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Abstract: Previous research has shown an 'interindividual-intergroup discontinuity effect': intergroup interactions generally lead to less cooperative outcomes than interindividual interactions. We replicate the discontinuity effect in the deterministic prisoner's dilemma, but find that groups are more cooperative than individuals in a stochastic version of the game. Three major factors that underlie the usual discontinuity effect were reduced in the stochastic environment: greed, fear, and persuasion power. Two group mechanisms are proposed to explain the reversed discontinuity effect: the motivation to avoid guilt and blame when making decisions that affect other's welfare, and the social pressure to conform to certain norms when one is in a group setting.

Key words: group decision, uncertainty, cooperation, experimental economics

JEL code: D81

Traditional game theoretical models focus on individuals choosing between alternatives, even though in many real-life situations, the decision makers are nations, firms, or families. It has long been known that we cannot infer group behavior directly from individual-level studies (see Davis, 1992 for a review), and groups behave differently from individuals with regard to judgmental biases (Kerr, MacCoun and Kramer, 1996; Bottom, Ladha and Miller, 2002), cooperation and competition (Insko et al. 1987), risk and uncertainty (Charness, Karni and Levin, 2007), trust and trustworthiness (Bornstein, Kugler, and Ziegelmeyer, 2004; Kocher and Sutter, 2005), and strategy learning (Sutter, 2005; Kocher and Sutter, 2007).

The current study examines the degree of group cooperation with uncertain outcomes, an important but largely ignored topic in both psychology and economics. The most related line of research studies a phenomenon labeled "interindividual–intergroup discontinuity effect": interactions between groups are generally more competitive and less cooperative than individual interactions in the context of mixed-motive matrix game,[1] usually the prisoner's dilemma game (for a review, see Wildschut et al., 2003). In the past two decades, this interesting individual-group difference with respect to cooperation has been well replicated in empirical studies in social psychology and experimental economics. The most recent example is Song (2008) in which the author replicates the basic discontinuity effect in a trust game and finds people trust less when they make decisions as representatives of 3-person groups than when they make decisions for themselves only.

To our knowledge, no research has been conducted on the degree of group cooperation under uncertainty or whether the interindividual-intergroup discontinuity effect

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1 Mixed-motive matrix game is defined as "any game in which the players' preferences among the outcomes are partly coincident and partly opposed, motivating the players both to cooperate and to compete, as in the Prisoner's Dilemma game." (Colman, 2001)

exists when outcomes are uncertain. There are at least two reasons why we may not be able to generalize the discontinuity effect found in deterministic games to a stochastic environment. First, previous research has found that groups have a tendency to behave in a more extreme manner when outcomes are uncertain than if individuals make choices on their own. This phenomenon, known as group risk and cautious shift, or group risk polarization, has been studied extensively by social psychologists (Stoner, 1961; See Isenberg, 1986 for a review). Depending on the risk attitudes of individual members of the group, groups may make more conservative or aggressive decisions than individuals. For a more detailed discussion on the general group polarization process, see Isenberg (1986).

Although most group risk polarization research was conducted by psychologists asking subjects' risk preferences directly, the group risk preference polarization has been confirmed by experimental economists inferring subjects' preference from their decisions using monetary incentives. For example, Shupp and Williams (2008) ask both individuals and three-person groups to evaluate lottery tickets that have a 10% to 90% of chance of winning $20 for individuals and $60 for 3-person groups. They find that "the average group is more risk averse than the average individual in high-risk situations, but groups tend to be less risk averse in low-risk situations." This behavior is consistent with group polarization theory, since in the same study they also find that individuals are more risk averse in high-risk situations than in low-risk situations. Individuals' risk-aversion tendency in high-risk situations and risk-seeking tendency in low-risk situations are enhanced and polarized by the group process. Therefore, the average group becomes more risk-averse (risk-seeking) than the average individual in high-risk (low-risk) situations.

If group risk preference polarization can be generalized to a strategic setting under uncertainty, such as a stochastic prisoner's dilemma in which cooperation reduces risks and is considered the more risk-averse strategy, we would predict that groups are less cooperative than individuals only if the majority of individual players have a tendency not to cooperate. Otherwise, groups may cooperate more than individuals if the majority of individual players have a tendency to cooperate. This group polarization prediction partially conflicts with the prediction of the discontinuity effect, because if we assume that the discontinuity effect can be generalized to scenarios under uncertainty, then we would expect groups to be always less cooperative than individuals, independent of how individual members of the group feel about cooperating.

Another reason why we cannot generalize the discontinuity effect from the deterministic to a stochastic setting is that previous studies report that individual players learn to cooperate more slowly and in general cooperate less in stochastic prisoner's dilemmas than in deterministic prisoner's dilemmas (Bereby-Meyer and Roth, 2006). In Berger and Hershey (1994), subjects are less likely to contribute to a public good when returns are stochastic rather than deterministic. Since our focus here is comparing intergroup and interindividual differences under uncertainty, the difference in behavior of individual players in the stochastic game and deterministic game complicates the comparison.

To summarize, when uncertainty is introduced into the picture, we cannot simply assume that the discontinuity effect still holds and groups are less cooperative than individuals. Our research is a preliminary investigation of how uncertainty affects the interindividual-intergroup discontinuity effect. Specifically, we study group cooperation in a two-party game where a party is either an individual or a group and the cooperation of one party reduces the risks of both parties. Mutual cooperation completely removes the risk for both parties.

