intriguing instance in which signals that are not enforceable nonetheless have an effect. Using a game similar to the "extensive form" game discussed above, they showed that when players were represented by stylized human faces with particular facial expressions, subjects were more likely to make trusting (cooperating) and reciprocating moves. Eckel and Wilson interpret these results as suggesting that the face icons emit reputational signals about the disposition of the players, and that this information mediates player decisions.

To summarize, it appears as though knowledge of a group's history can affect decisions, although this effect can be either positive or negative depending on the nature of the information. In addition, some subtle signals, such as choosing to play (Orbell & Dawes, 1993) and iconic representations of players (Eckel & Wilson, 1998) can have surprising effects.

The last set of models based on expectations emphasizes the role of *norms,* which Kerr (1995) defines as "expectation(s) about how one ought to act, enforced by the threat of sanctions or the promise of reward" (p. 33). This type of theory starts with the idea that people, when faced with dilemmas in public goods experiments (as in life), are uncertain about their choices. As a way to resolve this uncertainty, they look to information from the social environment and draw on their knowledge of societal norms so they can make a decision consistent with social expectations.

There is some evidence that people use the actions of others as a normative guide (Allison & Kerr, 1994; Wit & Wilke, 1998; but see Dawes, van de Kragt, & Obell, 1988) and a small amount of data that are at least consistent with the idea that decisions are mediated by internalized social norms or cultural mores (Alvi, 1998; Fleishman, 1980; Kerr, Garst, Lewandowski, & Harris, 1997; van Dijk & Wilke, 1997). However, it is very difficult to draw any significant conclusions about the role of norms in public goods games as very little work has been done to test hypotheses derived from norm models directly, and additional research is clearly needed to illuminate what role, if any, norms play in economic games (Kerr, 1995).

Social psychology: groups. A number of researchers, mostly from the field of psychology rather than economics, have proposed that behavior in public goods games might in part be a function of the psychology of groups. Much of this work has been motivated by social identity theory (Tajfel, Billig, Bundy, & Flament, 1971; Tajfel & Turner, 1979, 1986; Turner et. al., 1987; Turner, Brown, & Tajfel, 1979; Turner & Giles, 1981). This theory holds that people come to identify with particular groups due to such factors as similarity, proximity, or common fate, and value the status of the group with respect to other relevant groups. In particular, the theory holds that peoples' self-esteem becomes tied to the welfare of the group, and that therefore people will behave in such a way as to further the interests of the group as a whole as a means of maintaining or increasing their own personal and/or collective self-esteem.

In economic terms, social identity can be treated as a variable that increases one's valuations of the (aggregate) outcomes of the other members of one's group, or, on occasion, their outcomes with respect to the outcomes of members of other groups. Manipulations aimed at varying the extent to which individuals identify with groups have had significant impact on the amount of cooperation observed in public goods games. Brewer and Kramer (1986) varied the extent to which members of groups shared a common fate, a hypothesized mediator of group identity, by informing subjects that a lottery would be held to determine the value of the tokens that they would earn during the public goods experiment. In one condition, the group identity condition, they were told that one lottery would determine the whole group's token value, thus giving the subjects a sense of common fate. In another condition, they were told that each person's token value would be determined by a separate coin flip. Brewer and Kramer (1986) found that subjects cooperated more (under certain limiting conditions) when the group identity manipulation was used, a finding replicated by Wit and Wilke (1992), who used a similar procedure. Chen (1996) similarly found that social identity plays some role in eliciting contribution (see also Bouas & Komorita, 1996), but argued that it alone is not sufficient for doing so, a caveat noted by other researchers using a prisoner's dilemma paradigm, rather than a public goods game (Insko et. al., 1987).

It has been argued that communication conditions in public goods games that have been successful in increasing cooperation have their effect because discussion builds social identity, and thereby one's desire for positive collective outcomes, in turn increasing one's contributions to the public good. Dawes, van de Kragt, and Orbell (1988) do show that discussion increases contributions when they benefit other group members but not when contributions benefit strangers, strengthening the hypothesized link between conversation and group identity and weakening claims that conversation clarifies the dilemma or makes available social norms to the subjects.

Building in part on the social identity literature, Bornstein and his colleagues have generated a vast amount of research that implicates conflict between groups as a means of generating public goods within groups (Bornstein & Ben-Yossef, 1994; Bornstein, Budescu, & Zamir, 1997; Bornstein, Mingelgrin, & Rutte, 1996; Bornstein & Rapoport, 1988; Bornstein, Rapoport, Kerpel, & Katz, 1989; Erev, Bornstein, & Galili, 1993; Rapoport & Bornstein, 1989; Rapoport, Bornstein, & Erev, 1989). This approach in essence relies on the presence of an outgroup to increase solidarity within a group and increase the extent to which people are motivated to maximize group outcomes (after Campbell, 1965).

There is now a great deal of evidence that the presence of another group increases within-group cooperative choices compared to the case in which subjects are faced with structurally identical decisions without between-group competition. This occurs even when within-group cooperative choices lead to worse outcomes for all subjects in the aggregate (Bornstein, Budescu, & Zamir, 1997; Bornstein, Rapoport, Kerpel, & Katz, 1989). Both the patterns of results and explicit comments made by subjects suggest that within-group cooperative moves are often motivated by the desire to ensure that one's group enjoys an advantage over the competing group, even at the expense of the magnitude of gains to group members (Bornstein, Mingelgrin, & Rutte, 1996), a finding consistent with other results in the social identity literature (Brewer & Kramer, 1986; Insko et. al., 1987, 1990, 1992).

The results of this research program suggest that the presence of intergroup competition enhances players' regard for the outcome of their group, particularly with respect to a group's outcome relative to another group (see Erev, Bornstein, & Galili, 1993, for a fascinating real-world example of the success of intergroup competition in solving the free-rider problem). Interestingly, intergroup conflict situations also seem to enhance the extent to which individuals follow through on their non-binding pledges of support (Bornstein, Mingelgrin, & Rutte, 1996; Rapoport & Bornstein, 1989; see Chen, 1996, for an argument that social identity can increase promise-keeping even in the absence of an outgroup), suggesting one possible route by which social identity helps to solve the free rider problem in public goods environments. It should be noted, however, that common fate manipulations are not always successful at increasing contributions to public goods (Bouas & Komorita, 1996) and that keeping one's commitment might not be strictly related to social identity (Bouas & Komorita, 1996; Kerr & Kaufman-Gilliland, 1994; Orbell, van de Kragt, & Dawes, 1988).

Individual differences. The last approach taken to try to understand contributions in public goods games, and the one that has received the least amount of empirical attention, is individual differences.[29] From the perspective of pure game theory, individual difference variables should have no effect on contributions in public goods games: in game theory, all agents are created equal.[30] The prediction that these variables should have little effect was made explicit by Pruitt and Kimmel (1977): "In general, we would expect dispositional qualities to have little impact in an impersonal setting as represented by most gaming environments" (p. 379). Despite this prediction, there has been a small amount of research into this question.

Parks and Vu (1994) investigated cultural differences between American and Vietnamese students in a public goods game and found that Vietnamese students contributed significantly more than their American counterparts, the Vietnamese maintaining contribution rates of over 80% even after 30 trials. The

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[29] One important individual difference variable that has been considered has been sex of subjects, but I defer discussion of these results to the "sex differences" section below.

[30] This is of course an oversimplification. The idea of "Types" in game theory is evidence that there is room for individual variation. Nonetheless, game theoretic accounts assume agents are identical unless there is information that would lead one to believe otherwise.

implications for the importance of considering the culture from which subject populations are drawn for public goods games are obvious.

A limited amount of research has looked at differences between individuals within subject populations. One individual difference measure that has enjoyed some popularity in public goods games has been trust. Yamagishi (1986) used a "Trust Scale" to divide subjects into "high" and "low" trusters. He found that high trusters contributed more to a public good than low trusters. Parks (1994), using the same scale, obtained a similar result. Subsequent work (Parks & Hulbert, 1995) indicated that the difference in contribution rates between high and low trusters can be eliminated if payoffs in the step-level public goods game are changed such that a player's endowment is returned if it was contributed to a step-level public good that was not successfully provided. In this case, low trusters seem to be more inclined to contribute because they know that they can not end with a zero payoff.

A second individual difference measure that has been used is "social value orientation," which classifies subjects into one of four types: competitor, individualist, cooperator, or altruist (Kramer, McClintock, & Messick, 1986; Liebrand, 1984). Social value orientation has been found to have an effect in a prisoner's dilemma game, with competitors being more likely to defect against a simulated opponent that was always cooperating (McClintock & Liebrand, 1988).

However, Parks (1994) found no effect of this variable on contribution decisions in a public goods game.

Finally, Rapoport and Suleiman (1993), facing difficulties in accounting for the considerable variation in the data from their public goods game, segmented their subjects into three categories: those who valued "equity," those who valued maximizing their expected utility, and those who could not be categorized. This segmentation did in fact capture additional variance in their data, but this is hardly surprising, given that they have in essence added additional parameters to their model. Based on their findings, in perhaps the strongest endorsement of the individual differences approach, they suggest that there might be a need to "shift the focus of future research to identifying personality 'types' whose decision behavior in social dilemmas may be described by alternative models" (p. 193).

As with the other models discussed in this review, individual difference models seem to be important under particular conditions. Rapoport and Suleiman (1993) are probably correct: a complete account of all the variability in public goods games will include individual difference measures. An important question remains as to the conditions under which individual difference variables will be important in accounting for variability in contributions to public goods.

<u>Evidence from public goods: Summary and conclusions.</u> A number of broad conclusions can be drawn from the vast empirical efforts using the public goods game. First, consistent with game theoretical principles, subjects are often

responsive to the structural incentives of the public goods game, including the magnitude of the benefits to be obtained and their perceived probability of affecting their provisioning. However, a pure game theoretic account is insufficient to account for behavior across all games. Second, a number of ways to increase contributions have now been established, although each has boundary conditions associated with it. These include 1) allowing pre-play communication, 2) providing a mechanism for enforcing group-level commitments, 3) providing a mechanism for provisioning (cheap) sanctioning, and 4) framing public goods decisions in the context of inter-group competition. Third, a complete model of behavior in public goods environments is going to have to include both the structural features of the environment as well as the social context of the environment. Fourth, a complete model will likely include variables that mediate the relationship between the structural/social environments and ultimate play decisions. These variables might include items such as the players' (perceived) incentives, the players' expectations, and the value systems that players bring to the experiment.

On Human Rationality

Much of the research using economic games environments as a tool to investigate cooperative behavior has emphasized the game theoretical framework (e.g., Rapoport, 1987), if not always as a predictive theory, then at least as a normative one. Along with this framework comes its underlying assumptions, in particular that of rationality on the part of the agents that are being modeled (Andreoni, 1995, is a good example). Cosmides and Tooby (1994a) portray this worldview succinctly: "This assumption is that rational behavior is the state of the world, requiring no explanation" (p. 327). If the assumption of rationality[31] fails, then the utility of game theory as a model for human behavior is compromised. Therefore, a critical question is whether or not this assumption is warranted.

There are extremely good reasons to believe that it is not. Again, quoting Cosmides and Tooby (1994a): "Not behaving *at all* is the state of nature... All departures from this state of inaction require explanation" (p. 327, emphasis original). The "departures from this state," the behavior of humans, are the result of processes that occur in the actors' brains. This makes the question of the nature of the mind as important a question for economics it is for psychology.

In general, economists have not given a great deal of attention to the design of the human mind. Instead, most economic modeling leaves the nature of the computational devices in agents' heads unspecified, assuming instead that

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[31] The exact meaning of "rational" is the subject of some debate, and its meaning often varies by context. Here, I intend the meaning as used by economists modeling the behavior of agents in game theoretical contexts: choosing the option that will maximize one's payoff, under the assumption that all other players are doing the same.

agents somehow perform whatever calculations are necessary, including complex operations like probabilistic reasoning or backward induction. This view can be characterized as a "domain general" one: that the mind embodies a number of principles such as those of formal logic and the Bayesian calculus and applies these across the vast scope of situations that agents face.

Tooby and Cosmides (1992) have explored the difficulties with this view of the mind. They emphasize that an element that must be included in a discussion of the basic nature of the mind is that it is the product of evolution by natural selection. As such, its design consists of elements that have their features by virtue of their ability to solve adaptive problems that led to successful reproductive outcomes with respect to other possible designs. Because the adaptive problems are vast and varied for any organism, the information processing procedures that are required to generate "good" adaptive solutions to one problem differ from the procedures that would be needed to generate adaptive solutions to a different problem. This means that the mind must consist of a set of information processing systems designed to work on particular types of problems to generate particular solutions that are adaptively correct (Tooby & Cosmides, 1992).

In contrast, a domain general architecture is wholly unsuited to solving adaptive problems. Indeed, it is not possible to design, even in principle, a device that can simultaneously solve all possible problems. If the same operations were applied to each problem, solutions to individual problems would suffer, as adaptively correct solutions vary from domain to domain. In contrast, domain specific devices are well suited to solving an array of different problems, applying operations that are good for solving problems in a particular domain. This is because evolution can "assume" the recurrent structure of the environment with respect to particular adaptive domains, and mechanisms can therefore come to implicitly embody this information, adding to the power of the solution.

What this means is that we should not expect people (brains) to be "utility maximizers," but rather we should expect that they apply different types of operations in different types of situations. Quoting Cosmides and Tooby (1994a) a final time:

> "Triggered by cues that a particular problem type has been encountered, a network of dedicated computers can selectively deploy from its large repertoire those specialized procedures that are well designed for solving that particular problem. *For the problem domains they are designed to operate on, specialized problem-solving methods perform in a manner that is better than rational*; that is, they can arrive at successful outcomes that canonical general-purpose rational methods can at best not arrive at as efficiently, and more commonly cannot arrive at all" (p. 329, emphasis original).

Two points of clarification are in order. First, it is important to note that none of the operations need be "conscious." From the standpoint of evolution, all that matters is the correct functional outcome, where functional is defined with respect to its contribution to fitness. Second, this does not mean that mechanisms that were designed to solve adaptive problems and led to successful reproductive outcomes in the past will necessarily do so in the present. Because evolution works so slowly, human minds are designed to work well in the environments in which humans have been evolving over the last few million years. To the extent that environments differ, mechanisms that led to reproductive success in the past will not necessarily do so in the present (e.g., Symons, 1992).

Domain specificity and input specificity. This analysis leads to the conclusion that thinking of human agents as "rational" in the domain general sense is incorrect. Instead, brains should be viewed as a collection of information processing devices that have their properties by virtue of their ability to generate adaptive outcomes in the past. It may often be the case that these systems, under particular conditions or circumstances, generate behavior consistent with traditional normative models of rationality. On the other hand, it would be unsurprising if on other occasions they failed to do so (see Kahneman & Tversky, 1982, for a number of examples of mismatch between normative models and human behavior).

Many domain general approaches (implicitly or explicitly) construe mental contents as a set of propositions, and thought as the combination of these propositions in a relatively unconstrained manner. If this view of the mind were the correct one, information from any domain could be brought to bear on any problem or decision -- the relevant[32] propositions would merely have to be accessed and combined. In contrast to this view stands the modular view of the mind. The modular view assumes that information-processing systems take only particular kinds of inputs, an idea Fodor (1983) referred to as "informational encapsulation." Coupled with evolutionary approaches to cognition, this view suggests that any given information processing mechanism will take as input only information in a form that was relevant to solving the problem for which the mechanism was designed (Tooby & Cosmides, 1992).

Where some authors such as Fodor suggest that only some systems are modular (the "input" systems but not the "higher" processes), others have argued that most if not all cognitive mechanisms are (Sperber, 1994). I refer to this idea that only very constrained types of information are accepted by any given cognitive mechanism as "input specificity," and suggest that this must be true of any information-processing mechanism. That is, any device that is designed to

[32] It should be noted that what counts as "relevant" is as difficult a problem for a computational device to solve as what counts as "good."

process information, including human cognitive systems, must have a finite vocabulary of entities that the mechanism can take as input.[33]

Evidence for input specificity can be found at many different levels of cognitive processing. The lowest level on which one sees specificity is in sensory processes. Receptor neurons are designed to respond to one type of incoming energy. Photoreceptors are designed to respond to electromagnetic radiation of particular wavelengths, neurons in the tactile system are designed to react to pressure (mechanical energy), or temperature (kinetic energy), and so on. Specialized receptivity of these different neuronal systems can be seen as a kind of filtering system such that any particular system processes only information of a specific type. (As a side-effect of their design, these systems can sometimes be "fooled" – that is, activated by alternate energy sources, such as in the popular classroom demonstration in which mechanical pressure to the eye stimulates photoreceptors and evokes a visual sensation.)

Input specificity can also be seen at levels higher than that of perceptual systems. For instance, although the auditory system is sensitive to a variety of sounds (wavelengths of changes in air pressure), some are passed on to a phonetic

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[33] The easiest way to see this is to consider the reverse: what would an information-processing system look like that could take any kind of information, from numbers to planets, as inputs?

parsing system and are interpreted as language sounds, while others are not (Liberman & Mattingly, 1989). That is, sounds from a trumpet do not sound like unintelligible speech, unlike sounds emitted by someone speaking an unfamiliar foreign language. Both of these sounds are equally meaningless to the language comprehension system, but they are treated very differently. The language system seems to search for sounds that have language-like properties, which are then subject to phonetic processing. This system can also be "fooled" into parsing non-language sounds if they have the correct properties, as in the case of speech-mimics like the mynah bird (Pinker, 1994).

Moving "up" the cognitive system, evidence for specificity in higher processes has been accumulating in the literature on logical reasoning. For example, performance on the well-known Wason Selection task is exquisitely sensitive to content (Cosmides, 1989; Cosmides & Tooby, 1989, 1992). When subjects are asked to try to find violations of a rule of the form "if P then Q," their ability to do so is greatly enhanced if the proposition is in the form of a social contract (e.g., "if you assemble my desk, then I will take you to Disneyland") relative to a conditional that is not in the form of a social contract (e.g., "if you go to Boston, then you take the train").