The paper is organized as follows. Section 1 presents the experimental design and procedure. Two games, a deterministic prisoner's dilemma and a stochastic prisoner's dilemma, were played with individuals and 3-person groups as player types. The study was a

2x2 between-subject design [(2 game types) X (2 player types)]. The study results and data analysis are reported in Section 2. We found that there was an interaction between the game type and the player type: groups are less cooperative than individuals in the deterministic game, but more cooperative than individuals in the stochastic game. The effects were significant and large. Sections 3 and 4 compare our findings with previous research, and provide evidence from survey questionnaires and recorded discussion as to the underlying mechanisms of the phenomenon. Three major factors, greed, fear, and persuasion power that underlie the usual intergroup competitiveness, were reduced in the stochastic environment. Two group mechanisms were proposed to explain group cooperativeness under uncertainty: the motivation to avoid guilt and blame when making decisions that affect other's welfare, and the social pressure to conform to certain norms when one is in a group setting. Section 5 concludes and discusses future extensions. We believe that the findings in the current study will serve as a starting point towards integrating three important factors in many social dilemmas -uncertainty, cooperation, and group decision, and have prescriptive implications in encouraging cooperation to improve social welfare in the real world.

1. Experimental Design and Procedure

1.1 The Games

Two games were played in the current study: one stochastic prisoner's dilemma (SPD) and one deterministic prisoner's dilemma (DPD).

The SPD game adopts the structure of the Interdependent Security (IDS) game proposed by Kunreuther and Heal (2003) and extends IDS experiments with individuals (Kunreuther et al., 2008) to group decision-making. In an IDS game each player decides whether or not to invest (incurring an investment cost) to reduce his or her own risk of experiencing a larger loss. If one player invests, both players' risks are reduced, but the investor's risk is reduced more than her counterpart's. Joint cooperation (both investing) eliminates uncertainty completely and each incurs the investment cost only. As shown in Heal and Kunreuther (2007), a variety of problems fit into the interdependent security game model, such as airline security, bankruptcy of an entire company caused by a catastrophic loss from one of its divisions, etc. The stochastic prisoner's dilemma (SPD) is a special case of the Interdependent Security game.

The SPD game matrix is shown in Table 1. Negative numbers represent losses. Percentages are probabilities of various outcomes in certain decision combinations (cells). We used an experimental currency, Taler, with an exchange rate of 1 Taler=2 cents in the individual game, and 1 Taler=6 cents in the group game where a group consisted of three individuals making a joint decision.[2] Subjects were told at the beginning of the experiment that their payoffs would be based on a show-up fee ($10) and might also be based on their performance in the game.

[Table 1 about here]

By removing the uncertainty and substituting the four cells in the SPD game with the expected values, we have the corresponding DPD game as shown in Table 2. The Nash equilibrium assuming risk neutrality and using expected values is (Not Invest, Not Invest).

[Table 2 about here]

1.2 The Players

There were two kinds of players: individuals and groups. When two individuals played against each other, each person made a decision simultaneously as to whether or not to invest. In the group experiment the three subjects within each group made a collective decision and shared the final payoffs equally among the group members. Subjects were instructed to make unanimous decisions or use a 2 to 1 majority rule to specify their course of

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[2] The difference in the value of the Talers for the two games was designed to make the payoff magnitudes the same for individuals making decisions on their own and for those in 3 person groups.

action.[3] The personal identities of subjects were never revealed, but all subjects were aware as to whether their counterpart was an individual or group. An individual player's counterpart was always another individual while a group player's counterpart was always another group.

There were 202 subjects in the study, 88 of whom were male, 105 were female and 9 subjects did not report their genders. Most subjects were college students. 176 out of 193 subjects who reported their age were between 19 and 25.

1.3 The Experimental Design

The study was conducted in a behavioral lab of a northeastern university using Z-tree, a software for developing economic experiments (Fischbacher, 2007). Each individual or group used one computer to make their decisions. The computers were placed in two connecting rooms and in separate stations surrounded by cardboards to provide anonymity. Subjects were approximately 6 feet apart. One group could probably hear other groups talking, but it was very unlikely they could tell which one was their counterpart since there were usually 24 to 30 people in the two rooms. Most group discussions were recorded with the consent of the subjects.[4]

Each of the 202 subjects played either a deterministic or a stochastic prisoner's dilemma game, either as members of three-person groups or as individuals. That is, the study was a 2X2 between-subject design (2 game types X 2 player types). Table 3 shows the subject distribution in the four conditions.

[Table 3 about here]

Each player played multiple Supergames in the study. Players played against the

[3] Out of the 36 groups who indicated how they made their decisions in the survey questionnaires, 32 groups reached unanimous decisions and 4 groups applied majority voting.

[4] We had a mechanical failure in the study which prevented us from recording some group discussions.

same counterpart in one Supergame (10 rounds), then switched counterparts in the next Supergame. At the beginning of each Supergame, players were given 1500 Talers; one Taler is exchangeable for 2 cents in the individual condition, and 6 cents in the group condition; their wealth from the previous Supergame did not carry over to the current one. All rules, such as the number of rounds in a Supergame, the size of a player's endowment at the start of each Supergame, and the fact that one was playing with the same counterpart for one Supergame and then switching to another counterpart, were common knowledge. Depending on the decision speed and time available for the experiment, players played 5 to 12 Supergames, with a median of 8 Supergames. That is, each individual/group made 50 to 120 decisions during the experiment.

Subjects were told that their final payoffs might depend on one random Supergame of theirs before the game began. About 20 percent of the subjects were randomly chosen at the end of the experiment and received their actual payoff from one random Supergame. All subjects had to answer quiz questions regarding the procedure, game rules, and payment determinants before playing the game. Group players were aware at the beginning of the experiment that their discussion would be recorded unless they objected. No one objected. All subjects answered a survey at the end of the study that included questions regarding their strategies, decision rules, risk preferences, self-rated rationality, and demography.

2. Data Analysis and Results

2.1 Average Propensity to Cooperate

Before proceeding with a formal statistical model, we first investigate the data at its mean level by assuming the decisions in each round is independent of previous decisions and there are no significant differences in cooperation tendency among players. Table 4 shows the average cooperation rate (the proportion of times players invested) in each of the four conditions. These data are depicted graphically with respect to player type and game type in

Figure 1. As one can see there is an interaction effect between player type and game type: groups were less cooperative than individuals in the DPD game, but more cooperative than individuals in the SPD game.