This suggests that it is possible that outcomes on different tasks will vary as a function of both the information type and content available, even if the differences between contents are, from the perspective of a normative theory drawn from mathematics or logic, irrelevant to performing the task. For example, the Wason Selection Task can, in principle, be solved given any antecedent and consequent in propositional form. But one mechanism capable of generating a solution to the task (the cheater-detection mechanism) does not take just any propositions as inputs: it takes only social contracts. Even then, the system does not generate the *logically* correct response, but the adaptively correct response of detecting cheaters (see Cosmides & Tooby, 1992, for a complete discussion). In these experiments, the semantic content rather than the logical form of the proposition is mediating the operations performed on it -- some contents receive social contract processing, whereas others do not. Similarly, Gigerenzer and Hoffrage (1995) have shown that performance on statistical reasoning problems depends on the format in which information is presented. In this case, their interest was in the advantage subjects gain when information is presented in the form of frequencies as opposed to probabilities. Additional research on statistical reasoning continues to show that subjects' ability to solve experimental tasks varies with the nature of the entities they are asked to think about, even when the problems are formally identical (Cosmides & Tooby, 1996).

Evidence such as this suggests that contents that are treated in similar or different ways by the mind may or may not correspond to our intuitions about which contents are 'alike' (see Goodman, 1972, and Quine, 1970, on the difficulties with the concept of "similarity"). Thus, in the analogical reasoning literature, problems that seem the same in the sense that they are structurally equivalent and could be solved by similar operations are often not construed by subjects to be similar (e.g., Gick & Holyoak, 1980). An important task for psychologists then is to determine how different contents are typed (categorized) in the language of thought (after Fodor, 1975), as this will be informative about the operations that are likely to be performed on these contents. This approach holds the promise of explaining previously mysterious content effects (Cosmides, 1985).

A corollary of the input specificity view is that some information might not be used to perform certain tasks even if, in principle, it could be. That is, if information is available in the world, but not used by the mind as input to perform the particular task at hand, adding this information will not improve performance.

Hermer and Spelke (1994) demonstrated this phenomenon in an ingenious series of studies investigating the cues that young children use to navigate in an environment. In the condition of interest, young children (roughly 2 years old) were put in a rectangular room with a single blue wall. The shape of the room combined with the single colored wall uniquely specified each corner of the room. Children watched an experimenter hide a toy in one of two corners, and were then disoriented by a parent spinning them around. Children using both geometric and color information should have been able to go directly to the corner with the hidden toy. Children using only geometrical information should choose the correct corner half the time, and the diagonally opposite corner half the time. This latter result is exactly what was found. This suggests that early in development, the spatial navigation system has a very circumscribed set of inputs, namely geometric cues, that are used to perform its computations. This pattern is mirrored in other species: e.g., rats also use geometrical information to the exclusion of other information that could in principle be used to navigate (Cheng, 1987).

In the same way that we should not always see relevant information being used in cognitive systems, it should also be the case that we sometimes find that information that is (known to be) irrelevant *is* used by a cognitive mechanism. This contrasts with domain general accounts, which predict that if there is information that is known to be either irrelevant or incorrect, this information should *not* be brought to bear during the decision making. This process is often referred to as "discounting" or "correction," and there is a great deal of evidence that discounting often does not occur when it should (Gilbert, 1989).

A classic demonstration of this phenomenon was Ross, Amabile, and Steinmetz' (1977) study in which subjects were arbitrarily assigned either to generate and ask another subject questions or to answer questions generated by the other subject. A third subject observed the subsequent questioning of one subject by the other. Not surprisingly, answerers often got questions wrong. Interestingly, however, all subjects, whether questioner, answerer, or observer, judged the questioner to be more knowledgeable and intelligent than the answerer. This suggests that people in all three roles failed to discount the fact that the questioner was assigned the role and was free to devise questions in whatever area of expertise they happened to have.[34]

The failure of subjects to discount seems puzzling if one endorses a propositional or domain general view of the mind. However, advocates of domain specific accounts construe the issue not in terms of discounting, but rather in terms of what information in the environment might be used in drawing inferences. Thus, domain general views consider what information would be functional in the sense of solving the "problem" as construed by the experimenter, while domain specific views consider what information would have been functional in the sense of solving adaptive problems facing the organism over evolutionary time. On this type of account, the question changes from one in which one asks what kind of information is discounted to one in which one asks what kind of information will

[34] The authors don't describe this as a failure of discounting. They explain it with reference to the "fundamental attribution error": the idea that observers systematically attribute behavior to properties of the individual rather than to characteristics of the situation. In the terminology used here, this explanation would suggest that observers do not discount the rules that structured the interaction.

be used in different types of processes. The problem in the experiments described above comes because there is often a mismatch between modern experimental situations and the environment in which our inference systems evolved.

Given that formal education and psychological experimentation are recent cultural inventions, it is unlikely that our cognitive systems are designed to handle information in these contexts. That is, unlike the contrived environments of the laboratory and the classroom, there is in general a real causal link between information available in social situations and the "real" state of affairs in the social world. On this view, an individual's inability to answer a set of questions should, under normal conditions, be diagnostic of their intellectual abilities. So, the inference made by subjects in experiments would normally be a good one.

Indeed, it is in general the case that one would want to encode information from the environment as if it were "true." Representing the true state of affairs in the world is presumably extremely useful for generating adaptive behavior.[35] The exception to this would be cases involving communication, where it is easy for others to misrepresent the actual state of the world (see e.g., Byrne & Whiten, 1988). This may be why it is relatively easy to metarepresent other peoples'

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[35] Compare the utility of two different possible ways of representing seeing a lion: 1) "I see a lion," a representation about the observer, versus 2) "A lion is in front of me," a representation about the state of the world.

statements – that is, by representing speech content as "agent A *says* proposition P," the truth value of proposition "P" can be decoupled from the rest of the cognitive system, preventing potentially false information from cluttering up one's semantic memory. In this way, P is not taken to be true, but rather agent A is taken to have some attitude toward P. On this account, metarepresentation might be applied only under extremely limited circumstances such as speech or pretend play (see e.g., Leslie, 1987, 1994).

It may be that metarepresenting other peoples' nonverbal behavior is something for which the cognitive system is not well designed. On this account, nonverbal cues are taken at face value for purposes of drawing social inferences: because they cannot be cordoned off from semantic memory by being "filed" in a metarepresentation, they cannot be discounted, even if one learns that these cues were emitted because an experimenter induced the person to do so. Knowledge that other individuals have been coerced or induced to emit social psychophysical cues might not lead to discounting for this reason.

It might be that in ancestral environments, transient authority such as one sees in laboratory experiments would have been somewhat rare. This would decrease the need for metarepresentation for many different types of behavior, because one could in general be confident that behavior reflected the actor's interests rather than those coerced by a transient authority. Or, even if actions were coerced, if hierarchies were relatively stable, then a target's present actions may indeed be diagnostic of their future ones, because they were likely to remain in the same subordinate position for a substantial period of time. Of course, we do not have complete information about ancestral environments, making these remarks speculative, but at minimum, it seems to be the case that not all representations are discounted (perhaps through metarepresentation) with the same facility.

It is at least plausible that the same general argument holds for one's own behavior. That is, certain cognitive mechanisms may take one's own behavior as input. It seems reasonable to assume that one's behavior is typically the result of the smooth functioning of some set of cognitive systems. The output of these systems, behavior, can be considered just as much an output of a cognitive mechanism as any other type of output, although the format of the output may be muscle movements as opposed to representations.

Effects consistent with this account have been found in a number of domains. For example, the "facial feedback hypothesis" suggests that people's emotional experience depends in part on the state of the relevant facial muscle groups normally associated with particular emotions. Subjects induced to tighten or relax these muscles through artificial means, such as placing a pen in their mouths, experience emotions that would in normal circumstances be associated with the tension in these muscles (Larsen, Kasimatis, & Frey, 1992; Strack, Martin, & Stepper, 1988). This indicates that information about physical states acts as inputs to mechanisms computing the subjects' emotional state.

A long tradition in the social psychological literature seems consistent with this view that one's own behavior is an important cognitive input. Early experimental work showed that subjects' reported attitudes (Festinger, 1957; Festinger & Carlsmith, 1959) or beliefs (Bem, 1967) could be changed by inducing subjects to engage in behaviors that were counter to their pre-existing attitudes or beliefs. Similarly, Schachter and Singer (1962) found that subjects inferred their own emotions at least in part from physiological states subtly induced by experimenters.

Additional results consistent with these views have been obtained many times since these early experiments. For instance, an often used paradigm has subjects write persuasive essays that are counter to their stated attitudes. In these "forced compliance" experiments, after writing the essays, subjects' attitudes generally change in the direction of the position that they argue for in their writing, although the extent to which this occurs depends on a number of variables, including the magnitude of the inducement to write the counter-attitudinal essay (Cohen, 1962; Cooper & Fazio, 1984; Jones & Harris, 1967; Zanna & Cooper, 1976). It is now known that there are some additional boundary conditions on when this type of effect is observed, such as the amount of "cognitive resources" available to the subject and the degree to which one's behavior is discrepant from the previously held attitude or belief (Fazio, Zanna, & Cooper, 1977).

An important aspect of these experiments is that subjects do not always know why it is that their judgments change in the ways that they do. This is consistent with the modular view as well, in that there is no reason to think that the "conscious" cognitive system has access to the inputs that are determining attitudes or behavior. Nisbett and Wilson (1977) were among the first to espouse and provide evidence for this view, and a great deal of evidence supporting their general conclusions has accumulated since their original classic paper.

My own research is an investigation of the psychology of cooperation (in humans) in the context of the domain specific evolutionary view. In particular, the experiments described herein are an attempt to investigate social cues that might be fed to input systems that are designed for making decisions about cooperation in the context of groups. On the input specificity argument, these cues might affect behavior because they act as relevant inputs to cognitive mechanisms even though it is "known" by all subjects that these cues have been induced by the experimenter.

Coordination and Cooperation

The central focus in the public goods literature is on overcoming the free rider problem. Driven as it is by rational choice and domain general approaches, this is not surprising: on game theoretical models, the failure of subjects to free ride is a serious problem. Although the free rider problem is indeed an important one, the definition of cooperation I propose above suggests that the issue of coordination is also critical. This problem does not have to do with costs and benefits, but rather with the ability of group members to coordinate to achieve the group-level goal. Without the ability to coordinate actions, solving the free-rider problem does not solve the public goods problem: both must be solved to be effective. Coordinating the actions of multiple individuals is an extremely complex computational task.

Recall Tooby and Cosmides' (1996) discussion of externalities. A core component of this argument is that while the focus on costs and benefits in cooperation is important, the particular ways in which systems interact is critical as well. Consider a situation in which organism B "wishes" [36] to contingently reward organism A for performing a task in a particular way that benefits organism B, where "wishes" means that, all other things equal, organism B would enjoy greater reproductive success if it were the case that organism A performed an action in one way rather than another.

[36] I am using intentional language here to illustrate the engineering difficulties. Of course, natural selection has no such intentions. See Dawkins (1976) for a discussion of the utility of intentional language in understanding natural selection.

	X	Y
X	5, 5	0, 0
Y	0, 0	5, 5

Figure 3. Payoff structure for a two-player coordination game.

Now, consider the engineering task facing organism B. First, "rewarding" another organism is no mean feat. Indeed, in the space of interactions that are possible between two organisms, the island of helpful ones is small indeed (Tooby & Cosmides, 1996). Again, to paraphrase Tooby and Cosmides (1994a), behaving indifferently with respect to another organism's fitness is the state of the (biological) world. To benefit another organism requires an intricate meshing of one's own behavior with that of the organism being benefited. For cooperation based on contingent acts by another organism to be successful, natural selection must build machinery that 1) is able to detect when organism A has indeed acted in the preferred manner and 2) can reliably enhance organism A's fitness.

A simple game theoretic example illustrates this point. Consider a "coordination" game in which two players have only two moves in the universe of possible behaviors, called X and Y (see Figure 3). Players move simultaneously, and each does better by selecting the same move as the other player. It can be seen that even in this very simple universe, without the addition of extra systems (for signaling, for example), organisms only benefit one another half the time.

Now imagine a game in which three players must each choose one of ten numbers. The payoff matrix is structured such that if each player selects the same number, they all receive the preferred payoff. Now, even though all players have the same goals, without a means to signal or communicate, the odds of obtaining the reward are one in a hundred. Now consider the behavioral options available at any given time to a pair of organisms, and the number of those that will lead to mutually beneficial outcomes. It is easy to see that as more organisms get involved, the computational demands explode. Even in the incredibly simplified universe of game theoretical matrices, which vastly understate the possible behavioral options available to organisms, the coordination problem is an extremely important one.[37] For this reason, cooperative coordination demands intricate machinery to function.

The coordination game also simplifies things because in the matrix in Figure 3, both players' goals are in exact concordance. One consequence of this is that if a signaling method could be devised, it could work perfectly. If players'

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[37] From this perspective, games such as the prisoner's dilemma have *already* solved the coordination problem. The availability of a "C" move means that there is a way in which Row can benefit Column and vice versa. In a very real sense, it is not even possible to play the prisoner's dilemma game unless and until the coordination problem has been solved.

goals are not in synchrony, then the possibility of deceptive signals can become an issue, and signaling alone cannot solve the coordination problem.[38] In the coordination problem described here, it can be seen that a partial solution involves the ability to predict other players' intentions. To the extent that honest intentions can be signaled in the coordination game above (see Figure 3), players can arrive at an optimal solution with ease.

Because solving the coordination problem is such an important component of multi-individual cooperation, it should be the case that a well-designed system should be sensitive to evidence that coordination is possible. As such, the following hypothesis is offered:

> *Hypothesis$_1$: Decisions to cooperate will be mediated by the extent to which an actor has cues that coordination is possible within a group, with cooperation increasing as the ability to coordinate increases, all other things equal.*

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[38] Issues of honesty, costliness of signals, and concordance of interests have been the source of considerable reflection on the part of biologists considering the evolution of communication (Dawkins & Krebs, 1978; Guilford & Dawkins, 1991; Krebs & Dawkins, 1984). Hauser (1996) and Krebs and Davies (1993) both provide accessible accounts of this issue.

On the input specificity argument presented above, it must be the case that mechanisms for generating cooperation in groups are sensitive to only particular kinds of information as input. The present studies are an attempt to test hypothesis 1 through an investigation of possible cues to coordination.

Overview. The experiments I will present use a traditional public goods paradigm to investigate the hypothesis that the presence of cues that one is in a coordinated group will increase the extent to which people contribute to the public good. The manipulations described here are exploratory. The idea that cues to coordination might act as inputs to systems designed to evaluate the extent to which one is able to coordinate and therefore cooperate effectively with other members of a group is a new one. Although there are good reasons to believe each is relevant to coordination, there is no way to know a priori the nature of the hypothesized input systems.

These studies focus on four possible cues to coordination: ***mutual eye gaze***, ***touch***, ***rhythm***, and propositional ***communication***. To investigate these cues, subjects will be asked to match eye gazes, touch one another gently, tap out rhythms together, or communicate over a computer network. Contributions in groups in which subjects are asked to engage in these tasks will be compared to contributions in groups in which subjects do not interact with one another in these ways.

Mutual eye gaze. Recall that solving the coordination game, if not the coordination problem, can be helped along by the ability to signal one's (honest) intentions. Recent work suggests that eye gaze may play an important role in this process. This idea comes from the recent explosion of research on the so-called "theory of mind" (e.g., Baron-Cohen, 1995). Theory of mind mechanisms are systems designed to read the intentions of others. By inferring another individual's intentional state, predictions can be generated about an agent's probable future behavior (Dennett, 1987).

It is so easy and automatic for humans to infer the intentions, beliefs, and desires of others that we are "instinct blind" (Cosmides & Tooby, 1994c) to just how sophisticated the underlying cognitive machinery that generates these inferences is. Indeed, it is only when this ability is impaired, as in the case of autism, that we see how critical these abilities are to our everyday navigation of a bewilderingly complex social world (Baron-Cohen, 1995). Consider how simple it is for a normal adult to judge from the fact that a child's gaze is locked on a piece of candy that the child *wants* the candy. For people with autism, this seemingly straightforward inference is impossible (Baron-Cohen, 1994), and the severe deficits autistics have in social interactions are obvious. This kind of reading of intentions can be a critical component of coordinating efforts among individuals who wish to cooperate.

Baron-Cohen (1995) has proposed a set of cognitive systems that may serve the functions of inferring other peoples' intentions. The first is the Eye-Direction Detector (EDD), which detects eyes and gauges their direction of gaze. The second is an Intentionality Detector (ID), which assigns intentions to entities in the world based on a set of perceptual cues. Next, the Shared Attention Mechanism (SAM) is a representational system which allows the construction of intentional attributions about the self and another (agent A sees that I see object X). Lastly, the Theory of Mind Mechanism (ToMM) is an even more sophisticated representational system allowing beliefs to be inferred on the basis of input from the other three systems.

In essence, these mechanisms allow people to "read" other peoples' minds, judging their goals, actions, and wants, starting with the EDD. This capacity may underlie humans' abilities to coordinate actions to achieve cooperative outcomes. For this reason, it is hypothesized that the cues associated with making inferences about others' mental states might act as an important piece of information, and therefore be one type of input relevant to the psychology of cooperation. This leads to Hypothesis 2.

> *Hypothesis$_2$: Mutual eye gaze is an input to systems designed to detect the extent to which one can coordinate with others. This cue to coordination will increase the extent to which individuals are*

willing to endure costs to benefit other group members (i. e., cooperate).