[Table 4 about here]

[Figure 1 about here]

2.2 The Random Effect Logit Model and Results

Since subjects made a binomial choice and the 2X2 design was unbalanced, we applied a logistic regression model to analyze the interaction, assuming the investment decision depends on both the player types and the game types. But a standard logistic regression model cannot address two issues in our data.

First, each subject made repeated decisions in one Supergame (10 rounds) and played multiple Supergames. The round order as well as Supergame order may have had an effect on the cooperation decisions. Second, each subject made multiple decisions. It is unreasonable to assume that the decisions made by the same subject were independent of each other because of the heterogeneity of investment propensity among subjects. This interdependency among observations, if ignored, will cause one to more easily reject a null hypothesis than justified by the data because the estimated variances of coefficients are biased downward.

To account for the above concerns, we applied a random effect logit model with two sets of dummy variables. To control for the round and Supergame order effect, we included one set of round dummies and one set of Supergame dummies. To address to the second concern, subject individual difference, a random effect variable (α_i) was included in the logit regression as shown in Equation (1). α_i varied randomly between subjects and represents the deviation of each subject from the general investment propensity. It had a probability distribution with expectation zero and variance σ_α^2. Considering the fact that all explanatory variables in the logit model are experimental variables, and the study was a complete between-subject design, we doubt that there is a correlation between subject-specific effects and explanatory variables. Hence the random effect model should be the efficient and consistent model that is superior to the fixed effect model.

Specifically we regressed each decision (1 for Investing, 0 for Not Investing) as the dependent variable on the following independent variables: Player Type (group or individual), Game Type (DPD or SPD), the interaction of Player Type and Game Type, Round numbers and Supergame numbers. Formally, let i index the subject numbers, j index the Supergame numbers, and k index the round numbers, D_{ijk} is the binomial decision regarding whether or not to invest (cooperate) made by the Subject i in Supergame j, Round k. D_{ijk} is 1 if the subject invested and 0 if the subject did not invest. Let p_{ijk} be the probability that the ith subject invested in Supergame j, Round k. That is, $p_{ijk} = \Pr(D_{ijk} = 1)$. The random effect logit model can be written as:

$$\begin{aligned}\log(p_{ijk}/(1-p_{ijk})) &= \beta_0 + \beta_1 Group_{ijk} + \beta_2 Sgame_{ijk} + \beta_3 Group_{ijk} Sgame_{ijk} \\ &+ \beta_4 Supergame_j + \beta_5 Round_k + \alpha_i + \varepsilon_{ijk}\end{aligned} \quad (1)$$

where β_0 is the log odds of investing when there are no subject differences and all fixed effects are zero; $Group_{ijk}$ is 1 if the decision was made by a group, 0 if made by an individual; $Sgame_{ijk}$ is 1 if the decision was a SPD game decision, 0 if it was a DPD game decision; $Group_{ijk}$ $Sgame_{ijk}$ is the interaction term between Play Type and Game Type; $Supergame_j$ is a 12-element-long row vector with the jth element being 1 and all others being zeroes; β_4 is a 12-element-long column vector representing the fixed effect of each Supergame order, 1st, 2nd, …., 12th; $Round_k$ is a 10-element-long row vector with the kth element being 1 and all others being zeroes; β_5 is a 10-element-long column vector representing the fixed effect of each round order, 1st, 2nd, …., 10th; α_i is the subject random effect distributed $N(0,\sigma_\alpha^2)$ representing the deviation of each subject from the general investment propensity; ε_{ij} are model errors distributed $N(0,\sigma^2)$; random variables and model errors are independent.

Equation (1) was estimated using the xtlogit package in Stata. Because of the existence of the interaction term in the logit model, the interpretation of the coefficients and the calculation of the marginal effects are different from the one without the interaction term. For example, Group is part of the interaction term, and the marginal effect of Group cannot be interpreted as the overall comparison of Group to Individual. Instead, it is the effect of Group when the other independent variable in the interaction term, Sgame, is at the reference value, i.e. Sgame =0. We found that groups were less cooperative than individuals in the DPD game (β_1=-3.05, z=-5.9, p<0.01, marginal effect= -0.484). The marginal effect, 48.4%, is the probability difference between groups cooperating and individual cooperating in the DPD game, not their difference in the study in general. That is, the probability of groups cooperating in the DPD game was 48.4% lower than the probability of individuals cooperating in the DPD game, which is in line with the literature.

[Table 5 about here]

[Table 6 about here]

Table 5 reports a complete list of estimates. There was a significant interaction between Player Type and Game Type (β3=4.97, z=7.92, p<0.01, marginal effect= 0.793). Following Ai and Norton (2003), we calculated and reported four probability comparisons in Table 6. The comparisons were calculated using the estimates in Table 5. A reversed discontinuity effect was found in the SPD game: groups were more cooperative than individuals in the SPD game (marginal effect= 0.309). We also found individuals to be less cooperative in the SPD game than in the DPD game (β2=-3.51, z=-8.95, p<0.01, marginal effect= -0.549), which is consistent with previous research (Bereby-Meyer and Roth, 2006; Kunreuther et al., 2008). The opposite was true for the groups: groups were more cooperative in the SPD game than in the DPD game (marginal effect= 0.244).

Besides the interaction effect, the data also showed an interesting learning process as subjects played the game repeatedly. The marginal effects were monotonically decreasing as the round number increased, implying that subjects learned not to cooperate over time.

3. Four Complementary Explanations and Validity Discussion

The major finding of this paper is a significant interaction between Player Type and Game Type. The magnitude of the interaction was large enough to reverse the discontinuity effect: groups were more cooperative than individuals in the stochastic game (SPD).

To better understand the large differences in groups' cooperation when payoffs are known or uncertain, we first provide a brief review of three mechanisms suggested by previous research to explain the discontinuity effect in the DPD game and then propose a fourth explanation that is complementary to the other three. All four explanations assume no uncertainty. We then discuss the how uncertainty may affect the validity of the four explanations in the SPD game.