Is there any experimental evidence of a specific relationship between eye gaze and cooperation? Research on the effects and correlates of eye gaze has a short history, with very little work being done on the issue until the mid sixties. Nonetheless, there are data supporting a relationship. Kleinke (1976) investigated the effect of eye gaze on what was termed "compliance," although there was no obvious authority structure, making compliance seem like a less appropriate term than perhaps "helping" or even "altruism." Kleinke had female experimenters ask subjects who had just used a phone booth where dimes had been placed if they had found the dime and to return it dime if they had. In one condition, the experimenter gazed at the subject while making the request, while in another condition they averted their gaze while doing so. Subjects were more likely to return the dime in the eye gaze condition, although this effect was not statistically significant. In a similar experiment, subjects were more likely to lend a female experimenter a dime to make a phone call if the experimenter maintained eye gaze during the request. Kleinke (1980) replicated this finding, but found that the increase in compliance was eliminated when experimenters asked for a dime to buy a candy bar, and actually reversed when experimenters asked for a dime to buy gum. He interprets these results as indicating that there are boundary conditions on the efficacy of eye gaze increasing compliance, namely that the request must be regarded as legitimate rather than illegitimate.

More recently, Hornik (1987) obtained a similar result, finding that having experimenters look into the eyes of subjects increased the likelihood that subjects would fill out a questionnaire, especially when the experimenter was female. Note, however, that in this study experimenters simultaneously touched subjects on the arm in the condition in which they engaged in eye gaze, preventing any conclusions from being drawn as to which manipulation was responsible for the effect.

Perhaps more relevant to the present studies, some work has been done looking at the effect of the ability to see one another on players in prisoner's dilemma games. Wichman (1970) used a prisoner's dilemma format and assigned subjects to one of four conditions: one in which they were isolated from one another (the baseline condition); one in which they could see but not talk to each other; a third in which they could talk to one another, but not see each other; and fourth, one in which they could both see and hear one another. Although there was some evidence that merely seeing one another increased rates of cooperation (47.7% compared to the baseline of 40.7%), this effect was small compared with the effect that hearing only (72.1%) or both seeing and hearing (87.0%) had on rates of cooperation.

Two more experiments leave the role of eye gaze in economic games still in question. Kleinke and Pohlen (1971) failed to find a significant effect on subjects' cooperative moves in a prisoner's dilemma game when a confederate either made eye contact with subjects or avoided their eye gaze (subjects and confederates were all male). In contrast, Gardin, Kaplan, Firestone, and Cowan (1973) did find an effect of gaze in a prisoner's dilemma setting. However, they found that eye gaze interacted with the distance such that players seated relatively far apart from one another cooperated more when the other player engaged in large amounts of eye gaze, but that players seated close to one another cooperated less with greater amounts of visual contact.

In general, it is difficult to draw any strong conclusions about the relationship between eye contact and cooperation, although the evidence discussed above indicates that such a relationship exists, at least outside the context of laboratory games. The ambiguity in results in the literature on cooperation mirrors the uncertainty in the eye gaze research area more generally. It is interesting to note some claims made by Kleinke (1986) in his review of the eye gaze literature. Kleinke simultaneously claimed that: 1) "Researchers have demonstrated that gaze functions to communicate threat and dominance…" (p. 82); 2) "People gaze more when they share feelings of warmth and liking" (p. 82); 3) "People tend to increase their gaze when attempting to be persuasive and deceptive" (p. 82); and 4) "A witness in a videotaped courtroom trial was judged as more credible when he did not avert his gaze…" (p. 81). It is hoped that the current study will clarify the literature on eye gaze, rather than confuse it further.

Touch. In the *interpersonal touch* condition, subjects will be asked to play a version of the game "telephone." Subjects will be given a number from one to five and instructed to tap players next to them that number of times to communicate this number sequentially to the entire group. This game is a means of inducing subjects to touch one another, and their ability to communicate the number around the group is irrelevant to the manipulation.

Touch affords quiet, subtle communication between individuals, and therefore the possibility of coordination. An interesting feature of touch is that unlike other forms of communication, touch signals, although limited in bandwidth, can be passed from one individual to another without others being privy to the communication. To the extent that cooperation may include intergroup conflict, this type of communicative ability might be an important one.

Touch may also serve a function not specifically related to coordination: it may act as a social signal of closeness of relationship. Touch is a socially important act, although the significance of touch varies from culture to culture (e.g., Remland, Jones, & Brinkman, 1995). On the input specificity argument, it could be the case that being touched is a cue that one is in a close social relationship with the person touching, in much the same way that the state of one's facial muscles is a "cue" to one's emotional state (Larsen, Kasimatis, &

Frey, 1992; Strack, Martin, & Stepper, 1988). This might lead to more cooperative decisions based on the nature of the relationship (after Fiske, 1992). This analysis leads to the speculation that touch might play a role in systems designed for cooperation.

> *Hypothesis$_3$: Interpersonal touch will activate systems designed to detect social distance and allow subtle interpersonal communication. This cue will increase the extent to which individuals are willing to endure costs to benefit other group members.*

The theoretical literature on interpersonal touch is not as well developed as the literature on eye gaze. Nonetheless, there has been some research investigating the kinds of effects touch might have. As with eye gaze, one of the areas that has been investigated is the effect of touch on compliance.

In Kleinke's (1977) telephone experiments described above, subjects returned the wayward dimes and lent the experimenter a dime more often when the experimenter touched them than when the experimenter did not. A similar result was obtained by Smith, Gier, and Willis (1982), who found that in a supermarket setting, having experimenters touch subjects made them more likely to taste (and buy) some pizza. Willis and Hamm (1980) were also able to obtain increased compliance to sign a petition (Experiment 1) or complete a rating scale

(Experiment 2) when experimenters touched subjects just before making the request. Hornik (1987) has obtained similar results.

Other experiments suggest that there are serious limitations on the effect of touch on compliance. Kleinke (1980) found that having experimenters touch subjects in addition to gazing at them had no effect on their compliance with a request, and Powell et al. (1994) found that touch did not increase compliance in a laboratory experiment except when the experimenter and subject were both female. More recently, Bohm and Hendricks (1997) found that touch did not increase compliance with a request under any combination of male and female requestors and subjects.

Goldman, Kiyohara, and Pfannesnteil (1985) also found a limitation on the ability of touch to secure compliance. They found evidence that touch increased compliance with a request that the subject volunteer two hours of their time, but only if the subject had just been given a negative label, "unhelpful," in response to their giving directions to a confederate. It appears from the results of these studies that the mechanism by which touch has its effect is still poorly understood, but it is equally clear that it can have powerful social consequences, including nearly doubling the purchase of a particular variety of pizza (Smith, Gier, & Willis, 1982).

In addition to looking at the effect of touch on compliance, some research has been conducted looking at its evaluative effects. Lewis et al. (1995) found a positive relationship between the extent to which a nurse was observed to be in physical contact with a patient and peoples' judgments of how "socially supportive" and competent a nurse was. These results are complicated by a number of interactions with sex of observer (discussed below) and are extremely small in magnitude. Alagna, Whitcher, Fisher, and Wicas (1979) similarly found that subjects' evaluations of a counseling interaction were more positive when the interviewer touched the subjects during the course of the interview, although these results were not necessarily due to touch alone, as the protocol suggests that the interviewer increased eye gaze in this condition as well. In sum, there is evidence that touch can have important effects, but, as with eye gaze, understanding of touch is still murky.

Rhythm. In a third condition, subjects will be induced to tap out *rhythms* in synchrony with one another. Little has been written in the psychological literature about the intuitive appeal of rhythm and beats and its possible functional origins, although there have been some suggestions that rhythm might play a role in human mating (Grammer, Kruck, & Magnusson, 1998).

Rhythm has two interesting properties. First, it allows synchronization. In essence, it sets up an inductive process by defining temporal spaces. By hearing three beats in a (regular) rhythm, one can infer when the fourth will be. This affords the possibility for synchronization in time, which is of course why when people want to begin a task in unison they will often count down with a cadence.

Second, because “natural” (non-biological) events tend to occur more or less at random, rhythm represents a good cue that some kind of "man-made" signal is present.

Because rhythm provides a way to synchronize extremely effectively, it may be that the appeal of rhythm lies partly in its ability to facilitate complex cooperation.

> *Hypothesis$_4$: Tapping out rhythms in synchrony might activate systems designed to detect how well a group can coordinate. This cue will increase the extent to which individuals will try to sustain a group-beneficial cooperative outcome.*

Communication. The last condition in Experiment 1 will test the role of communication. The input specificity argument suggests that while the exchange of propositional information may be an important way to coordinate, the form that communication takes is important as well. That is, the inferences that one draws might be quite different if communication is face to face as opposed to via a computer network. Typed messages may be less psychologically cogent than verbal messages, as verbal speech was designed to be heard, not seen. This leads to hypothesis 5.

> *Hypothesis$_5$: Communication over a computer network will not activate mechanisms designed to detect the extent to which one is a part of a coordinated group. If the ability to coordinate through*

propositional content is precluded, communication over a computer network will not increase contributions relative to a baseline condition in which no such communication is possible.

To test this hypothesis, one condition in Experiment 1 will allow communication among subjects through a virtual "chat room." Subjects will be able to type messages to one another which will appear on their computer screens. However, they will be told that they may not discuss the content of the game. This allows a test of hypothesis 5, although the prediction is the null hypothesis, making the interpretation of results potentially problematic.

The evidence that face to face communication increases contributions is well documented, as discussed above, although the reason for this effect is still a matter of some debate (Kerr & Kaufman-Gilliland, 1994; Orbell, Dawes, & van de Kragt, 1990). However, there is some small support for the notion that communication must be relevant to have an effect. Dawes, McTavish, and Shaklee (1977) found that even face to face discussion did not increase contributions when subjects were told to discuss an irrelevant (to the game, not necessarily to the subjects) topic. This stands in stark contrast to the relevant communication condition, in which contributions increased from 27% to 74%. Very similar effects were recently obtained by Bouas and Komorita (1996), who replicated the finding that irrelevant conversation has no effect on rates of contribution. In a similar vein, Wilson and Sell (1997) found that communicating one's intended contribution over the computer terminal also had no effect on contributions.

Sex differences. An evolutionary approach to cognition suggests that the cognitive architecture of males and females should be identical to the extent that each sex faced the same adaptive problem (Darwin, 1871). However, to the extent that they did not, we should expect differences in the cognitive architecture of the two sexes.

The literature on mating is illustrative. Male and female mammals face different adaptive problems with respect to mating. Males have a much higher variance in the number of offspring they sire, while females are limited in their maximum reproductive potential. This should lead to systematic differences in the nature of the psychology of mating (Trivers, 1972). Such differences are well documented in humans by David Buss and his colleagues (Buss, 1989; Buss & Schmitt, 1993). However, to a large extent, males and females' problems overlap with respect to mating. In particular, for either sex, it is advantageous to have a mate who is kind and intelligent. Data on mate preferences indicate that male and females are indeed alike in preferences on these dimensions, while they differ on dimensions relating to preference for a variety of partners (with males preferring more variety in partners than females), consistent with differences in the adaptive problems faced by the sexes (Buss & Schmitt, 1993).

It seems likely that cooperation resembles mating in that there is overlap in the problems faced by the sexes, but it is also likely that there are some important differences as well. Social exchange, for example, is a type of cooperation that is relevant to both males and females. There does not seem to be any a priori reason to believe that males and females would have differed in the degree to which gains in trade could be of benefit. Further, a large literature has emerged looking at the cognitive underpinnings of the reasoning mechanisms that underlie social exchange, and there is no evidence that there are sex differences in this vast literature (e.g., Cosmides, 1989). On the other hand, other cooperative tasks, in particular hunting and warfare, might have constituted different adaptive problems for men than for women. There are good theoretical reasons for believing this to be the case (Hawkes, 1993; Tooby & Cosmides, 1988; Tooby & DeVore, 1987), and anthropological evidence is consistent with this view (Alexander, 1979; Chagnon, 1988). There is evidence of cooperative hunting of big game in the archaeological record, and in extant hunter-gatherer societies, where it is a predominantly (if not exclusively) male activity (Lee & DeVore, 1968). Similarly, across cultures, warfare is conducted almost exclusively by men (Alexander, 1979; Chagnon, 1988; Fried, Harris, & Murphy, 1968).

Do warfare and hunting require coordination that economic exchange does not? It seems likely that the answer is yes. Consider economic exchange in Trivers' (1971) conception. He emphasized that the exchange need not be simultaneous, seriously decreasing the computational requirements for a system capable of exchange. In modern contexts many social exchanges are simultaneous. However, it seems very likely that this is possible only because humans have developed a storage of value, money, an invention only a few millennia old, not nearly long enough to have shaped the psychology of social exchange (Cosmides & Tooby, 1992).

On the other hand, both hunting and warfare demand that the parties involved work together in real time, changing their actions to mesh with those of their comrades to achieve the goal. This means that complex calculations about factors such as positioning with respect to allies and targets must be done swiftly. The importance of coordination in warfare is suggested by the organization of modern military infrastructures. The "modular" hierarchical structure in the military and the extreme emphasis on the importance of "command and control" exist to enable large forces to be coordinated effectively. In similar fashion, it has often been remarked that success on the playing field, a miniature (and usually less lethal) version of warfare, is often due more to the way in which players work together than to the individual skills of the players.

Taken together, the evidence that men were more likely to be engaging in cooperative hunting and warfare along with the suggestion that these adaptive tasks require systems capable of real time spatio-temporal synchrony and coordination lead to hypothesis six.

Hypothesis$_6$: There are sex differences in the extent to which evidence of coordination will impact decisions to cooperate because males are more sensitive to cues that one is able to coordinate. The experimental manipulations -- eye gaze, touch, and rhythm -- will be more effective in increasing contributions in all-male groups than they will be in all-female groups.

Is there evidence for sex differences in public goods games? Unfortunately, while most experimental studies often (but not always) report the number of male and female subjects, they rarely report sex differences, or even if sex differences were tested. There are some cases in which it is made explicit that sex differences were tested and their existence rejected (Caldwell, 1976; Dawes, McTavish, & Shaklee, 1977, Experiment 1; McClintock & Liebrand, 1988; Yamagishi, 1986).

There is, however, some evidence for sex differences in behavior in economic games, although this evidence is inconsistent. Early work using a prisoner's dilemma game suggested that male subjects playing with other male subjects cooperated more than pairs of females (Kahn, Hottes, & Davis, 1971, Experiment 1; Rapoport & Chammah, 1965), a finding that is not always replicated (Orbell, Dawes, & Schwartz-Shea, 1994).

In the realm of public goods games, Dawes, McTavish, and Shaklee (1977, Experiment 2), found evidence that females were more cooperative in a condition in which subjects were allowed to discuss the game, but they also reported that they had been unable to replicate the sex difference finding. More recently, of three recent experiments using all male and all female groups, one indicated that males contribute more (Brown & Kruse-Hummels, 1993), and two found that females contributed more, one significantly so (Nowell & Tinkler, 1994), the other finding only a non-significant trend (Sell, 1997).

In public goods games in which groups are of mixed sex, there is similar ambiguity. One recent study found that in mixed groups females contribute more (Seguino, Stevens, & Lutz, 1996), while another recent study found the reverse (Sell & Wilson, 1991). Data from economic games other than the public goods game show similarly inconsistent results (see Eckel & Grossman, in press; Mason, Phillips, & Reddington, 1991).

In short, there is evidence that there are sex differences in economic games, but their source is as yet elusive, and they seem to disappear or reverse themselves with disturbing frequency.

<u>Sex differences in experimentally manipulated variables.</u> Is there evidence that these as yet poorly understood sex differences will interact with the specific experimental manipulations? There is evidence that there are systematic differences in the impact of eye gaze on men and women. Larsen and Shackelford (1996) argue that eye gaze serves different communicative functions for the two sexes. This claim is supported by data showing differences between men and

women in the correlation between an individual's tendency to "gaze aversion" and various psychometric scales, including personality measures, as well as a finding that women engage in "gaze aversion" significantly more often than men. Kleinke (1986) also suggested that there are sex differences in the impact of eye gaze, suggesting that "women have more tolerance and more favorable reactions than men when receiving gaze from others" (p. 85) and that high levels of eye gaze between males leads to a decrease in liking.

More direct evidence that eye gaze has different tangible effects on males and females comes from studies of compliance. Hornik (1987) found that more people complied in a condition in which the experimenter gazed at and touched subjects when the experimenter was female. This is consistent with results obtained by Kleinke (1977, Experiment 2, 1980) who had only female experimenters making requests for compliance. He found that males complied more than females in his experimental (eye gaze) condition, although of course the fact that no male experimenters were used means that a meaningful comparison cannot be made.

There is some evidence of sex differences in reactions to touch as well (Nguyen, Heslin, & Nguyen, 1975). Lewis et al. (1995) report that females' ratings of nurses when they were observed touching patients was more favorable than men's ratings of the same interaction. Alagna et al. (1979) found a slightly more complicated relationship, showing that opposite sex touch led to more favorable evaluations of the interaction.

Recalling the compliance literature, there is some evidence that females are more likely to elicit compliance with their touch (Willis & Hamm, 1980), although other evidence suggests the female advantage in eliciting compliance with touch may be restricted to the case when females are also the target of the request (Powell et al., 1994). Still other research suggests that there are no effects of the sex of the experimenter or the subject in eliciting compliance with touch (Smith, Gier, & Willis, 1982), leaving the issue in some doubt. In general, the weight of the evidence might lead to the prediction that touch will increase cooperation more in all-female groups than all-male groups, contrary to the prediction derived from hypothesis six.

In sum, Experiment 1 is designed to test hypotheses based on considerations of the computational complexity of coordination and the adaptive tasks for which adaptations for cooperation in groups might be designed. The predictions for Experiment 1 are twofold. First, I predict that people in groups who engage in mutual eye gaze, touch, and tapping out rhythms will contribute more to a public good than people in groups who do not engage in any of these behaviors or engage in only extremely restricted communication. Second, I predict that this increase in contributions will be more pronounced for male subjects than for female subjects.

Experiment 1

Method

Subjects. Two hundred eighty-three subjects were recruited from the University of California Santa Barbara undergraduate community. Each subject was told that they could earn up to twelve dollars for their participation. The amount that each subject actually earned depended on the results of the experiments as described below.

Design. The experiment used a 5 (Condition: Baseline, Eyegaze, Touch, Rhythm, Communication) X 2 (Subject Sex: Male, Female) between-subjects factorial design.

Procedure. The procedure was a standard public goods game that largely duplicated that used by Marwell and Ames (1979). Subjects were given a time to report to the laboratory and told that they would earn a $2 bonus if they arrived on time. Six same-sex subjects were recruited for each experimental session. However, due to absences, not all groups consisted of exactly six people. If fewer than four people appeared for an experimental session, the session was canceled. Five groups were run in each of the ten cells.

As subjects arrived in the laboratory, they were seated at six computer terminals arrayed in a circular configuration in the center of the room. This arrangement allowed subjects to see one another but not the screens of the other subjects. Once all six subjects had arrived, they were asked to read the instructions (modified slightly from Davis & Holt, 1993) on their computer screens, which explained the nature of the public goods game and how it was to be played (see the Appendix for the text of these instructions). They were informed that they would be playing ten rounds of a public goods game, that they would start each round with ten tokens, and that they would receive fifty cents per token for their average token total over the course of the ten rounds. The instructions informed them that they could divide their endowment (in units of whole tokens) any way they chose between the two accounts each round, and that they would earn the full value of each token they put in their Personal Account, as well as a fraction of the value for each token they and the other subjects put in the Public Account. The amount they earned from the Public Account (the MPCR) was one-third of the total number of tokens placed in the account. This information was provided in a table visible to the players during their contribution decisions. After having read the instructions, subjects familiarized themselves with the interface that they would be using to register their allocation of tokens to their Private Account and Public Account. Any questions were answered by the experimenter, who was in the room during the course of the experiment.

In the Baseline condition, once all subjects had completed reading the instructions and indicated that they were ready by clicking on a small box on the computer screen, round 1 automatically began. Each player was prompted to indicate their choice of allocation of tokens to the two accounts. Once the last person had made a selection, the computer calculated the total number of tokens contributed to the Public Account and provided this information to each player. Each player saw how much they had earned for that particular round (their share of the Public Account plus their contribution to their own Private Account) and the total token contribution to the Public Account by all players. Players were not told how much any of the other players individually contributed.

Subsequent rounds proceeded similarly. Between rounds, players were able to see previous rounds' Public Account token totals. Once round 10 was completed, the game was over. At this point, the computer generated a list of the total payoffs to each individual player, and the experimenter assembled envelopes with appropriate totals out of view of the subjects. Subjects were paid fifty cents for every token that they earned on average over the course of all ten rounds. Subjects were called by the experimenter individually, given their envelope, debriefed, and dismissed.

In each of the experimental conditions, a manipulation was added before each round began. In the oblique Eyegaze condition, subjects were instructed that they were to look obliquely[39] into the eyes of the players next to them for three seconds before each round. The text of the instructions was as follows:

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[39] Because direct eye-gazes could be interpreted as threatening, oblique eye-gazes were used. In addition, oblique eye gazes allow two people to coordinate while

> Before you make your contribution decisions each round, we are going to ask you to make eye contact with other members of your group. All you will need to do is, at the appropriate time, shift your eyes to the left or right (you will be told which) to meet the gaze of the person next to you, who will similarly be moving their eyes to look toward you. While you do this, keep your head as still as possible, turning only far enough so that you can see the person next to you out of the corner of your eye. In addition, please try to keep your expression neutral.

The computer coordinated the eye gazes with a series of countdowns and beeps. Before each eye-gaze, subjects saw a three second countdown and were instructed to turn when the countdown reached zero so that they could synchronize their gazes. One half of the subjects (in every second seat) were directed to look right first, and the other half were first directed to look left. After this, subjects performed the same procedure, but in the opposite direction. In this way, each subject matched gazes with the person to their right and to their left. In the few cases when fewer than six subjects were present, subjects were still

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making it difficult for others to see that they are doing so. Subsequent work, not reported here, indicates that there is no difference in contributions when direct eye-gazes are used.

directed to look in the appropriate direction, even if there was no one in the direction that they were looking. After the sequence was complete, subjects were prompted to indicate their allocation decision.

In the Telephone Touch condition, the procedure was similar except that instead of gazing at one another, subjects were told to touch one another lightly on the shoulder. Subjects were informed that they were going to mimic the game "telephone":

> Before each round, we are going to ask you to play a version of a game sometimes called "Telephone." One of the members of your group will be selected to begin. They will be shown a number on their computer screen between 1 and 5. The goal is to communicate this number to every other member of the group. However, the only way you are allowed to communicate is by tapping your neighbor (lightly) on the shoulder or arm. Tap once for one, twice for two, and so on.

At the beginning of each round one subject was randomly selected by the computer to begin, and the direction that the telephone game was to proceed was also randomly determined. When the last player had indicated the communicated number by entering it into the computer, subjects were prompted to make their allocation decision.

In the Rhythm condition, subjects had two opportunities to hear a rhythm and were then directed to tap out the rhythm in synchrony with the other subjects. Each rhythm lasted between three and five seconds. Subjects saw the following instructions:

> Before each round, we are going to ask you to tap out a simple rhythm. Once everyone is ready, the computer will start a short countdown. You will see numbers counting down and hear beeps once per second. When the countdown reaches zero, you will hear the rhythm. Simply listen while the rhythm is being played. Next, the computer will begin another countdown and play the rhythm a second time. After the rhythm has played twice, the countdown will begin a third time. When it reaches zero, copy the rhythm that you heard, tapping it out on the desk in front of you. This time, the computer will not be playing the rhythm along with you. So that everyone starts tapping simultaneously, use the beeps to determine when to begin tapping.

Five different rhythms were used whose order was preset. The five rhythms were played in this order in the first five and the last five rounds of the game. The computers were set to prompt subjects to make their allocation after sufficient time had elapsed to allow them to tap out the rhythm.

In the Communication condition, subjects had the opportunity to type messages to the other players for thirty seconds prior to each round. Subjects saw six boxes on their screen, each one containing the messages typed by one of the other subjects. Where each subject's messages were placed was randomized between rounds. Pre-testing showed a tendency for subjects to send messages about the content of the game despite explicit instructions not to do so. To strengthen this directive, a notice that they were being monitored and recorded was added to try to encourage compliance with the rule that the game not be discussed. The instructions were as follows:

> After all players have indicated that they are ready to begin each round, a countdown clock will begin. You will have thirty seconds to send notes to the other players in the room. Every player will see everyone else's notes.
>
> You may type whatever you wish, EXCEPT you MAY NOT SEND ANY NOTES ABOUT THE GAME YOU ARE PLAYING. That is, YOU MAY NOT ASK OR ANSWER ANY QUESTIONS ABOUT ALLOCATING TOKENS OR ANY OTHER ASPECT OF THE GAME. You may discuss anything else you wish. Note that everything you type is being monitored and recorded.

After thirty seconds had elapsed, subjects were prompted to make their contribution decision.

Results

Dependent variables. The dependent variable was the number of tokens that subjects, on average, contributed to the Public Account. First, the average contributions across all ten rounds were analyzed. Second, average contributions from rounds one through five were compared to average contributions from rounds six through ten to examine the extent to which contributions changed over the course of the game as a function of condition and subject sex (mean contributions are shown in Table 1; for a more detailed look at the progression of contributions over time, refer to Figure 4 for male subjects and Figure 5 for female subjects).

Looking first at average contribution across all rounds, a 5 (Condition: Baseline, Eyegaze, Touch, Rhythm, Communication) X 2 (Subject Sex: Male, Female) ANOVA was conducted.[40] This analysis yielded a main effect for condition, $F(4, 278) = 2.675$, $p < .05$, with contributions in the Baseline condition being significantly lower than those in the Eyegaze and Communication conditions (p's < .05). Although condition did not interact with sex, subsequent

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[40] Preliminary analyses were run to ensure that there were no significant between-group differences within cells.

Condition	n	Contribution: All Rounds	First Half	Second Half
Male Subjects				
Baseline	27	3.06	3.85	2.27
Eyegaze	27	4.39	4.94	3.83
Telephone	28	4.18	4.44	3.92
Rhythm	27	3.81	4.47	3.14
Communication	30	4.76	4.93	4.59
All Conditions	139	4.05	4.53	3.58
Female Subjects				
Baseline	29	4.02	4.42	3.62
Eyegaze	29	4.00	4.17	3.83
Telephone	29	4.17	4.37	3.97
Rhythm	27	4.25	4.65	3.85
Communication	30	4.81	5.17	4.45
All Conditions	144	4.25	4.56	3.95

Table 1. Mean Contributions in Tokens by Sex and Condition.

analyses were run looking at the data for male and female subjects separately since hypothesis six predicts systematic sex differences in the effect of the manipulations on contributions.

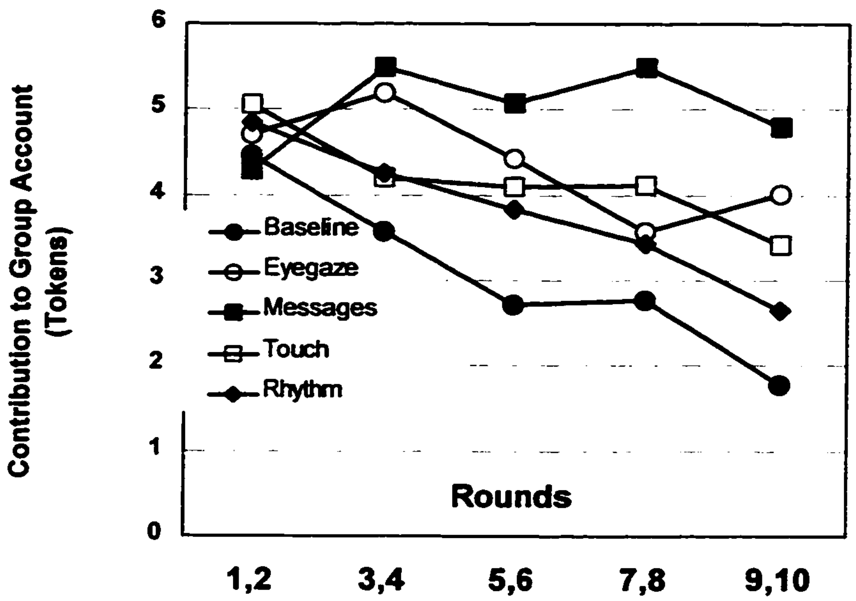

Figure 4. Average contribution (in Tokens) of Male participants over the course of the game broken down by pairs of rounds in the Baseline, Eyegaze, Communication, Touch, and Rhythm conditions in Experiment 1.

A one-way ANOVA was conducted on average contribution for male subjects with condition as the independent variable. This analysis yielded a marginally significant main effect, $F(4, 134) = 2.363$, $p = .056$. To see if experimental conditions varied from Baseline, one-tailed Dunnett tests were conducted, with Baseline as the control condition. Results indicated that contributions in the Eyegaze and Communication conditions were significantly

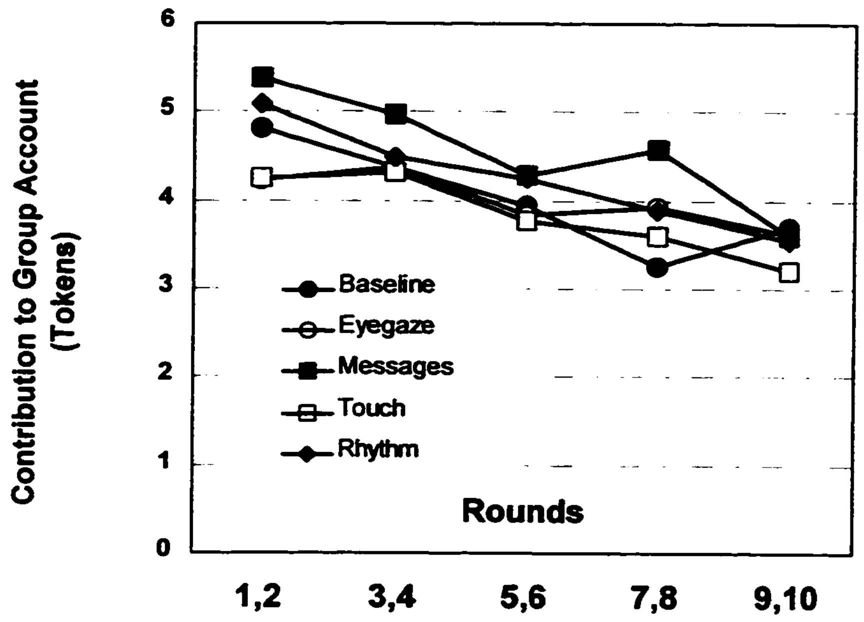

Figure 5. Average contribution (in Tokens) of Female participants over the course of the game broken down by pairs of rounds in the Baseline, Eyegaze, Communication, Touch, and Rhythm conditions in Experiment 1.

higher than contributions in the Baseline condition (both p's $< .05$) and that contributions in the Touch condition were marginally higher than contributions in the Baseline condition, $p = .10$. Mean contributions in the Rhythm condition were not significantly different from mean contributions in the Baseline condition (see Table 1 for these means).

A similar one-way ANOVA was performed on the data from the female subjects. In contrast to the analysis on the data from male subjects, there was no main effect of condition for female subjects. That is, females did not show differential contributions as a function of condition, $F < 1$.

A second set of analyses was conducted examining the mean contributions in the first half compared to the second half of the game. A 5 (Condition: Baseline, Eyegaze, Touch, Rhythm, Communication) X 2 (Subject Sex: Male, Female) X 2 (Time: First Half, Second Half) mixed factorial ANOVA was performed with time as a repeated measure. This analysis indicated a strong main effect for time, $F(1, 278) = 77.889$, $p < .001$, replicating previous findings that contributions in general tend to decrease over the course of the game (see Table 1).

There was also a significant interaction between time and condition, $F(4, 278) = 2.606$, $p < .05$. Breaking this interaction down, a one-way ANOVA on mean contributions from the first half of the game yielded no main effect for condition, $F(4, 283) = 1.496$, $p = .203$, while a similar ANOVA on the mean contributions from the second half of the game yielded a significant main effect for condition, $F(4, 283) = 4.519$, $p < .005$. Dunnett tests with Baseline as the control condition indicated that this effect was driven by significant differences

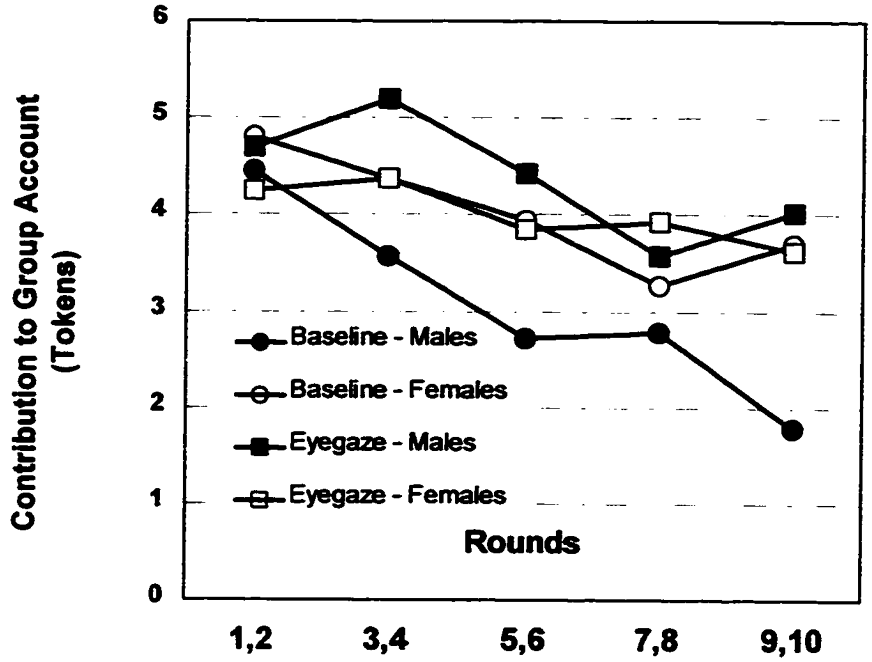

Figure 6. Average contribution (in Tokens) of Male and Female participants over the course of the game broken down by pairs of rounds in the Baseline and Eyegaze conditions in Experiment 1.

between the Baseline condition and the Eyegaze, Touch, and Communication conditions with contributions being lower in the Baseline condition (all p's < .05). There was no significant difference between contributions in the Rhythm and Baseline conditions.

There was also an interaction between time and subject sex, $F(1, 278) = 4.075$, $p < .05$. This interaction derives from the fact that male contributions fall off faster than female contributions, although contributions in the first half of the game were significantly higher than in the second half of the game for both males, $t(138) = 6.59$, $p < .001$, and females, $t(148) = 5.48$, $p < .001$.

These three effects were qualified by a marginal three-way interaction between time, condition, and subject sex, $F(4, 278) = 1.640$, $p = .16$. Again, because sex differences were predicted, two separate 5 (Condition: Baseline, Eyegaze, Touch, Rhythm, Communication) X 2 (Time: First Half, Second Half) ANOVA's were conducted with time as a repeated measure. Results of this analysis for male subjects revealed a main effect for time, $F(1, 134) = 47.403$, $p < .001$, qualified by an interaction between condition and time, $F(4, 134) = 2.883$, $p < .05$. Breaking this interaction down further, Dunnett tests with Baseline as the control condition indicated that in the second half of the game, mean contributions differed from Baseline in the Eyegaze, Communication, and Touch conditions (all p's $< .05$), with contributions in the Baseline condition being lower than in the experimental conditions. There were no significant differences from Baseline in the first half of the game in any experimental conditions, and there was no evidence of any effects of the Rhythm manipulation.

Similar tests for female subjects revealed a main effect for time, $F(1, 144) = 29.471$, $p < .001$, with contributions decreasing from the first half to the second half of the game, but no interaction involving condition emerged. Although sex differences were predicted only in the impact of the experimental manipulations on contribution decisions, one additional test was run to determine if contributions in the Baseline condition differed between male and female subjects. This analysis yielded a marginally significant difference, $\underline{t}(54) = 1.907$, $\underline{p} = .062$ (two tailed), with female contributions being higher than male contributions (Figure 6 compares contributions in the Baseline and Eyegaze condition to illustrate the interactions among subject sex, condition, and time).