3.1 Three Mechanisms Underlying the Discontinuity Effect

After performing a quantitative review of 130 comparisons of interindividual and intergroup interactions, Wildschut et al. (2003) summarize three complementary explanations for the discontinuity effect in the DPD game: identifiability, social support, and schema-based distrust.[5] The first two explanations center on greater greed by groups than individuals, and the third explanation points to greater fear by groups than individuals.[6]

[5] Wildschut et al. (2003) also identify four moderators of the discontinuity effect: opponent strategy, procedural interdependence, communication, and conflict of interest, which are not very relevant to this paper because our experimental design made the four moderators the same in all treatments.

[6] Following research on cooperation, greed is defined as greed for larger profit by taking

According to the *identifiability explanation*, the anonymity of being in a group shields each individual member from social sanctions by the other group members, thus encouraging groups to act more competitively and less cooperatively out of greed when the other group cooperates (Schopler et al., 1995). The source of greed based on the *social support explanation* is that group members provide mutual reinforcement for the group to defect in the name of group interest should the other group decide to cooperate (Insko et al., 1990).

According to the fear explanation, groups are less willing to cooperate than individuals are because groups have greater fear than individuals that their cooperation will not be reciprocated by the other group and that, instead, the other group will take advantage of their cooperation by defecting (Insko and Schopler, 1998). This explanation assumes an out-group schema of distrust (Sherif et al., 1961), "consisting of learned beliefs and expectations that intergroup interactions are aggressive, deceitful, and competitive" (Wildschut et al., 2003). That is, foreseeing greater competition between groups than between individuals, a group is more likely to suspect that its counterpart group will defect than an individual suspects that her counterpart individual will defect.

3.2 Smart-strategy Persuasion – A Fourth Explanation

Besides the identifiability, the social support, and the fear explanations, we propose a fourth mechanism that helps explain why intergroup interactions were less cooperative than interindividual ones. This explanation, which we name *smart-strategy persuasion*, argues that group members can be persuaded by their team members to apply the “smart” strategy which, in the case of the Prisoner’s Dilemma game, is defection (Not Invest).

The smart-strategy persuasion explanation is based on the recorded group

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advantage of the other party’s cooperation, and fear as fear of being exploited by the other party if self cooperates.

discussions and after-study surveys undertaken in our experiments. In the DPD game, once one member figured out that defection was the dominant strategy, it was quite easy for him or her to use numbers to persuade other groups that defection was the smart thing to do. This process was also reported in subjects' after-study surveys. For example, when asked how her group made decisions, one subject said: "One proposed and explained. We all nodded." In a sense, the deterministic game with certain payoff numbers is a "eureka-type" problem in which once certain insight is provides, the truth wins (Cooper and Kagel, 2005). Smart-strategy persuasion process greatly improved the group's chance of discovering and following the dominant strategy (Not Invest) relative to an individual operating on his or her own.[7] Hence groups became less cooperative than individuals.

Figure 2 summarizes all four explanations underlying the interindividual-intergroup discontinuity effect observed in the DPD game. The identifiability issue (the difficulty to identify individual group members from the group), and social support to maximize total profits, encourage groups to be more greedy and defect more than individuals; the fear of being taken advantage of by the other group discourages groups from cooperating; and a smart-strategy persuasion process enables groups to discover and choose defection as the profit-maximization strategy more effectively than individuals. As shown in Figure 2, greed and fear coupled with a smart strategy argument decrease groups' tendency to cooperate and jointly function as an explanation of the discontinuity effect in the DPD game.

[Figure 2 about here]

3.3 Validity of the Four Explanations in the SPD Game

The current study found that groups behaved dramatically differently in the DPD

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[7] Imagine that an average subject has a 1/2 chance to figure out the dominant strategy. If we assume that once one member figures it out, the whole group follows her, an average group with 3 subjects has $1-(1/2)^3 = 7/8$ chance to find the dominant strategy.

game than in the SPD game. The discontinuity effect in the DPD game was reversed in the SPD game. Are the four explanations for the discontinuity effect in the DPD game still valid in the SPD game? How does uncertainty influence subjects' emotion (greed and fear) levels and their decision processes? Can one or any combination of the four explanations explain the reversed discontinuity effect in the SPD game? In this subsection we will address those questions by discussing the validity of each of the four explanations in the SPD game and how uncertainty may interfere with the group decision process.

As shown in Figure 2, the first explanation for the discontinuity effect is identifiability. There is no reason that being shielded from social sanctions should be a function of whether a game has deterministic or stochastic outcomes. So it is difficult to see how this could be the reason for differences in group cooperation in the DPD and SPD games.

The second explanation for the discontinuity effect is the social support explanation: group members provide mutual social support for the pursuit of self-interest in the name of group interest. This social-supported-greed explanation seemed reasonable in the DPD game in which defection obviously maximized the group profit, but was questionable in the SPD game because expected-profit maximization might not be in the best interest of the group when uncertainty is present. Although defection in the SPD game had a higher expected value than cooperation for the party making the decision, defection also had a higher variance. This uncertainty could be reduced by investing and would be completely removed if both players invested. Some group members might have thus considered cooperation to be in the interest of the group because it was a "safer" strategy than defection.

This possibility is supported by evidence from recorded discussions and survey questionnaires. We successfully recorded 14 groups in the DPD game and 30 groups in the SPD game. 13 out of these 14 groups in the DPD game always accepted the proposal whenever a group member suggested defection for higher profits when compared to cooperation. In the SPD game, however, 11 out of these 30 groups rejected a member's defection suggestion at least once, several groups rejecting this idea multiple times. Interestingly 59% of the rejections were based on risk preference differentials, such as "I prefer a safer bet and cooperate." or "The probability of loss looks too high to me if we defect." Results from the post-study survey questionnaire indicate that there existed a positive correlation between subjects' risk-averse propensity and their influence on the group decisions.[8] Those who were more concerned about risks had a greater influence on the group decisions (t(157)=2.20, p=0.03), which often led to cooperative behavior.