Discussion

The main findings from this study can be summarized relatively straightforwardly. Three experimental manipulations, Eyegaze, Communication, and Touch effectively increased male contributions relative to the Baseline condition. In large measure, these effects were driven by contribution decisions in the latter half of the game. The last experimental condition, Rhythm, had no detectable effect on contribution rates.

In contrast, there was no evidence that any of the experimental manipulations increased contributions for female subjects. In fact, average contributions for females across rounds in all conditions were strikingly similar to one another (see Figure 5).

Contrary to predictions, contributions increased for males in the Communication condition. However, there is evidence that male subjects did not obey the restriction that they not discuss the game itself in their communications. Statements recorded from this condition included: "Lets all give 10 to the account and get paid 20 tokens," "All unite and go big we make out like villains," and

"Let's attack the psych guy and just take all the money!" In contrast, messages from female subjects typically revolved around the weather, food (especially ice cream), and relationships. In short, it looks as though despite specific instructions to the contrary, male subjects had no compunctions about discussing the dilemma and soliciting contributions. This may explain in part the higher contribution rates of males in this condition. Recall that Dawes, McTavish, and Shaklee (1977) found that conversation on an irrelevant topic did not increase contributions. Future research should employ techniques that can enforce the rules of the conversation. The only precaution in these experiments was informing subjects that their remarks were being recorded and monitored. This seems to have been insufficient to ensure compliance.

The lack of increase in male contributions in the Rhythm condition is interesting and also counter to predictions. It does indicate, however, that not just any manipulation will increase contributions above the Baseline condition for male subjects. One potential explanation for the failure in this condition comes from observations on the part of the research assistants conducting the individual sessions. Apparently, although pains were taken to pre-test the rhythms for ease of learning, subjects were often unable to tap out rhythms in synchrony with one another, particularly in the first five rounds of the game. If subjects were out of sync, perhaps this was a cue to the *lack* of coordination, as opposed to a cue to its presence, undermining contribution to the public good. Although the predictions for the rhythm condition were not borne out, this route may still be worth pursuing. Further care should be taken in subsequent studies to ensure that subjects can tap the rhythm in synchrony. The use of more practice trials or familiar rhythms are potential solutions to this difficulty.

Experiment 2

Experiment 1 indicated that it is possible to increase the extent to which male participants contribute to public goods by having them interact with one another in relatively subtle ways. Except for the Rhythm condition, all of the experimental manipulations led to increased contributions. These results raise the possibility that virtually any kind of mutual activity among male subjects will keep public good provisioning at this enhanced level. Experiment 2 is an attempt to find the boundary conditions of this effect by systematically reducing the cues in the interaction to see at what point contributions decline.

Consider the Touch condition in Experiment 1. It was hypothesized to have its effect (Hypothesis 3) by virtue of its activating systems designed to detect social distance as well as its ability to allow subtle communication. It should be possible to tease apart these two distinct hypotheses. Subtle communication is possible even without body-to-body contact – light tapping with an instrument of some kind can convey information just as well as tapping with one's finger. In contrast, bodily contact seems to be an important aspect of social distance. Touch mediated by a tool seems very different from touch that brings one person's body into contact with another person's.

So, if the effect of the Touch condition were due to bodily contact and the intimacy this implies, playing the Telephone game without requiring players to touch one another directly should eliminate the effect. To test this, a condition in which players use pens to touch one another to communicate the designated number is included in Experiment 2.

> *Hypothesis$_7$: The effect of interpersonal touch is due to its impact on systems designed to detect social intimacy. Physical interaction without body-to-body contact will not increase contributions in a public goods game.*
>
> *Hypothesis$_{7a}$: The effect of interpersonal touch is due to the impact of physical interaction among subjects. Physical interaction without body-to-body contact will still increase contributions in a public goods game.*

If contributions remain high in the Pen Touch condition, falsifying Hypothesis 7 but not Hypothesis 7a, an alternative explanation is still possible. It could be the case that merely playing the Telephone game regardless of any physical interaction will induce males to cooperate more than they otherwise would.

Hypothesis$_8$: The effect of interpersonal touch is due simply to the fact that players are involved in an interaction of some kind. Playing the Telephone game without physical interaction will not increase contributions in a public goods game.

A second condition, Mouse Telephone, is incorporated into the design in order to test hypothesis 8. In this condition, the designated number will be communicated around the circle of players as in the Touch and Pen Touch conditions, but the means of communication will be by way of mouse clicks by each player in sequence. If contributions are higher in the Pen Touch condition than in the Mouse Telephone condition, it would be reasonable to conclude that the increase from Baseline observed in Experiment 1 was due to the physical interaction as opposed to merely playing the Telephone game.

If hypothesis 8 is falsified and contributions remain high in both of these conditions, the source of the increase in contributions in Experiment 1 will still not be known. It might be reasonable to conclude that playing the Telephone game itself leads to increased contributions, but this would leave the question as to what it is about the game that induces more cooperativeness.

An interesting aspect of the Telephone game as played in these studies is that play is spatially sequential. In the Mouse Telephone condition, although players are not physically interacting, because they are in such close proximity they are able to see and hear whose turn it is and observe that play proceeds in a circle. That is, in the same way that rhythm affords predictions because it sets up inter-temporal intervals, observing sequential play allows for predictability with respect to the actions of the players – once two players have played, one can predict the sequence in which others will do so by virtue of the fact that play proceeds in order around the circle. In some sense then, playing sequentially is a spatial cue to coordination in the same way that rhythm is a temporal cue to coordination – players are able to detect a regular spatio-temporal ordering of plays.

Hypothesis$_9$: The effect of playing the Telephone game is due to the fact that players are involved in a spatially sequential interaction. Playing the Telephone game without spatially sequential moves will not increase contributions in a public goods game.

The final condition, Random Telephone, removes the spatial ordering of plays by having play proceed randomly, eliminating cues that players are in a tight spatially ordered sequence. This condition is in essence a control condition, removing all possible external cues to coordination while maintaining the Telephone task structure. If performing the task in sequence were responsible for the effect observed in Experiment 1, contributions in this condition will be lower than those in either the Mouse Telephone or Pen Touch conditions. If contributions remain high, then one might reasonably infer that the aspect of Telephone that is increasing contribution is the act of communicating a single message among members of a group -- even when the content of this message is unrelated to the task itself. That is, the intentional sharing of a message among members of a group might itself be a cue of coordination. (It should be noted that this is different from cheap talk, where conversation is unconstrained – i.e., many different messages are shared, and each is only shared among some, but not all, members of the group.)

In summary, Experiment 2 is designed to test hypotheses that the increased contributions by male participants in the Touch condition in Experiment 1 are due to body-to-body contact (Pen Touch), physical interaction (Mouse Telephone), or observing spatially sequential play in the Telephone game (Random Telephone). In addition, Experiment 2 provides an additional test of the sex difference hypothesis: male contributions should return to baseline levels when the cue responsible for elevated contributions in Experiment 1 is removed. So, for example, if hypothesis 8 is correct and any physical interaction is sufficient to increase male cooperativeness, contributions in the Pen Touch condition should be higher than those in either the Mouse Telephone or the Random Telephone condition for male subjects. This difference should not be seen for females.

Method

Subjects. Participants were recruited in the same manner as in Experiment 1, and 172 undergraduates participated and were again paid in cash at the end of the experiment depending on the amount that they earned during the session.

Design. The experiment was a 3 (Condition: Pen Touch, Mouse Telephone, Random Telephone) X 2 (Participant Sex: Male, Female) between-subjects factorial design.

Procedure. The procedure was the same as that used in Experiment 1 with the exceptions described below.

In the Pen Touch condition, participants read the following instructions in addition to the general instructions explaining how to play the public goods game. These instructions were virtually identical to the instructions in the Touch condition in Experiment 1, with the exception that participants were instructed to use a pen rather than their fingers to communicate the number that they were given.

> Before each round, we are going to ask you to play a version of a game sometimes called "Telephone." One of the members of your group will be selected to begin. They will be shown a number on their computer screen between 1 and 5. The goal is to communicate this number to every other member of the group. However, the only way you are allowed to communicate is by tapping your neighbor (lightly) on the shoulder or arm with the pen we have given you. Tap once for one, twice for two, and so on.

In the Mouse Telephone condition, the substance of the telephone game was preserved, but the physical social interaction was eliminated. The instructions given to participants were identical to those in the Pen Touch condition, except that they were told to communicate the designated number not by touching one another, but by clicking on a box on the computer screen using the mouse. The instructions read as follows:

> Before each round, we are going to ask you to play a version of a game sometimes called "Telephone." One of the members of your group will be selected to begin. They will be shown a number on their computer screen between 1 and 5. The goal is to communicate this number to every other member of the group. However, the only way you are allowed to communicate is by clicking on the screen with the mouse. Click once for one, twice for two, and so on.

The third and final condition in Experiment 2 was the Random Telephone condition. The procedure was the same as that used for the Telephone condition except that instead of proceeding around in a circle, the "message" was sent randomly from one participant to the next via computer until all participants had gone. The instructions for the 'Random Telephone' condition were identical to the instructions for the "Mouse Telephone' condition.

<u>Results</u>

Because a separate Baseline condition was not run for Experiment 2, data from the Baseline condition in Experiment 1 were used as a control class for the conditions in Experiment 2. A 4 (Condition: Baseline, Pen Touch, Mouse Telephone, Random Telephone) X 2 (Participant Sex: Male, Female) X 2 (Time: First Half, Second Half) mixed factorial ANOVA was conducted with time as a repeated measure (see Table 2 for means and Figures 7 and 8 for a more detailed look at contributions over time for male and female subjects respectively). This analysis revealed a main effect for time, $F(1, 220) = 47.985$, $p < .001$, with contributions decreasing from the first half to the second half of the game. In addition, there was an interaction between time and condition, $F(3, 22) = 3.966$, $p < .01$. This interaction derives largely from the very low contribution rates in the second half of the game in the Baseline condition. Lastly, this analysis revealed a marginal interaction between time and participant sex, $F(1, 220) = 3.494$, $p = .088$, driven by lower male contributions in the second half of the game. There were no other significant interactions.

Again, because of the presence of the marginal interaction between participant sex and time and because sex differences were predicted, data were analyzed separately for males and females. A 4 (Condition: Baseline, Pen Touch, Mouse Telephone, Random Telephone) X 2 (Time: First Half, Second Half) mixed factorial ANOVA for male participants yielded a main effect for time, $F(1, 109) = 23.392$, $p < .001$, replicating findings from Experiment 1 and past research on the public goods game that contributions drop from the first half to the second

Condition	n	Contribution: All Rounds	First Half	Second Half
Male Participants				
Baseline (Exp. 1)	27	3.06	3.85	2.27
Pen Touch	27	4.93	5.48	4.38
Mouse Telephone	27	3.75	3.94	3.57
Random Telephone	28	4.13	4.37	3.89
Female Participants				
Baseline (Exp. 1)	29	4.02	4.42	3.62
Pen Touch	29	3.82	4.15	3.50
Mouse Telephone	27	4.03	4.12	3.94
Random Telephone	30	3.83	4.07	3.58

Table 2. Mean Contributions in Tokens by Sex and Condition in Experiment 2 plus Contributions from the Baseline Condition in Experiment 1.

half of the game. There was also a main effect of condition, $F(3, 109) = 3.378$, $p < .05$. To determine which conditions were driving this effect, Dunnett tests were again conducted. This analysis indicated that the main effect for condition derived from the difference between the Baseline and Pen Touch conditions, p <

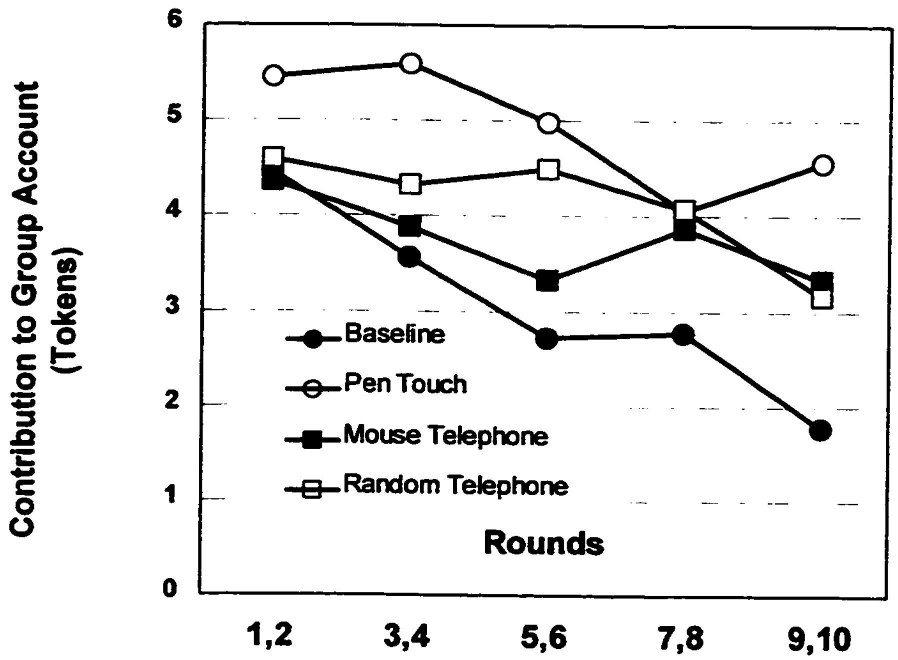

Figure 7. Average contribution (in Tokens) of Male participants over the course of the game broken down by pairs of rounds in the Pen Touch, Mouse Telephone, and Random Telephone conditions in Experiment 2 and Baseline condition in Experiment 1.

.005, with the mean in the Pen Touch condition higher than that in the Baseline condition. The differences between mean contributions in the Baseline condition compared to either the Mouse Telephone or the Random Telephone conditions were not significant. There was also a marginal interaction between time and condition, $F(3, 109) = 2.362$, $p = .075$, again due largely to the decrease in

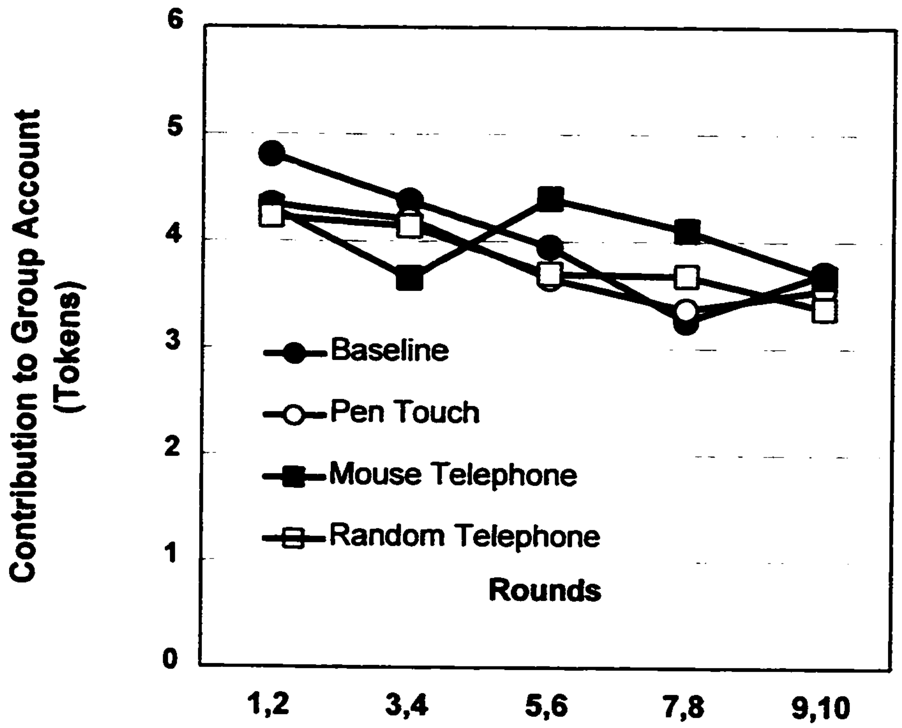

Figure 8. Average contribution (in Tokens) of Female participants over the course of the game broken down by pairs of rounds in the Pen Touch, Mouse Telephone, and Random Telephone conditions in Experiment 2 and Baseline condition in Experiment 1.

contributions in the second half of the game being more pronounced in the Baseline condition than in the other conditions.

A similar 4 (Condition: Baseline, Pen Touch, Mouse Telephone, Random Telephone) X 2 (Time: First Half, Second Half) mixed factorial ANOVA for females yielded only a main effect for time with contributions being lower in the second half of the game, $F(1, 111) = 32.007$, $p < .001$, with no significant effect for condition and no significant interaction.

Given these results, an additional analysis was conducted eliminating Baseline from consideration to determine if contributions differed between Pen Touch and the other two conditions. A 3 (Condition: Pen Touch, Mouse Telephone, Random Telephone) X 2 (Time: First Half, Second Half) ANOVA for male participants yielded a main effect for time, $F(1, 83) = 9.344$, $p < .001$, replicating the finding that contributions drop from the first half to the second half of the game. There was also a marginal effect of condition, $F(2, 83) = 1.878$, $p = .159$. Dunnett tests using Pen Touch as the comparison condition indicated marginal differences between the Telephone condition and Pen Touch condition, $p = .055$, and between the Random Telephone and Pen Touch condition, $p = .166$. Similar Dunnett tests, this time looking at the first half and second half of the ten rounds separately, indicated that in the first half of the game, contributions in the Pen Touch condition were significantly different from those in the Mouse Telephone condition, $p = .016$, and marginally different from those in the Random Telephone condition, $p = .072$. In contrast, no significant differences in contributions were observed in the second half of the game. A similar analysis for females yielded no significant effects except for the decrease in contributions over the course of the game, $F(1, 83) = 20.008$, $p < .001$.

Discussion

The results of Experiment 2 supported hypothesis 7a, that physical interaction is the important variable in increasing contributions by male subjects. The data do not support the hypothesis that playing the Telephone game in and of itself is sufficient to increase contributions. They also do not support the hypothesis that bodily contact is necessary in yielding increases in contributions.