Turning to the third explanation, the schema-based distrust, or fear, the source of this concern in the DPD game was from the "expectation" that the other group would defect and exploit a decision on our part to cooperate. In the SPD game, it is possible that the schema-based fear was reduced because group members observed reduced social-supported greed of their own group (as discussed above) and inferred less greed from the other group as well (Dawes and Thaler, 1988). Thus groups expected less competitiveness from the other group than in the DPD game. That is, Group A would be less afraid of being taken advantage of by Group B if Group A cooperated in the SPD game than in the DPD game. The reason for this reduced concern is because Group A itself is less likely to take advantage Group B if Group B cooperates in the SPD game than in the DPD game.

To test the above possibility of reduced fear in the SPD game, we counted the frequencies of groups expressing explicit or implicit fear (to be exploited by the other group), such as "I do not trust them", or "what if they defect?", etc. The absolute frequencies of fear

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[8] Data are from another study in which subjects played the same game as the current one except that the investment was 36 instead of 45. Subjects in that study were from the same subject pool as the current study.

expressions in the DPD or SPD game were not significantly different (t(42)=0.62, p=0.54). But considering the fact that subjects talked considerably more in the SPD game than in the DPD game,[9] the relative frequency of fear expressions or the salience of fear in the SPD game was probably lower than in the DPD game. This is consistent with our theory that the fear underlying the discontinuity effect was modified and less salient in the SPD game.

Regarding the validity of the fourth explanation under uncertainty, we believe that smart-strategy persuasion had less influence in pushing groups to defect in the SPD game than in the DPD game for three reasons. First, in the SPD game, the probabilities associated with different payoffs made it more difficult to determine the smart strategy. Data compiled from recorded group discussion indicate that only 17% of the groups in the SPD game had at least one member who discovered the dominant strategy (defection), while 50% of the groups in the DPD game had at least one member who knew that defection was the game theoretic strategy to follow. Second, in the SPD game, even if one member successfully identified defection as the smart strategy, it was harder to persuade other members that this was the appropriate action to take given the complexity of probabilities, outcomes and expected-value calculations required in the SPD game that were absent in the DPD game with certain and clear-cut payoffs. Third, even after the smart member convinced the whole group that defection was the rational strategy with higher expected payoff, the group might still refuse to apply the "smart" strategy because it was unclear that being smart and defection was in the best interest of the group because of risk preference differentials among group members. Some members might prefer a safer strategy (cooperation) with lower expected payoffs than a riskier strategy (defection) with higher expected payoffs.

In summary, we argue that three out of four mechanisms underlying the discontinuity effect in the DPD game were affected by uncertainty in the SPD game. As

[9] This is an observation we made while listening to the tapes, not quantitative data.

summarized in Figure 3, the three arguments in the DPD game shown in Figure 2 are circled by dotted-lines because they are mitigated by the uncertainty in the SPD game. Those mitigated reasons then cause reduced greed, fear, and persuasion power, which explains why the discontinuity effect disappeared in the SPD game. However, the reversed discontinuity effect remains a puzzle. There is no evidence or reason why groups would have less greed or fear, or the persuasion process would make groups less smart (in terms of identifying the smart strategy) than individuals. Then why were groups more cooperative than individuals in the SPD game? This question will be the focus of the next section.

[Figure 3 about here]

4. Two Group Processes Underlying the Reversed Discontinuity Effect

In this section, we propose two complementary explanations for the reversed discontinuity effect in the SPD game. We argue that groups were more cooperative than individuals in the SPD game for two reasons: an aversion to guilt and the motivation to avoid blame when making decisions that affect the welfare of others (Charness and Dufwenberg, 2006; Charness and Jackson, 2009), and the social pressure to conform to certain norms when in a group and observed by others (see Turner, 1991 for a review on social conformity).

4.1 Guilt Aversion and Blame Avoidance under Uncertainty

The first explanation is based on how group members perceive responsibility when making decisions with collective outcomes. It has been known that people suffer from guilt if they inflict harm on others (Baumeister et al., 1994). The term, guilt aversion, is adopted from Charness and Dufwenberg (2006) where they define a guilt-averse player as someone who "suffers from guilt to the extent he believes he hurts others relative to what they believe they will get." They find that, in a trust game, people try to live up to others' expectations to avoid guilt. In a more recent paper, Charness and Jackson (2009) find that, in a Stag Hunt game, one third of the subjects are sensitive to the responsibility issue and make different decisions whether or not their actions impact on another person's outcome. More specifically, 90% of those responsibility-sensitive subjects take on more risk when choosing only for themselves only than when choosing for both themselves and a silent partner. In that paper, the risky choice is the one with which the player either gets a high (9) or low (1) payoff depending on the other player's choice, while the safe choice is the one that gets the fixed payoff (8) no matter what the other player chooses. The authors argue that one of the reasons for opting for the safe option is to avoid blame, which is related to the notion of guilt aversion.

Similar reasoning can be applied to the group decision process in the SPD game. Imagine that a smart group member in the SPD game figured out that defection had a higher expected payoff for the group. But she was also aware of the higher probability of suffering a loss associated with defection than with cooperation. Similar to players in the Stag Hunt game in Charness and Jackson (2009) even if she believed that defection was the rational strategy and she by herself was willing to take the risk for the sake of higher expected payoff, she might be reluctant to suggest that the group defect, because the person would foresee the *ex post* guilt she would feel and the ex post blame she would get from other members, if the group followed her suggestion to defect and a large loss occurred. When all group members engage in such a safety-first adjustment process, the group becomes more conservative and less willing to take on risks than when individuals act on their own. Hence more groups than individuals opted for cooperation to reduce risks in the SPD game. Note that here we argue that guilt aversion and blame avoidance are two different motivations associated with the same risk-reduction action.