A closer look at the data from Experiment 2 indicates that there might have been considerable noise in the Mouse Telephone and Random Telephone conditions for male participants. In particular, there was much more variability in contributions between groups in these two conditions than in the Pen Touch condition. Indeed, looking at the average contributions of each group within condition, there was more than fifty percent more variance between groups in the Mouse Telephone and Random Telephone conditions than in the Pen Touch condition.

It is not clear why these differences emerged. Care was taken to ensure that experimental procedures were standardized across conditions, and assignment to condition was random within each experiment. There seem to be at least two possibilities. Either these between-group differences represent noise, or there was some way in which certain groups within conditions systematically differed from one another in ways that it is not possible to determine. In any case, the results of these studies should be interpreted cautiously.[41]

As in Experiment 1, female participants' contribution decisions seemed to change very little across conditions. Indeed, female contributions were remarkably similar across all conditions of both experiments (see Figures 5 and 8).

General Discussion

Summary of Findings

It was hypothesized that having participants emit social psychophysical cues including mutual eye gaze, touch, and tapping out rhythms in synchrony that might convey information that they were a coordinated unit would increase cooperation as measured by contributions to a public good. This effect was predicted for both sexes but was expected to be stronger for males than females. It was, in fact, completely absent for females, but present under certain conditions for males. In particular, exchanging eye gazes and touching one another gently increased contributions to the public good for male subjects. Contrary to

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[41] Again, separate analyses were run to see if there were significant between-group differences within each condition. A hint of an effect of group appeared in the Mouse Telephone condition for male participants. Rerunning the analyses omitting the anomalous groups does not significantly change any of the results.

predictions, tapping out rhythms in synchrony did not increase contributions for male participants. Also contrary to predictions, it was found that communicating over a computer network also increased rates of contributions by male subjects. It is possible that this increase was due to the content of the messages rather than the process of communicating itself, since male participants discussed the game despite instructions not to do so.

The results of Experiment 2 suggest that the effects observed in Experiment 1 were due to the presence of physical interaction rather than the mere act of performing a task together. Because the data in the Mouse Telephone and Random Telephone conditions were somewhat noisy and only marginal results were obtained, it is difficult to draw any firm conclusions.

Female participants seemed completely unaffected by any of the manipulations. In general, female participants were (marginally) more cooperative than male participants (see Figure 6), and the contribution decisions made by females were remarkably consistent across conditions. No differences due to the effect of experimental manipulations emerged between conditions for female participants in either experiment. Future work might be aimed at finding ways to change the rates of female contribution.

The effectiveness of the presence of psychophysical cues in eliciting greater contributions from male subjects lends support to the idea that systems mediating decisions to cooperate are at least to some extent "informationally encapsulated." All subjects knew that the other subjects only emitted these cues by virtue of the direction of the experimenter and that therefore the cues could not be meaningfully interpreted as indications of commitment. The fact that this information was nonetheless effective in increasing cooperation suggests that it was not discounted and indicates that only particular kinds of information are used in the calculation of contribution decisions.

The findings in the present studies are consistent with previous findings in public goods experiments. As in many experiments in the past and observations from the real world, participants in this series of experiments chose to contribute to public goods despite the fact that every unit contributed was, in an immediate sense, an act against their financial self-interest. Contributions began at roughly 50% and declined over the course of the game, a finding common in the public goods literature. Indeed, the patterns of contributions in these experiments are quite robust – the Baseline condition in Experiment 1 averaged across sex looks strikingly like the results obtained by Isaac, Walker, and Thomas (1984), whose experiments used similar conditions, including an identical MPCR. The consistency of results in these different research programs suggests that the psychology of cooperation is relatively stable across (American) populations and time in a public goods environment.

Models of the Evolution of Cooperation

It is difficult to incorporate these findings into the existing theoretical structure surrounding public goods games. This is largely because there is as yet no overarching framework from which to understand the results of the large number of experiments investigating the provisioning of public goods other than game theory as applied to human actors, and it is very clear that this approach, at least in its purist form, is inadequate to account for a vast of array of results, including those obtained in the current study.

Evolutionary psychology provides a new framework from which to understand behavior in economic games (Cosmides & Tooby, 1994a; Hoffman, McCabe, & Smith, in press).[42] This approach entails considering adaptive problems to provide a basis for thinking about the design of cognitive systems that could solve these problems (Tooby & Cosmides, 1992). This raises the following question: what were the problems faced by our ancestors over evolutionary time that led to adaptations that generate cooperative behavior in modern environments?

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[42] Caporael, Dawes, Orbell, and van de Kragt (1989) similarly suggest an evolutionary framework, but do not incorporate arguments about domain specificity, the core of the logic behind evolutionary psychology (see also Caporael & Brewer, 1995).

A number of candidate adaptive problems have been discussed, but three seem particularly important: benefiting kin, reaping gains in trade, and inter-group conflict. I omit a consideration of adaptations for delivering benefits to kin, as the central focus of the present discussion is non-kin based cooperation. Although the development of theory surrounding kin-based altruism is quite advanced (e.g., Hamilton, 1964), the psychology of kin is relatively poorly understood, a result of systematic neglect on the part of the mainstream psychological community (Daly, Salmon, & Wilson, 1997).

Adaptations for social exchange. Unlike kin selection, the adaptive problem of reaping gains in trade has been explored in considerable depth. The theory of reciprocal altruism, an important solution to the problem, has a long history (Trivers, 1971), and developments have continued apace, aided by the powerful theoretical tools provided by game theory (e.g., Axelrod, 1984; Axelrod & Hamilton, 1981).

It is important to note that the insights from game theoretic modeling of the evolution of cooperation are only valuable[43] to the extent that the environment in which strategies compete in evolutionary simulations matches the structure of the environment in which evolution actually occurred. A model of an

[43] Valuable, that is, to understanding the design of adaptations. These models might, of course, have value in other contexts.

environment will be useless to understanding the design of adaptations to the extent that it does not actually reflect the structure of the environment in which a species underwent natural selection. It is worth a very slight digression to point out why there is good reason to believe that the prisoner's dilemma environment, the basis of a great deal of theorizing with respect to reciprocal altruism, represents a good model of important aspects of the environment in which humans evolved (see also Boyd, 1988).

Reciprocal altruism relies on there being an object or commodity that is of different value to two different agents. Indeed, two such items must exist for gains in trade to be achieved, although the two items do not have to exist at the same time or at the same place. Hunting, an activity our ancestors were known to do (e.g., Tooby & DeVore, 1987), suggests the origins of at least one type of item that fits this description. Hunting is a highly variable exercise, success being as often a matter of luck as skill. This leads to high variance in the amount of meat a hunter obtains. In addition, meat tends to come in relatively large packages (animals) and has a diminishing rate of return, the second incremental unit of meat being much less valuable to an individual than the first – that is, a portion of meat is more valuable to a hungry person than to a satiated one. So, hunters find themselves in the position of occasionally having a great deal of meat whose value is greater to others than to themselves, and occasionally being in the reverse position, placing a high value on others' kills when they have none. The solution to this problem, a suite of adaptations designed for reciprocal altruism, allow for the "smoothing" of this variance, resulting in a more steady consumption of meat over time (Cosmides & Tooby, 1992; Wilkinson, 1988).[44] A successful hunter can share his kill one day with the knowledge that he will in turn receive the benefits of others' kills on days in which he is not as fortunate.[45]

The point of this digression is that the adaptive problems associated with hunting make the prisoner's dilemma environment an appropriate one for modeling the evolution of reciprocal altruism. In particular, the prisoner's dilemma captures the opportunities for agents to benefit one another over time afforded by a commodity like meat. Cosmides and Tooby (1989) began the process of articulating the specific design features of psychological mechanisms that exist to support humans' ability for reciprocal altruism, more commonly known in the realm of human affairs as social exchange. In particular, they list fourteen such features which, with some loss of precision, can be collapsed into five principles relevant to the present discussion. Cosmides and Tooby (1989)

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[44] Note that there is not universal agreement regarding the relationship between the evolution of reciprocal altruism and hunting (Hawkes, 1993).

[45] No doubt other examples of commodities with different values to different agents at different times exist. "Social support," for example, may be one: how valuable it is depends on how much one already has, and so forth.

suggest that to solve the problems of reciprocal altruism, humans must possess systems that can:

1) Detect when one is in a potential social exchange situation (Cosmides & Tooby's point 1).
2) Calculate costs and benefits of various states of the world with respect to oneself and others (points 2 and 3).
3) Decide to take those courses of action in which benefits to self outweigh costs to self (points 5, 6, and 7).
4) Detect when an agent has violated an exchange (cheated/defected) and choose to punish these agents (points 10 and 11).
5) Identify and remember agents and their histories so that decisions to enter exchanges can be modified by knowledge of past behavior (points 12 and 13).

This is a simplified version of a list which itself is only an incomplete account of the machinery necessary for social exchange. However, even this short list is extremely interesting in the context of the results of the public goods games described above. On this account, adaptations for solving the problem of reciprocal altruism include cognitive mechanisms that are able to calculate costs and benefits to self and others[46] and select those options (*ceteris paribus*) in which one's benefit exceeds one's cost.

Two notes are in order. First, the smooth functioning of these systems is dependent on their ability to evaluate costs and benefits. To the extent that this is not possible, for example if choices are expressed in a "language" for which no cost/benefit calculation systems exist, we should expect the system to function sub-optimally. Second, other cognitive systems might also influence economic decision making, as the present studies illustrate. Therefore, we should not expect these systems alone to dictate decisions. Indeed, to the extent that there are cues

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[46] Note that this analysis does not specify how this is done. For the present discussion, I assume that these features exist in some form. Importantly, these calculations are likely performed by different systems in different domains: calculating the "value" of a piece of meat is a very different problem from calculating the "value" of having sex with some particular partner, and therefore different subsystems are required for performing these calculations. The medium of money simplifies this problem in the context of experimental games, giving cognitive systems a nice input to these calculations. Why money "works" with human cognitive systems is an interesting and open question, but well beyond the scope of the current discussion.

in a decision-making task that bring other systems into a judgment, cost/benefit calculations will be less relevant.

This analysis suggests that when certain conditions hold, people will choose options in which their benefits exceed their costs (thus appearing "rational"). These conditions include: 1) that the options available are transparent with respect to cognitive systems that are evaluating these options, and 2) that there are no other factors in the decision including, importantly, the cost/benefit structure to other (human) actors.

Condition two is included because an important component of selecting options is a consideration of the effects these actions will have on others. Over evolutionary time, because populations were so much smaller than they are today, the structure of the environment was such that every interaction was in essence a play in a "repeated game." That is, we should expect the mind to be structured so that it expects that actions that are calculated to have a negative impact on others will be resisted or punished by others, and actions calculated to benefit others potentially rewarded.

This second condition is too broadly stated to make specific predictions in any given experiment. However, we should in general expect that the removal of social factors should lead to the sole activation of cost/benefit analysis systems and the decreasing influence of other mechanisms designed for navigation of the social world. That is, to the extent that making choices that benefit the self will have no adverse consequences for others, we should expect people to maximize their benefits as long as condition one also holds.[47]

How do these predictions fit with results of economic games? Data from the ultimatum and dictator games seem to support the idea that removing the social context leads people to make decisions based solely on their cost/benefit calculations. When the choice is extremely straightforward (How much of $10 shall I keep?), and the social context is removed (No one else will know what I've done), people tend to choose the option that leaves them with the largest benefit (Hoffman, McCabe, & Smith, 1996).

Data from the public goods game seem consistent with this analysis as well. For example, the fact that players increase contributions when the MPCR (or its equivalent in the prisoner's dilemma game) increases (Isaac & Walker, 1988; Komorita, 1976; Komorita, Chan, & Parks, 1993; Rapoport, 1967) is consistent with humans' postulated ability to calculate costs and benefits and act in a way so as to maximize their outcomes (points two and three in the list of

[47] More colloquially, the idea here is that humans' behavior will be consistent with the following: "Benefit myself to the extent that I don't hurt anyone else, as long as I can figure out how."

design features above).[48] In addition, the data from certain step-level goods games seem to be consistent with this account of adaptations for social exchange. A player who is "critical" to provisioning a public good can benefit himself by contributing, and will benefit others by doing so as well (Bornstein, 1992; Chen, Au, & Komorita, 1996; Sell, 1997; van de Kragt, Orbell, & Dawes, 1983).

An interesting test of this approach is that it predicts that not knowing when the game will end will have little impact on cooperation rates since by hypothesis the cognitive structure of the mind embodies the assumption that all interactions will be repeated. On this view, the findings that there are high levels of cooperation in one-shot games (e.g., Marwell & Ames, 1979, 1980) and the fact that there is no change in behavior when the endpoint of a public goods game is not known (Chen & Komorita, 1994; Komorita, Chan, & Parks, 1993; Rapoport, 1990) are much less surprising.

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[48] These findings are also largely consistent with domain general rational choice models and so do not allow one to choose between such models and the social contract view. The caveat "largely" is needed because pure game theoretic models predict zero contributions under any MPCR less than one, and so technically can not account for these data. Rapoport's (1988) model, based on game theoretic principles, can handle this result, however.

Beyond social exchange: Cooperation in groups. The reciprocal altruism model is instructive in considering adaptations for cooperation in the context of interactions between two individuals. However, the solutions that can explain the evolution of cooperation in dyads do not necessarily apply to large groups. So, separate models for the evolution of cooperation in groups are needed (Boyd & Richerson, 1992).

In much the same way that the prisoner's dilemma was used to formalize the analysis of cooperation in dyads, public goods games have formed the basis of some models of cooperation in groups. On their surface, these models indicate that people should not provision public goods because a better strategy is to free ride, allowing others to provide the good. Olson (1965) was among the first to propose ways in which the public goods problem could be solved. He suggested that a public good could be provided in cases where the benefit of the good, once produced, disproportionately benefited one of the group members. Then, if the benefit generated by the production of the public good to the single individual offset the cost of that individual providing it, the good would be provided and others would benefit from the public good as well. In his own words, Olson maintains that public goods will be provided "...when it is in the interest of an individual unit in a group to act in the interest of the group as a whole" (p. 26-27). Note here that "unit" can be a subgroup within the larger group as well as a single individual, and is sometimes referred to as a "privileged" group.

This leads Olson to argue that provisioning of a public good gets harder as the largest share of the benefit of the public good to one member decreases: "The smaller the F_i's [fraction of the benefit of the good to agent i]...the more serious the sub-optimality [in public good production] will be" (p. 28). Since the magnitude of this fraction tends to decrease as groups get larger, Olson suggests that producing public goods becomes increasingly difficult as groups get larger, a conclusion consistent with later game theoretical modeling (Boyd & Richerson, 1988, but see Oliver, 1980, and Isaac & Walker, 1988). Thus, if one agent receives a disproportionate return on public good provisioning, this agent may provision the good to the benefit of all.

Since it is not clear when this situation obtains, other authors have tried to discover alternate routes to cooperation in groups. Much of this work has emphasized the punishing of non-contributing group members as a relatively cheap way to induce cooperation. However, this leads to a higher-order public goods problem, since provisioning punishment itself represents a public good (Axelrod, 1986; Boyd & Richerson, 1988, 1992; Oliver, 1980).

A number of authors have approached this issue and suggested that using punishment as a solution to the problem is nevertheless at least in principle tractable. Hirschleifer and Rasmusen (1989) suggest that excluding non-cooperators from future group interactions is one way to achieve cooperation in an N-player prisoner's dilemma. However, their model assumes that expulsion is costless, and they admit that their strategy "banishment," the strategy that in essence solves the problem, is not an equilibrium strategy if this assumption is violated. In essence, this work eliminates the second-order free riding problem by assuming it away. However, in real biological systems, it may not be costless to enforce this type of punishment. There is no reason to expect that agents should give up access to benefits if they can play a strategy of taking benefits without paying any costs.

A related approach is one taken by Boyd and Richerson (1992), who similarly use an N-player prisoner's dilemma environment. They consider first the case where second-order defection (not punishing punishers) is not allowed and suggest that cooperators and punishers of non-cooperators can be stable in such a population under particular conditions. They show that when second-order defection is possible, "moralistic" strategies, ones that cooperate, punish non-cooperators, and punish non-punishers, can be evolutionarily stable. There are a number of restrictions and assumptions that must hold for this to be a workable model, and Boyd and Richerson add the caveat that their "moralistic" strategy has difficulty getting started in a population.

In sum, it is not clear that game theoretic modeling has provided a complete account of the evolution of cooperation in non-kin groups, and the search for a good model continues. Existing models do, however, point up the importance of solving the free rider problem, the possibility of using punishment as a solution, and the importance of solving the second-order free riding problem.

The warfare model. Recall that the success of the prisoner's dilemma as a model for the evolution of cooperation is due to the fact that it accurately reflects properties of the environment in which humans evolved. It is not clear that the same can be said for models that purport to explain the evolution of cooperation in groups. It seems at least plausible that the relative failure of these models derives from the fact that they might not capture important features of ancestral environments. For example, models such as Boyd and Richerson's (1992) do not specify what, exactly, the products of cooperative moves are in their environment.

A more productive approach might be to ask what adaptive task individuals were solving by cooperating in groups or, more precisely, what problem systems that in modern environments generate cooperative behavior in (non-kin) group contexts were designed to solve. A number of possibilities suggest themselves. Hunting is an obvious candidate, and the fact that other species hunt in groups (e.g., some felines, canids) is suggestive. While it seems likely that this was indeed a selection pressure on the hominid line, it does not seem that hunting is a sufficient pressure to explain all the features of the human psychology of groups, including ethnocentrism and related phenomena (e.g., Campbell, 1965).

Another possible selection pressure is intergroup conflict, and Tooby and Cosmides (1988) have developed a model that focuses on intergroup aggression, or warfare, that seems to be a good candidate for explaining the features of adaptations for cooperation in human groups. The model begins with the observation that cultures across the span of human history have produced groups that have chosen to engage in violent conflict with other groups. The ubiquity of the phenomenon makes it plausible that there may be a suite of adaptations designed exactly for this purpose. This idea is reinforced by the historical and cross-cultural finding that the stakes of warfare are often direct access to reproductive females, obviously a critical limiting factor of male reproductive success (e.g., Chagnon, 1988).

Tooby and Cosmides (1988) argued that the reason that warfare is relatively infrequent in the rest of the animal kingdom is that there are large computational barriers to developing a set of mechanisms that is capable of the large-scale cooperation necessary for group aggression. They suggest that there are not only the same barriers that exist for reciprocal altruism, including the very important problem of detecting and deterring cheaters, but also a set of barriers that emerge from the computational complexities of cooperation in multi-individual groups (recall the discussion of the multi-player coordination game above).

Nonetheless, they suggest that there are specific adaptations designed for the purpose of intergroup conflict, including mechanisms that are capable of the detection and punishment of cheaters and of fulfilling the necessary functions of coordination. Tooby and Cosmides (1988) claim that, given a set of mechanisms that can perform these functions:

> It can be shown that given 1) certainty of victory, 2) the assurance of a random distribution of risk of death among participants, 3) the assurance of a relatively "fair" allocation of the benefits of victory, and 4) efficiency in the utilization of reproductive resources on a zero-sum basis, *selection will favor participation in the coalitional aggression regardless of the existence or even the level or mortality (within broad limits).* (p. 6, emphasis original)

In sum, the "risk contract of war" (RCW) suggests that, in principle, there can be selection for adaptations designed for cooperation within groups for the purpose of intergroup conflict even if death is a possible outcome for the participants. This argument hinges on a critical fact about male reproduction: that total reproductive success of a particular group (and therefore the average reproductive success of members of the group) is a function of the number of females, not the number of males (as long as at least a single male is in the population). So, as males are lost in a population, the average reproductive success of males remains constant, while for females, average fitness decreases with the number of female casualties.

In passing, it should also be noted that the constraints in the quotation above may not be as onerous as it seems at first glance. Constraints one through three can be put in probabilistic terms rather than certainties. In the end, the probabilistic benefit structure and the probabilistic payoff structure must yield a positive individual payoff. So, for example, as the certainty of victory decreases, the magnitude of the benefit would have to increase to compensate. Other similar adjustments could compensate for a limited amount of play in the distribution of risks and benefits. Indeed, Olson's (1965) view and the solutions to the public goods problem suggest that it may be important that rewards be shared unequally instead of equally to ensure that there is a core group that can and will provision punishment of defectors. Lastly, it might be possible to relax the restriction on the randomness of the distribution of risk largely for the same reason. Relaxing these conditions makes the RCW an even more attractive model for the evolution of cooperation in groups.[49]

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[49] One of the most important insights of the RCW is not restricted to warfare. That is, any activity where the *probability of exclusion* (the probability of not consuming any of the benefit at all) is shared equally among all participants will lead to the same formal structure as the risk contract in the sense that this potential

Adaptations for Intergroup Conflict

On the RCW argument, there are practically always opportunities to gain from group cooperation if there are other individuals in the environment to exploit. To reap these gains, both the coordination problem and the free rider problem must be solved. Solving the coordination problem is necessary for successful group endeavors, and solving the free rider problem allows for the evolution of mechanisms that are designed to incur costs (possibly in the form of risks) to achieve the group goals.

The coordination problem. The coordination problem is of course not unique to the RCW. Adaptations for enabling coordination might exist by virtue of a number of adaptive problems, including those associated with benefiting kin and engaging in reciprocal altruism. The Theory of Mind system is a likely candidate for a set of adaptations that function to solve the coordination problem in multiple contexts. Similarly, language might have been selected for in part by virtue of its ability to solve coordination problems in a number of domains.

However, as argued above, the real-time demands of multi-individual action put additional requirements on the cognitive system if the coordination problem is to be solved for activities such as warfare and hunting, discussed

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cost can be removed from consideration. This derives from the fact that natural selection only sees average reproductive outcomes.

above. Are there adaptations for coordination that exist solely, or at least largely, to solve the coordination problem in groups?

It seems that this is likely. As argued above, adaptations designed to generate and appreciate rhythms might serve the function of coordinating groups, although the present studies do not lend any support to this claim. Another possibility is that adaptations for "leader" and "follower" psychology exist in part because the presence of a leader allows for efficient coordination. This proposal is attractive because leadership psychology may also be an important component of solving the free rider problem, discussed below.

In short, the specific nature of adaptations to support coordination in groups remains mysterious. This question has not been studied in the lab extensively because the format of experimental games often solves the coordination problem by virtue of its structure. That is, the "cooperate" move in the prisoner's dilemma and the "public account" in the public goods game provide straightforward means to benefit others. By providing these options, the heart of the coordination problem, finding actions that deliver benefits, is solved.

In a few cases, a modified version of the coordination problem arises when experimenters provide subjects with an environment in which the (Pareto) optimal solution is not simply for everyone to contribute maximally to the public good. Consider, for example, the case in which a step-level public good is provided if at least three out of five individuals contribute their endowment. Here, the problem is how to get the exact number of contributors needed. Under these conditions, the free rider problem is replaced with the coordination problem because when the good is provisioned optimally, no one has an incentive to switch from contributing to not contributing (after van de Kragt, Orbell, & Dawes, 1983).

An interesting finding is that face-to-face communication is extremely effective in these circumstances (van de Kragt, Orbell, & Dawes, 1983). In several studies, allowing communication does not necessarily increase contributions (for instance, in cases in which if everyone contributes an inferior outcome for the group members is likely), but does lead to an effective solution within the group allowed to communicate, with groups attaining efficiency rates of 90% or more (Bornstein, 1992; Bornstein, Rapoport, Kerpel, & Katz, 1989; Rapoport & Bornstein, 1989) Findings such as these lend weight to the claim that the value of communication is to be found, at least in part, in its ability to coordinate actions.

The free rider problem and the commitment problem. For the RCW to function, the free rider problem must also be solved. There are two interesting avenues by which this might be accomplished: commitment and punishment. In many circumstances, (binding) commitment is not a particularly good strategy. Consider a typical public goods game. By unilaterally committing to contributing, a player is in essence committing to getting exploited and removing the possibility of using his own contribution as an inducement for others to contribute. Human psychology seems well attuned to this fact. Recall Chen and Komorita's (1994) condition in which players were required to make commitments that were binding on them alone. In this situation, commitments (and contributions) were extremely low.

However, there are cases in which commitment can actually be helpful. Recall that in the chicken game or the coordination game, committing to a particular move can lead to a better payoff to the player who (believably[50]) commits.[51] That is, the availability of a commitment option can help to "solve" the problem. A stylized public goods game illustrates how this idea can be applied in the context of groups. Consider a game with N players each given an endowment E in which if a minimum *m* of them contribute their endowment, each contributor receives a bonus B, with $N > m$ and $B > E$. Endowments that are contributed are lost whether or not the bonus is successfully provisioned. There are two phases, the commitment phase and the contribution phase. In the

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[50] Commitment is of no value unless it is known and believed by other players.

[51] The real-life situation from which the chicken game is derived illustrates this. If two cars are speeding toward each other, and driver A removes the steering wheel and throws it out the window so that driver B can see that A has taken away his own ability to maneuver, driver B is forced to turn away, giving A the "victory."

commitment phase, a player can commit to contributing in the subsequent phase. The commitment phase continues until all players have decided to commit or not (players can see other players' commitments). Now, when *m*-1 players have committed, since B > E, a player does better by committing than not committing. So, when *m*-2 players have committed, committing is also favored because players know that when there are *m*-1 players, other players have an incentive to commit, and so on. So, by the process of induction, allowing a strategy of commitment enables the bonus to be provisioned.

This game is intended to model a situation in which there is some critical minimum number of individuals needed to accomplish a particular group goal, a situation which may or may not characterize evolutionary environments.[52] Under these conditions, the availability of a commitment strategy supports cooperation.[53]

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[52] There is some reason to believe it does. It was probably the case that intergroup conflicts were won by the side with more individuals (Tooby & Cosmides, 1988). Thus, if the number of other individuals was known, the number required for victory was also known. Technology has, of course, changed this feature of conflict in the modern world.

[53] It is possible that the evolution of adaptations for commitment was aided by the processes of "deep engagement" described by Tooby and Cosmides (1996). As

The effectiveness of this idea in experimental games, if not in an evolutionary sense, is illustrated by Chen, Au, and Komorita's (1996) experiments in which moves were sequential – players had information about what some fraction of the other players' moves were before they were forced to make their own decisions.[54] In six cells in which players had information such that they could infer that their contribution would not by itself provision the good, but would put a subsequent player in the position that that player's contribution would be sufficient, contribution rates were roughly 75% (see Fleishman, 1980, for a similar finding).

A second and possibly related solution to the free rider problem is found in Olson's (1965) idea of a privileged unit. If an agent has a strong interest in provisioning a public good, it seems plausible that this agent would be willing to incur the costs of provisioning punishment as a route to generating the good. Such an agent would be one who could wield coercive power to punish[55] non-

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one group member A comes to value the outcomes of other group members, so member A becomes more valuable to the other group members.

[54] Actually, this information was faked, but the subject could assume the information to be true.

[55] The (genuine) commitment to punish can be as effective as the commitment to cooperate.

cooperators, and would enjoy a differential share of produced public goods. In essence, this is the description of a dictator.

The idea of using a dictator to solve the public goods problem is not a new one. Indeed, the suggestion can be traced back at least as far as 1651 with the publication of Hobbes' *Leviathan*. More recently, a number of authors have made proposals that resonate well with Hobbes' idea of an absolute dictator. Axelrod (1984), for example, notes the possibility of a "central" player who "would have a greater unilateral incentive to be vengeful against defections" (p. 1104). In addition, Boyd and Richerson (1992) propose a similar solution: "Consider, for example, strategies that punish but do not cooperate. Such individuals might be able to coerce more reluctant cooperators than cooperator-punishers, and therefore support cooperation in still larger groups. If so, such models might help understand [*sic*] the evolution of groups organized by full-time specialized, 'parasitical' coercive agents like tribal chieftains" (p. 185).

Thompson and Faith (1981) propose a central figure in the experimental literature as a solution to the commitment problem. In essence, they suppose that there is a dictator who can punish anyone else if they don't follow their (that is, the other players') committed cooperative strategy, and they back up the plausibility of the existence of such a dictator with their claim that "in the real world, almost any healthy adult can inflict damages on almost any *single* other individual to the extent that the victim would prefer serving as a slave to suffering the damages" (p. 373, emphasis original).

The similarity of these conclusions is suggestive. Olson's arguments for a privileged unit together with conditional punishment strategies converge on the idea that if it is in the interests of one individual (or set of individuals) to provision a public good, or, perhaps less restrictively, in the interests of one or more of the cooperators to punish those who don't cooperate, possibly in part by punishing those who do not punish non-cooperators, cooperation can evolve. Empirical evidence as well as formal modeling suggest that the dictator concept is workable (Vehrencamp, 1983).

Note that punishment of defectors might be an important issue in groups not just because of its importance in solving the free rider problem, but also because defection in group contexts might be particularly disastrous. Consider that the coordination of multiple individuals is an extremely complex process, and hugely anti-entropic. For this reason, it is relatively easy to disrupt its order and the consequences of this disruption are likely to be severe. This means that the importance of commitments to punish defectors in group contexts might be particularly significant, even beyond its importance in the models described above.

In sum, there are a number of adaptive problems that might have generated psychological mechanisms that support cooperative behavior. These problems include delivering benefits to kin, reaping gains in trade, and engaging in intergroup conflict. Although a great deal more work will be needed to determine the nature of the psychological mechanisms designed to solve these problems, this analysis points in particular directions for the search.

From Problems to Solutions to Designs: Revisiting the Literature

The analysis of the problems associated with the RCW and the possible solutions to these problems yield some general predictions about the nature of the psychology designed for cooperation in groups. In particular, the foregoing indicates that commitment, punishment, and coordination represent key problems that components of systems supporting cooperation must be able to solve. This analysis suggests that there should exist specific psychological mechanisms that are designed to induce one to:

1. Join groups.[56]
2. Commit oneself to a group and communicate one's commitment to the group.
3. Commit oneself to bearing costs to punish defectors against one's group.

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[56] I omit here a consideration of the important topic of the ontological status of "groups." For current purposes, the term group should be interpreted in its intuitive sense.

4. Bear costs to punish defectors against one's group.
5. Detect and evaluate others' commitments to a group and commit oneself to the extent that others have.[57]
6. Detect and monitor others' costs (possibly in the form of risks) endured for the benefit of the group.
7. Detect and monitor distribution of benefits that have been obtained by virtue of group activity.
8. Detect the ability to coordinate well with group members.
9. Monitor the existence of other groups.
10. Regard as threatening groups to which one doesn't belong.
11. Monitor the standing of one's group relative to other relevant groups (especially with respect to formidability, size, commitment of members, and ability to coordinate).
12. Tolerate disproportionate benefits to leaders in exchange for their role in coordination and in punishing defectors.
13. Activate these systems and change cost/benefit decision weightings differentially in the presence of other groups.

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[57] This is probably complicated. There might be a tension between undercommitting, which might not induce others' commitments optimally, and overcommitting, allowing one to be exploited by a group.

This list of course represents only a partial account of possible psychological design features necessary for generating cooperation in groups. Even so, it is worthwhile to briefly examine these proposals to check to see if they at least pass first muster for plausibility, while simultaneously revisiting some of the psychological literature in the context of these hypothesized systems.

Joining groups. The claim that there are psychological systems designed to induce people to join groups might seem trivially true given the vast amount of data from psychology and anthropology that people everywhere form groups. However, a substantial literature in social psychology suggests that the dynamics of group interactions can be understood with respect to very general processes, especially categorization (Brewer & Harasty, 1996; Hamilton & Sherman, 1994; Smith & Zarate, 1990; Tajfel & Turner, 1979; Turner et. al., 1987). Although categorization processes appear to play a role in group interactions (e.g., Tajfel, Billig, Bundy, & Flament, 1971), it seems extremely unlikely that the same principles that give rise to categorizing objects will be able to explain the intricacies and dynamics of the interactions between groups. The exact nature of adaptations for group interactions and their specificity remains a vast empirical question.

Commitment. Are there specific mechanisms designed to commit oneself to a group and communicate this commitment? Frank (1988) has suggested that a potentially interesting place to look for systems designed for commitment is emotions. He claims that "specific emotions act as commitment devices that help resolve these [social] dilemmas" (p. 4-5). One possibility is that mechanisms that support phenomena associated with "social identity" [58] are "strategic emotions" of this type, designed to commit oneself to a group (Dawes, van de Kragt, & Orbell, 1988, suggest something along these lines). The behavioral consequences of identification with groups has some interesting features that lend credence to this speculation. Certainly, there are affective components associated with membership in groups -- it is not an accident that "fan," a term denoting one's enthusiasm for a particular group, is short for "fanatic." More generally, the link between groups and strong affect is well documented across cultures (e.g., Campbell, 1965; Horowitz, 1985)

Recall that the experimental data indicate a strong relationship between commitments made in group discussion and actual contribution decisions and that there is some indication that this relationship is mediated by social identity (Brewer & Kramer, 1986; Chen, 1996; Orbell, van de Kragt, & Dawes, 1988; Wit & Wilke, 1992), although this is not always the case (Bouas & Komorita, 1996;

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[58] On the account described here, "social identity" is not the best way to describe the hypothesized set of mechanisms. A term such as "group engagement" or "group commitment" might be more appropriate. I continue with "social identity" in deference to tradition.

Kerr & Kaufman-Gilliland, 1994). Taken together, the results of a large number of experiments indicate that solving the commitment problem is critical to increasing contributions, and that building social identity is one way, but not the only way, that the problem is solved.[59]

Of course, the importance of social identity as an important suite of mechanisms designed for commitment is dependent on the existence of systems that cause one to advertise one's commitment.[60] Some evidence for this is the extremely common practice of group members of adorning themselves with "badges" of that particular group (Caporael, Dawes, Orbell, & van de Kragt, 1989, make a similar suggestion). Interestingly, in military contexts, where one would expect adaptations for intergroup conflict to be most strongly activated, one often finds tattoos, a (mostly) permanent commitment to a particular group.[61] It should

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[59] Chen's (1996) results illustrate this nicely. Face-to-face communication, which was found to increase social identity, increased cooperation to the same extent as providing a group-level binding pledge.

[60] The "of course" here might be presumptuous -- Dawes, van de Kragt, and Orbell (1988) suggest that deceptive commitment is not a problem because of the difficulty of maintaining the deception.

[61] The psychology of commitment to groups is no doubt complex. At the risk of wholesale speculation, other activities such as the performance of intricate rituals

be noted that on this account, badges are not merely costless signals, and therefore useless. To the extent that the psychology of groups is designed to be suspicious and fearful of members of outgroups, decorating oneself with a badge puts oneself at potential risk from members of other groups (Brase, 1997).

In general, it seems as though it is at least possible that a portion of the psychology of groups is a system to commit oneself to a group and advertise this fact. Additional research is needed to clarify how precisely social identity mechanisms function and the circumstances in which they are active.

Punishment. Is there a specific psychology of committing to punish and actually punishing members who defect against the group? Certainly there is evidence in the experimental literature that subjects are willing to endure costs to punish those who have not cooperated in ultimatum games (Bolton & Zwick, 1995), extensive form bargaining games (Rutherford, Kurzban, Tooby, & Cosmides, 1997), and public goods games (Yamighishi, 1986). Indeed, it is also clear that people have moral intuitions about equity and justice and have extreme negative reactions when these principles are violated (Tyler & Smith, 1998). It is

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and the public espousal of what would otherwise be absurd belief systems might also be components of advertising one's commitment to a group. In addition, the idea that permanent "badges" might help commitment to groups might be relevant to understanding the ease with which racial groups form and persist.

not difficult to imagine that these intuitions and reactions to the violations of ethical principles are components of a psychology designed to punish defecting group members.