4.2 Social Pressure to be Pro-group, Smart, and Nice

The second mechanism underlying group cooperativeness (reversed discontinuity effect) in the SPD game has to do with the conformity process in groups (see Turner, 1991 for a review). That is, a group member feels social pressure from other members to conform to certain norms. Under a strategic setting, such as in a Prisoner's Dilemma, three norms are especially relevant for a group member whose behavior is observed by other members: the norm of being pro-group, the norm of being smart, and the norm of being nice.

The norm of being pro-group arises from the in-group favoritism existing in even temporary and meaningless group categories (Tajfel, 1982). For example, in one study, Tajfel and his colleges grouped British schoolboys solely on whether they over- or underestimate the number of dots on a slide, which hardly had any meaning to either group. However, later in the experiment the boys tended to allocate more money to those in their own group than those in the other group. In a PD game, in-group favoritism is manifested in striving for the best interest of the group (Bornstein and Ben-Yossef, 1994; Baron, 2001).

The being-smart norm states that in a strategic setting with conflicting interests, one should struggle for good outcomes and avoid being a sucker. Previous research has found that people are averse to playing the sucker so that others can and let others free ride (Orbell and Dawes, 1981). Fear of being a sucker plays an important role in people's cooperation decisions in social dilemmas (Rapoport and Eshed-Levy, 1989). One feature of being smart is not being a sucker and thus being taken advantage of by the other party. In the case of the Prisoner's Dilemma, this implies defection because of a fear that the other party will defect. Another feather of being smart in the Prisoner's Dilemma indicates following one's own interest, which also implies defection because one is better off by defecting than by cooperating, independent of the other party's decision.

The norm of being nice indicates a desire to cooperate with others. For example, people may cooperate in social dilemmas because "they are not the kind of people who benefit at the expense of others" (Dawes 1980). Note that the niceness norm implies another form of guilt aversion: people may feel guilty when their action (Not Investing) harms the other group, especially when they cannot adequately justify themselves, as will be discussed below. The motivation of being nice when one's behavior is observed by group members may drive people to choose cooperation over defection, because in a PD game both parties cooperating leads to better outcomes than both parties defecting, and cooperation is regarded as socially desirable behavior.

In the DPD game, both the pro-group norm and the smartness norm implied defection since the group was always better off defecting than cooperating regardless of the other group's decision. As discussed before, inflated greed and fear, together with smart-strategy persuasion, reinforced the defection strategy as the *smart* strategy that maximizes group profits and is in the best interest of *group* (as well as individuals). The niceness strategy of cooperation was clouded by being pro-group and being smart. Hence we observed the discontinuity effect in the DPD game that groups were less cooperative than individuals.

In the SPD game, however, the salience and importance of norms was changed by the uncertainty. As summarized in Figure 3, it was ambiguous as to whether defection was really in the best interest of the group when uncertainty was present, and it was harder for the group to identify and agree on defection as being the smart strategy in the SPD game. As a result, being pro-group and being smart became less obvious, and being nice became more salient in the SPD game than in the DPD game. In other words, when defection could not be justified by being pro-group and being smart, more weight was put on being nice and not to cause harm to the other party, thus encouraging cooperation as socially desirable. When one is in a group, there is social pressure to conform to social norms and perform social desirable behaviors, especially when one's behavior is observable by other members in the group (Turner, 1991). Thus, in the SPD game, group member were more likely to conform to the niceness norm and choose the socially desirable strategy (cooperation) than individuals.

Hence a reversed discontinuity effect was observed in the SPD game.

5. Conclusions and General Discussions

Previous research has shown a 'discontinuity effect': groups are less cooperative than individuals (Insko et al., 1987; Wildschut, et al., 2003). We replicated the discontinuity effect in the DPD game, but found a reversed discontinuity effect when uncertainty existed: groups were more cooperative than individuals in the SPD game. We suggest the three major factors that underlie the usual discontinuity effect, greed, fear, and persuasion power, were reduced in the stochastic environment. Two complementary explanations for the reversed discontinuity effect in the SPD game were proposed: guilt-aversion tendency and blame-avoidance motivation when making decisions that affect others' welfare, and the social pressure to conform to the niceness norm when it was unclear what strategy was pro-group and smart.

As a summary, Table 7 illustrates all decision mechanisms discussed in this paper and provides a general framework for explaining both the discontinuity effect in the DPD game and the reversed discontinuity effect in the SPD game.

In the DPD game, it is fairly easy to identify defection as the pro-group and smart strategy. The greater greed and fear in groups, as shown by previous research, and the persuasion argument we proposed, encourage groups to defect by following a smart strategy and behaving with the best interest of the group in mind. Hence groups defect more than individuals and the discontinuity effect is observed.

In the SPD game, however, uncertainty influences group preferences through two mechanisms: role of responsibility and conformity pressure. Guilt-aversion and blame-avoidance cause groups to opt for the safer strategy (cooperation) when facing uncertain outcomes. The existence of uncertainty complicates the game, and makes it harder to identify defection as the pro-group and smart strategy. The norm of being nice, which was clouded by the norm of being pro-group and smart in the DPD game, becomes more salient in the SPD game where the pro-group and smart norm no longer play a central role. With the social pressure to conform to the niceness norm, groups become more cooperative than individuals under uncertainty, and a reversed discontinuity effect is observed in the SPD game.

[Table 7 about here]

The discontinuity effect appears to cast doubt on the efficiency of group decisions to cooperate, but the reversed discontinuity effect under uncertainty rekindles hope of groups making cooperative decisions in the interest of social welfare since most scenarios in the real world are probabilistic ones. This finding has implications for many social dilemma problems. We may actually be able to use uncertainty to improve intergroup cooperation. For example, when two groups face a social dilemma problem, a regulator or a mediator can emphasize the probabilistic nature of the outcomes as a means of reducing group greed and fear associated with defection, while at the same time activating guilt-aversion and blame-avoidance to encourage cooperation. In another scenario where the uncertainty is obvious and people make individual decisions, one may be able to encourage cooperation by categorizing people into groups with common interests.

Before carrying out any application of the group cooperation under uncertainty in the field, there are questions that warrant further investigation. First, the two mechanisms we propose in the paper to explain the inter-group cooperation or the reversed discontinuity effect are based on previous literature rather than empirical studies. That is, the current data are not sufficient to either verify or refute these two mechanisms. Is either one or both of them necessary for the existence of group cooperativeness under uncertainty? Will one of them be sufficient to initiate the reversed discontinuity effect? Are there other group mechanisms that are underlying the group cooperation under uncertainty besides those discussed here? These are all important questions to be answered in order to fully understand the phenomenon.

Second, the generality of the reversed discontinuity effect in the SPD game remains open to discussion. For example, the current study uses a security game with negative outcomes to mimic real-world scenario in which players invest to reduce the risks of suffering a loss. What if it is an investment game with positive outcomes? Researchers have found that people encode losses and gains differently (Seymour et al., 2007) and typically show greater sensitivity to loss than to gain (Kahneman and Tversky, 1979). The guilt-aversion and blame-avoidance motivations underlying the reversed discontinuity effect may be stronger in a loss-domain game than in a gain-domain game. If a loss occurred, the regret from not investing in risk-reducing measures is likely to be larger than if additional revenue could have been earned from investing in a profit-enhancing measure in a gain-domain game. That is, groups may be more loss averse than individuals. It will be interesting to test whether there is a triple interaction between the loss/gain domain, the group/individual player type, and the DPD/SPD game type. In fact, this triple interaction is confirmed in one of the follow-up studies the authors are conducting. Preliminary results show that groups cooperated more than individuals in SPD games with both positive and negative payoffs, but the group-individual cooperation difference is bigger in the game with negative payoffs than in the one with positive payoffs.

Aside from loss domain, there are at least two additional categories of factors that are relevant to the generality issue of the group cooperation under uncertainty phenomenon: factors that change group structure or the decision rules, and factors that alter the game context or structure. The group factors include leadership, voting mechanism, within-group interest conflict, etc. The game factors include, but are not exclusive to, length of the game (one shot vs. repeated), between-player communication, partial/full feedback system, nature of uncertainty, type of games (PD game or other games), multiple-player game, etc.

To conclude, we believe that the findings in the current study will serve as a starting point towards integrating three important factors in many social dilemmas -uncertainty, cooperation, and group decision. Further investigation of these questions will provide possible applications for regulators and organizations to control risks, encourage group cooperation, and improve social welfare.

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Table 1: Possible outcomes in the SPD game

		Player 2	
		Invest	Not Invest
Player 1	Invest	*-45; -45*	*20% lose 145,80% lose 45; 40% lose 100,60% lose 0*
	Not Invest	*40% lose 100,60% lose 0; 20% lose 145,80% lose 45*	*52% lose 100,48% lose 0; 52% lose 100,48% lose 0*

Table 2: Possible outcomes in the DPD game

		Player 2	
		Invest	Not Invest
Player 1	Invest	*-45;- 45*	*-65;- 40*
	Not Invest	*-40;- 65*	*-52;- 52*

Table 3: Subject distribution in the four conditions

	Individual Player		**Group Player**	
	# of Subjects	# of Decisions	# of Subjects/# of Groups	# of Decisions
DPD	22	2400	48/16	1440
SPD	42	3100	90/30	2080

Table 4: Cooperation rates in the four conditions

	Group Player	**Individual Player**
DPD	32%	78%
SPD	52%	22%

Table 5. Estimates of logit model for cooperation probability

Variable	Mean	Coefficient	Standard Error	z value	Pr(>|z|)	Marginal Effects (dy/dx)*
Dependent Variable						
Cooperation	0.458					
Independent Variables						
Constant		2.839	0.342	8.30	0.000	0.343
Sgame	0.574	-3.513	0.401	-8.77	0.000	-0.549
Group	0.390	-3.051	0.521	-5.86	0.000	-0.484
Fixed Effects						
Round2	0.100	-0.341	0.123	-2.76	0.006	-0.050
Round3	0.100	-0.378	0.123	-3.07	0.002	-0.055
Round4	0.100	-0.503	0.123	-4.09	0.000	-0.073
Round5	0.100	-0.633	0.123	-5.16	0.000	-0.092
Round6	0.100	-0.741	0.123	-6.04	0.000	-0.107
Round7	0.100	-0.877	0.123	-7.15	0.000	-0.127
Round8	0.100	-1.185	0.123	-9.62	0.000	-0.169
Round9	0.100	-1.935	0.127	-15.22	0.000	-0.268
Round10	0.100	-3.064	0.142	-21.63	0.000	-0.388
Supergame2	0.120	-0.594	0.113	-5.26	0.000	-0.087
Supergame3	0.120	0.013	0.112	0.11	0.911	0.002
Supergame4	0.120	-0.163	0.112	-1.46	0.145	-0.024
Supergame5	0.120	-0.765	0.117	-6.53	0.000	-0.112
Supergame6	0.111	-0.320	0.122	-2.62	0.009	-0.047
Supergame7	0.095	-0.411	0.122	-3.36	0.001	-0.060
Supergame8	0.095	0.081	0.135	0.60	0.548	0.012
Supergame9	0.071	-0.176	0.140	-1.26	0.208	-0.026
Supergame10	0.062	-0.115	0.167	-0.69	0.491	-0.017
Supergame11	0.038	-0.289	0.190	-1.52	0.128	-0.042
Supergame12	0.024	-0.528	0.187	-2.82	0.005	-0.077
Interaction Term						
Sgame*Group	0.224	4.973	0.638	7.800	0.000	0.793
Rho		0.396	0.041			
Log likelihood				-4169.8		
Sample size				9020		

Notes: * Because the independent variables are binary, we calculated discrete changes of dummy variables from 0 to 1 following Long (1997). Please refer to Table 6 for the interpretations of the marginal effects of variables in the interaction term.