From the real world, there is a great deal of cross-cultural evidence that defectors against groups are dealt with in the harshest of terms, a finding with some empirical support as well (Rabbie, 1992). In military as well as other contexts, the penalty for treason or even cowardice (which can be seen as a refusal to accept equal risk) is often ostracism or sometimes death. Although this evidence is suggestive, it does not, of course, establish definitively that there are specific adaptations for punishment in a group context. Such a suggestion seems, however, quite plausible.

Detecting commitments. The RCW suggests that we should expect design features that cause individuals to endure costs to benefit the group to the extent that they have reason to believe others are also willing to endure these costs. So, for example, players in a public goods game on this theory should not feel "free ridden" if they have contributed half of their allocation as long as others have as well.

Indeed, this idea is so firmly entrenched in human psychology that it has led to some errors on the part of certain researchers in the field. For example, in a recent review, Komorita and Parks (1995) suggest that people "would be foolish to contribute if we [people] believed no one else was going to do so" (p. 193). In fact, from the perspective of game theory, players are "foolish" whenever they contribute *regardless* of how many others are going to do so. Giving up one's contribution in a standard public goods game is always incurring a cost to the self to benefit others.

There is strong evidence that people are willing to contribute as much as but not more than others in a public goods environment. The evidence reviewed above indicating that there is a correlation between players' expectations of others' contributions and their own subsequent contributions is of course suggestive. Also recall Chen and Komorita's (1994) condition in which commitments were binding at the group level. In this situation, players' commitments and contributions were high, indicating that players are willing to commit to the extent that others do. Additional tantalizing evidence of a link among cooperation, commitment, and the risk contract comes from Dawes, Orbell, and van de Kragt's (1988) finding that promises were only effective when they were unanimous.

Another line of evidence suggesting that commitment is important derives from the observation that contributions tend to decline over time in public goods experiments. If contributing *no more* than other group members is important to subjects, then participants contributing more than the average each round should tend to decrease contributions in subsequent rounds, while players contributing at or below the average will not change their contribution rates.[62] This of course sets up an inevitable spiral process. As long as there is some variability in contributions, some fraction of the participants will have contributed more than the average. If these participants roll back their contributions slightly while the other participants keep their contributions constant, the inevitable result is a downward slope to zero.

There is direct evidence that this occurs in at least some experiments. Andreoni (1995) included a condition in a public goods game in which participants were explicitly told where their contributions ranked with respect to other group members' contributions. If the spiral process were responsible for decreasing contributions over time, this condition should lead to a faster drop because over-contributing is completely transparent when this information in provided. In fact, contributions did slope downward significantly faster. By round four (of a ten-round game), contributions in this condition were roughly half those in a control condition and less than a quarter of contributions in the control condition by round nine. Also, recall Wilson and Sell's (1997) intriguing

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[62] This ignores the effect of decision rules that call for subjects to ensure they contribute *no less* than the average, as part of the psychology of solving the commitment problem. Which hypothesized decision rule exerts the greater force likely changes with context.

finding that contributions in a multi-round game were higher when subjects were not given any information about what other subjects had contributed in previous rounds, suggesting that this information tends to drive contributions down when it is provided.

Monitor costs. There is ample evidence that people are interested in ensuring that others are putting forth sufficient efforts for attaining shared group goals and punishing those who do not (Sherif, 1956; Tyler & Smith, 1998; Yamagishi, 1986). For purposes of the RCW, a more interesting issue is peoples' stance toward sharing of risks. An obvious real-world example of the expression of the psychology of the spreading of risks is the simple observation that people in the military are garbed in uniforms, the word itself of course capturing the distribution of risk that individuals are supposed to be running.

Results from the laboratory in which a small number of individuals are needed to make a sacrifice for the group are suggestive. In these situations, people seem quite willing to settle the issue by lottery, even abiding by the result when the decision to sacrifice or not is made in private (van de Kragt, Orbell, & Dawes, 1983).

Monitor benefits. There can be little doubt that people are extremely concerned with the equitable division of benefits, and there is copious evidence that people have strong moral intuitions about sharing, equity, and equality (e.g., Tyler & Smith, 1998; Van Lange, 1992; Walster, Walster, & Berscheid, 1978).

There is evidence from the experimental literature that supports this general conclusion. For example, in one public goods game in which benefits were necessarily going to be unequally distributed, contributions were very low, less than a third of those found in a more traditional game (Andreoni, 1995; see Yamagishi & Sato, 1986, for a similar finding).

Coordination. Very little can be said about psychological systems designed to detect the extent to which individuals are able to coordinate with other members of groups, the focus of the current studies. However, the results obtained from the present studies are at least suggestive in this regard, indicating the need for further research in this area.

Outgroups. If the psychology of within-group cooperation is designed in part for between-group competition, then it is reasonable to assume that groups to which one does not belong are potential threats. Indeed, to the extent that these groups are large and coordinated, the threat is more serious. Is there evidence that people are sensitive to the existence of other groups and find them threatening?

Again, the psychological and anthropological evidence are quite clear on this issue. Xenophobia and ethnocentrism are known to be universal aspects of human cultures (e.g., Campbell, 1965; Horowitz, 1985), and psychological data that outgroups are less trusted (e.g., Brewer, 1979), more feared (Schopler &

Insko, 1992), and more likely to behave competitively (Kramer & Messick, 1998) leave little room to doubt that this is largely true.[63]

Relative group standing. If it is presumed that groups are "for" competing, then the whole point of being in a group is to ensure that the group one is in is superior to other relevant groups. Again, support for the importance of relative group standing is overwhelming in the experimental literature, and it is not uncommon to find that subjects are willing to incur a cost to themselves in order to ensure that the members of their group receive outcomes (in aggregate) that are greater than the outcomes received by the other group (e.g., Bornstein et al., 1982[64]; Bornstein, Mingelgrin, & Rutte, 1996; Brewer, 1979; Lemyre & Smith, 1985). A consistent finding in the groups literature is that subjects play more "competitively," attempting to ensure relative superiority of outcomes when they

[63] Actually, despite what seems to be an avalanche of evidence, the conclusion that these effects are due to specific mechanisms for intergroup conflict *is* in doubt. Kramer and Messick (1998) conclude that "many of the social-cognitive correlates of collective paranoia reflect rather ordinary social information-processing goals and motives gone awry" (p. 249).

[64] Interestingly, evidence for maximizing relative advantage in this paper was restricted to male subjects.

are playing in or with groups (e.g., Insko et. al., 1990, 1994; Sherif, 1956; Tajfel, 1982).

Toleration of leaders. The role of leadership in the psychology of cooperation in groups is as yet unclear. The fact that numerous models make reference to a "central player" or "privileged unit" is suggestive when taken together with the finding that people seem to be able to assume roles of superiors and subordinates so easily (e.g., Haney, Banks, & Zimbardo, 1973). Leadership seems to have the potential to solve both the coordination problem and the commitment problem simultaneously, making it an extremely attractive avenue for research. It seems likely, however, that the position (and tendency) of leaders to extract a disproportionate share of benefits obtained from group activity puts this system in conflict with mechanisms designed to enforce equality (or perhaps equity) of benefits. This suggests that the activation of leadership and followership might be highly context specific, emerging only under particular conditions in which a central player is particularly critical.

Some evidence supporting the context-specificity of leadership comes from a fascinating experiment by Messick et al. (1983), who gave subjects feedback that a resource pool from which they could draw rewards was either being overused or not. After being given this feedback, subjects were allowed to vote whether or not to have a leader dictate future resource allocation decisions.

When the pool was being overused, subjects were much more likely to vote to install a leader, presumably to coordinate future allocations.

Differential activation. On the RCW, the presence of another group should increase the extent to which the systems designed for cooperation in groups are activated because being exploited by other groups carries potentially extremely high costs, including the possibility of death. That is, belonging to a group and bearing costs to ensure that the group is viable and members are committed becomes much more important when one is in the position of being exploited by another group. Thus, the mechanisms described above should be easiest to see in situations in which a group is threatening or when one's own group is in a position to exploit another group.

Consistent with this analysis, Bornstein and Ben-Yossef (1994) point out that "…the most recurrent and explicit hypothesis of the intergroup conflict literature is that intergroup conflict increases intragroup cooperation" (p. 53). They also note Campbell's (1965) observations that under conditions of intergroup conflict, "punishment and rejection of defectors become more severe, more authoritative leadership emerges, and conformity pressures are intensified" (p. 54). These remarks echo Sumner's (1906) earlier but similar observation that "the closer the neighbors, and the stronger they are, the more intense is the warfare, and then the more intense is the internal organization and discipline of each" (Sumner, 1906, pp. 12-13, quoted in Rabbie, 1992). In the context of the

RCW and the analysis presented here, these observations are completely unsurprising.

Summary. Considering intergroup competition as a driving force of adaptations for within-group cooperation holds the promise of illuminating and systematizing at least some fraction of the vast literature examining the psychology of cooperation in groups. Future work can be benefited by consideration of the adaptive problems associated with within-group cooperation and plausible models for how these problems might be solved by humans' cognitive systems.

General Conclusions

Stepping back, the analysis of adaptations for solving the problem of cooperation in groups allows some general observations about when cooperation should be elicited in public goods games. Given the foregoing discussion, it should be possible to predict when one should see cooperation by virtue of how well the environment allows for systems designed to solve the free rider problem (or the commitment problem) and the coordination problem to operate.

Recall that many public goods environments already solve the coordination problem in the sense that the public account allows for members to benefit one another. So, we should expect cooperation in a traditional public goods game when the free rider problem is also solved. These situations might include:

1. When the other players are all close kin.
2. When subjects' perceptions of incentives change such that they infer that they are better off contributing than not contributing, such as when:
   a. There is a sequential contribution process, allowing forward induction.
   b. MPCR (or its equivalent) increases.
   c. There is a step-level good in which there exists a solution whereby subjects are made "critical" *and* coordination is made possible through communication.
3. When cheap punishment is available, solving the second-order problem.
4. When effective leaders can emerge.
5. When random procedures can be used to distribute risks.
6. When adaptations for commitment are activated through:
   a. Activation of "social identity" by virtue of the presence of a competitive group, perceptions of "common fate", or (perhaps) simple communication.
   b. The availability of an institution to enforce commitments.
   c. Providing information of others' commitments to the group in the past or likely commitment to the group in the future.

d. Providing evidence that subjects are part of a well-coordinated group.

This analysis also suggests that there are situations in which one should not expect increases in cooperation. These include games with unknown endpoints, games in which incentives favor contribution but are in a form not well handled by the cognitive system, and games in which pledges can be signaled but not enforced (unless supported by activation of social identity systems).

These expectations are, in general, well borne out by existing experimental data.[65] Additional work will be required to design experiments to give these predictions *ex ante* rather than *post hoc* evaluation.

Concluding Remarks

This work began with the hypothesis that the human cognitive system included mechanisms designed for the purpose of cooperating in groups and that inputs to these mechanisms included subtle movements suggesting the ability to coordinate actions. This hypothesis received partial support – cooperation in some public goods games increased when subjects were induced to emit these psychophysical cues of coordination, but this increase was found only for male subjects.

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[65] I omit specific references for this claim because evidence supporting it can be found throughout the "From Problems to Solutions" section above.

The study of such inferences about the social world is not new. Indeed, researchers have been looking at how the mind decodes "intentional" motion and the inferences that this motion affords for over half a century. In their classic study, Heider and Simmel (1944) asked observers to describe the movements of a number of simple geometrical objects such as triangles and squares on a screen. Overwhelmingly, subjects used intentional language, making reference to the beliefs and desires of the objects in question. From this study and others, it appears as though the psychophysics of motion seems to drive inferences of intentions, even in the face of strong evidence that the entities being assigned these intentions can not be "alive" in the traditional sense. Further, there is evidence that this inference system becomes functional extremely early in life (Gergely, Nadasdy, Csibra, & Biro, 1995; Premack, 1990).

Systematic investigations of these issues have largely been limited to populations of people with autism (Baron-Cohen, 1995) and young children (Gergely, Nadasdy, Csibra, & Biro, 1995). The experiments described here are an attempt to bring this research program into the domain of normal adult humans.

The findings from these studies are somewhat striking in that the manipulations that increased contributions in male subjects were subtle indeed -- no information in the traditional sense was communicated, and the cost/benefit structure of the game was constant across conditions. Interactions between rounds lasted literally only a matter of seconds. In addition, each participant knew that the only reason the other participants were behaving as they did was that they were instructed to do so by an experimenter.

These results are both encouraging, and, in some sense, alarming. They are encouraging in that team building and cooperation in groups may turn out to be a relatively easy process to facilitate, especially in men. Extremely subtle cues seem to induce males to increase the extent to which they are willing to sacrifice a portion of their own gain to benefit the rest of the group. However, they are also alarming in that it seems that males are ready to accept extremely scant evidence that they are in a meaningful group capable of cooperating.

If indeed male psychology is well designed for cooperating because of adaptations for intergroup conflict, then the ease with which males form cooperative associations is also the ease with which males can form groups for the purpose of intergroup conflict. This analysis points up the importance of understanding both the precursors and consequences of group formation and group processes. It is perhaps through our understanding of (potentially competitive) groups that the conflicts that have historically plagued society can be understood and thus avoided.

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Appendix

The general instructions for playing the Public Goods game were as follows:

Welcome. Instructions and messages will appear in this part of the screen. Since we have now begun, please keep your attention on your own computer screen and stay silent throughout this experiment unless otherwise instructed. To go to the next instruction screen, click on the button below.

It is important that you fully understand these instructions -- your actual payment will depend on the decisions you make. If you need to review any instructions, use the 'back' button at any time to return to previous instruction screens.

This is an experiment in the economics of group decision-making. You have already earned $2.00 for showing up at the appointed time. If you follow the instructions closely and make decisions carefully, you can substantially add to this total.

There will be ten decision-making periods in this experiment. In each period, you are given an endowment of Tokens. Your problem is to decide how to divide these Tokens into either or both of two accounts: a Personal Account and a Group Account.

Each token you place in the Personal Account generates a cash return to you (and to you alone) of one point. Tokens placed in the Group Account yield a lower return. However, every member of the group also receives that same return for each token you place in the Group Account.

Similarly, you receive a return for every token that other members of the group place in the Group Account. Thus, earnings in a decision period are the number of Tokens you place in your private account, plus the return from all Tokens you and other members of the group place in the Group Account.

Returns to the group account are listed in the table entitled Return from the Group Account. This table will be available for you to refer to during all playing periods. The numbers in the column labeled 'Tokens in Group Account' (one of which is currently highlighted in blue) show the possible number of Tokens contributed by all six players. The columns labeled 'You Earn' indicates how much you earn given each particular number of Tokens contributed to the Group Account.

Example: Here, a total of 24 Tokens have been contributed to the Group Account. So, in this round, you would thus get 8 Tokens from the Group Account in addition to the number of Tokens that you kept in your Personal Account. Each other player would similarly get 8 Tokens from the Group Account plus whatever they kept in their own personal accounts.

Each period proceeds as follows: First, decide on the number of Tokens to place in the private and in the Group Accounts by using the slider bar on the bottom of the screen. Note that the sum of your Tokens in both accounts will always be 10 Tokens, your endowment for each round. While you make your decision, the other members in your group will also divide their token endowments between Private and Group Accounts. Take a moment to familiarize yourself with the slider bar.

Second, after everyone has made a decision, the computer will calculate the total number of Tokens contributed to the Group Account and will report this information to you and to all the other members of the group.

Third, your earnings in a decision period are the sum of the Tokens you placed in your Private Account, and the return from the total of Tokens placed in the Group Account. The computer will calculate your returns from the Group Account according to the 'Returns from Group Account' table to the right. Your earnings in a period are the sum of your contribution to your Personal Account and your returns from the Group Account.

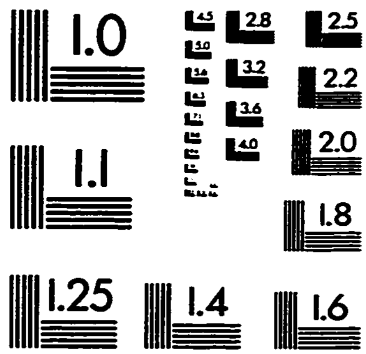
In each subsequent period, the same procedure will be followed. The table below will allow you to review the results from previous rounds. After the last period, your total from each period will be calculated by the computer. Each member of the group will individually proceed to the next room where you will receive an envelope with your earnings for the entire session.

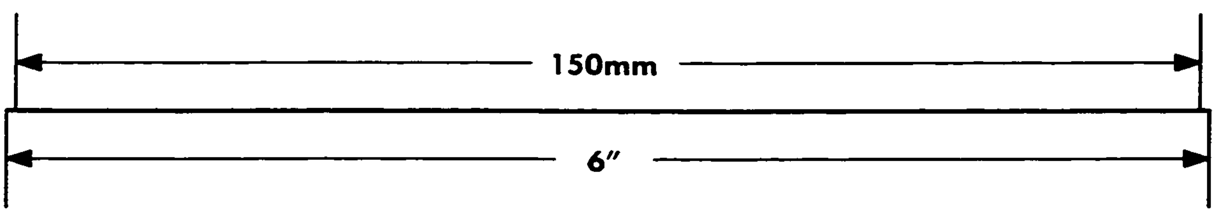
This is an example assuming that there are six players in the group. Let's say that three players each contributed 4 Tokens to the Group Account (and therefore kept 6 Tokens in their Private Accounts) and that three players contributed seven Tokens to the Group Account (and thus kept three Tokens in their Private Account). The total contribution to the Group Account for that round would be: (3 X 4) + (3 X 7) = 33 Tokens.

From the table, we see that each player receives a return of 11 Tokens from the Group Account. So, in this round, each of the three players that contributed 4 (and kept 6) would have earned 6 + 11 = 17 Tokens. Each of the three players that contributed seven Tokens (and kept 3) would receive 3 + 11 = 14 Tokens.

You have now completed the instructions. If you have any questions, raise your hand and ask the experimenter. Otherwise, click on the continue button. When you do so, you will exit the instructions. Please be sure that you have understood the instructions before continuing.

IMAGE EVALUATION TEST TARGET (QA-3)





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