Table 6: Cooperation probability comparison (marginal effects)

			Marginal Effects	**Interpretation**
Game Type	DPD	Group-Individual Difference	-0.484	Groups are 48.4% less likely to cooperate than individuals in the DPD game
	SPD	Group-Individual Difference	0.309	Groups are 30.9% more likely to cooperate than individuals in the SPD game
Player Type	Group	SPD-DPD Difference	0.244	individuals are 24.4% more likely to cooperate in the SPD game than in the DPD game
	Individual	SPD-DPD Difference	-0.549	individuals are 54.9% less likely to cooperate in the SPD game than in the DPD game

Table 7: A summary of group cooperation in the DPD and SPD game

<table>
<tr><td colspan="3" rowspan="3"></td><td colspan="6">Game Types</td></tr>
<tr><td colspan="3">DPD Game</td><td colspan="3">SPD Game</td></tr>
<tr><td>Effect of No Uncertainty</td><td>Effect on Cooperation</td><td>Group-Individual Difference</td><td>Effect of Uncertainty</td><td>Effect on Cooperation</td><td>Group-Individual Difference</td></tr>
<tr><td rowspan="5">Group Processes</td><td rowspan="2">Role of Responsibility</td><td>Guilt Aversion</td><td>No ex post guilt from uncertain outcome (Section 4.1)</td><td></td><td rowspan="5">Discontinuity Effect</td><td>Foreseeing ex post guilt→safer strategy (cooperation) (Section 4.1)</td><td>Increase</td><td rowspan="5">Reversed Discontinuity Effect.</td></tr>
<tr><td>Blame Avoidance</td><td>No ex post blame from uncertain outcome (Section 4.1)</td><td></td><td>Foreseeing ex post blame→safer strategy(cooperation) (Section 4.1)</td><td>Increase</td></tr>
<tr><td rowspan="3">Conformity Pressure</td><td>Pro-group</td><td>Pro-group strategy (defection) is reinforced by greater greed and fear(Section 3.1)</td><td>Decrease</td><td>Unclear what the pro-group strategy is (Section 3.3)</td><td></td></tr>
<tr><td>Smart</td><td>Smart strategy (defection) is reinforced by smart-strategy persuasion (Section 3.2)</td><td>Decrease</td><td>Hard to figure out and convince other members what the smart strategy is (Section 3.3)</td><td></td></tr>
<tr><td>Nice</td><td>Nice strategy (cooperation) is clouded by being pro-group and being smart (Section 4.2)</td><td></td><td>Niceness is more salient than being pro-group and being smart; Social pressure pushes groups to be more cooperative than individuals (Section 4.2)</td><td>Increase</td></tr>
</table>

Figure 1: Player Type and Game Type Interaction

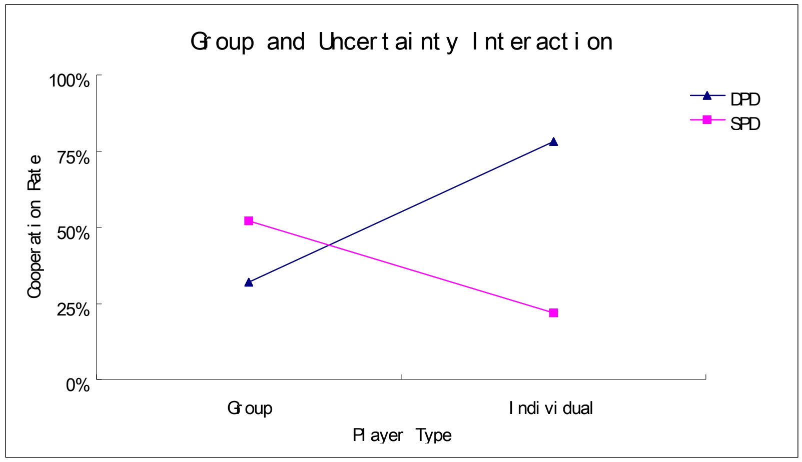

Figure 2: Four Complementary Explanations for the Discontinuity Effect in the DPD

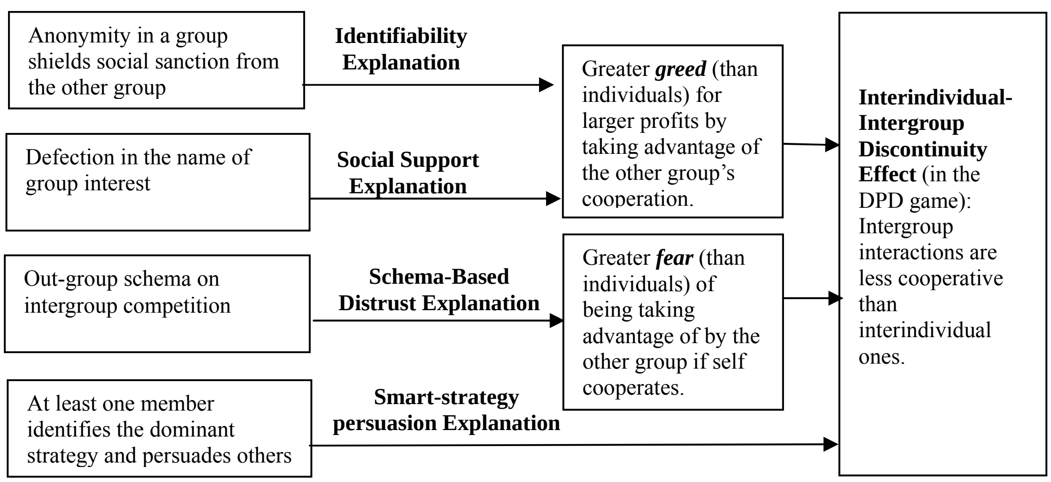

Figure 3: The Disappearance of the Discontinuity Effect in the SPD