The Role of Risk Aversion and Cautiousness in Belief Formation

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Abstract

This study examines how a decision-maker's subjective belief is determined by her risk preference in a coordination game. We conduct a laboratory experiment where the participants played a repeated, fixed-partner stag-hunt game. In the experiment, we elicited the participants' subjective belief, risk aversion and cautiousness levels. Here, we confirm the findings from past studies that suggest that the traditional measure of risk aversion in economics cannot explain people's behavior. Additionally, we find that the psychological concept of cautiousness plays a key role in determining the origin and the evolution of the decision-maker's belief. Specifically, we find that cautiousness affects the way people form the mental representation of their partners. A decision-maker with a higher cautiousness level is less likely to believe that her partner will choose the risky option. When the stag-hunt game was played repeatedly, a high cautiousness level prevents the decision-maker from updating her belief effectively, and consequently impedes cooperation between the players.

Keywords: Subjective Belief, Coordination Game, Risk Aversion, Cautiousness

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1. Introduction

In a variety of social environments, people must decide whether to engage in mutually beneficial but risky cooperation with others. Cooperation is risky if it leads to losses when not reciprocated. Many authors have examined how the structure of payoffs and subjects' risk aversion impact decisions in these environments (Cooper et al.,1990; Van Huyck et al., 1990; Russell et al, 1992; Carlsson and Van Damme, 1993; Harsanyi, 1995; Selten, 1995; Straub, 1995; Battalio et al.,2001; Schmidt et al.,2003; Chaudhuri et al., 2010; Roos and Nau, 2010). However, the origin and evolution of beliefs about others' behavior has received much less attention. In this study, we experimentally examine whether the economic concept of risk aversion or the related psychological construct of cautiousness, a personality trait, can explain a decision-maker's subjective beliefs about her partner's action in a repeated stag-hunt game.

Consider the game in Figure 1 in which players independently decide between Red and Blue. The game has two pure-strategy equilibria: a payoff-dominant equilibrium [Red, Red] and a risk-dominant equilibrium [Blue, Blue][2]. While the payoff-dominant equilibrium is Pareto optimal, playing red is risky as coordination failure [Red, Blue] will result in an inferior outcome. Therefore, a player's optimal strategy depends on the player's beliefs about the likely strategy of her partner.

As a typical case of risky cooperation, the stag-hunt game has attracted a lot of attention in the last two decades. Cooper et al. (1990) showed that variations in a player's payoff from an opponent's play of a cooperative strategy influences equilibrium selection. Battalio et al. (2001) and Dubois et al. (2011) showed that in repeated stag-hunt games, the increase in the expected earning difference between the two strategies made the subjects pay more attention to results from previous periods. Consequently their strategy selections converged to the equilibrium outcomes more rapidly. Schmidt et al. (2003) showed that changes in risk-dominant equilibrium payoffs are more likely to influence behavior than changes in payoff-dominant equilibrium payoffs. Chaudhuri et al. (2010) showed that a recommendation to play the payoff-dominant equilibrium is successful in resolving coordination failure. These studies examine how institutional changes impact outcomes in games, yet none provide an explicit decision-making mechanism. Yet, the findings from these studies suggest the importance of examining belief formation and coordination. For example, Chaudhuri et al. (2010)'s study shows that manipulating beliefs changes outcomes, while results in Battalio et al. (2001) and Dubois et al. (2011) imply that the evolution of the subjective beliefs affect people's behavior.

Recent experimental studies have also investigated the relationship between risk preference and strategy selection in stag-hunt games (Neumann and Vogt, 2009; Buyukboyaci, 2012; Al-Ubaydli et al., 2013). To our knowledge, only null findings have been returned, finding (perhaps paradoxically) little relationship between risk aversion and behavior. However, the calculation of an optimal strategy entails not only risk but also

2 These equilibrium notions are defined by Harsanyi and Selten (1988).

beliefs (Nyarko and Schotter, 2002; Rey-Biel, 2009). These past studies use various proxies for beliefs, such as the mixed-strategy Nash equilibrium or the proportion of people selecting a particular strategy.

We propose that the decision-maker's subjective belief concerning the other player's action is the key to understanding the decision-making mechanism in these contexts. The subjective belief should be understood as the outcome of one's heuristics and reasoning, and therefore potentially widely heterogeneous. In order to reveal how people make decisions, we directly elicit subjective beliefs and investigate where these beliefs come from.

While past studies focus exclusively on the economic concept of risk aversion to measure risk preference, we introduce the psychological construct of cautiousness (Moss, 1961). Wearing a seatbelt, skydiving, and taking social risks, are often decisions based not on carefully-calculated weighing of risks and rewards, but reflect an innate personality trait (Levenson, 1990; Trimpop, 1994; Lauriola and Levin, 2001; Weber et al., 2002; McDaniel and Zukerman, 2003; Breakwell, 2007). Both risk aversion and cautiousness relate to how people react to uncertainties, yet they are essentially different from each other in two aspects. First, whereas the estimated risk aversion reflects the change in the decision-maker's gratification level toward possible gains only, the cautiousness measure assesses the decision-maker's attitude toward potential negative outcome. Second, whereas the risk aversion measure concerns isolated individual decisions, the cautiousness measure concerns people's thoughts and actions in social interaction situations. We find that cautiousness (but not risk aversion) helps explain subjects' beliefs—and therefore actions—in a stag-hunt game.

1.1. The Source of Subjective Beliefs in the Coordination Game

In the first period of a fixed-partner repeated game, the decision-maker will make her prediction without any information about her partner's characteristics. Under such circumstances, how can she effectively "predict" what her partner will do? We propose a simple heuristic: she will first establish a mental representation of her partner based on her own personality traits, and then predict what the "imaginary partner" will do. In particular, a decision-maker who has low risk-tolerance might project the same characteristic on to her partner, and consequently predict that her partner is unlikely to take the risky action. To put it in another way, the decision-maker expects that her partner will choose the same strategy as she does. In the first period of the stag-hunt game, the decision-maker's reasoning would be "my partner must do the same thing as I do, otherwise she is crazy." This type of reasoning is known as the "*Stackelberg heuristic*".

The concept of "*Stackelberg heuristic*" was coined by Colman and Bacharach (1997). The essential idea of it is that "both players in a game choose strategies that maximize their own payoffs on the assumption that any choice will invariably met by a counter strategy that maximizes the co-player's payoff, as if the co-player could choose second in a perfect information version of the game with foreknowledge of the first player's choice" (Colman and Stirk, 1998). Substantial evidence have shown that the Stackelberg heuristic is commonly used by individuals. From the decision making literature, many past studies have observed the fact that people employ the Stackelberg heuristic to solve problems where the outcome depends on social interactions. For example, Eells (1984), Nozick and Rescher (1969), Quattrone and Tversky (1984), Nozick (1994), Camerer (2003), Jeffrey (2004) found that people often make decisions by maximizing the conditional expected value of possible acts rather than the pure expected utilities as in the traditional theory. From the psychology literature, the phenomenon that people's estimates of behaviors or attitudes of others are often positively related to their own behaviors or attitudes has been repeatedly observed and intensively investigated (see Hoch, 1987, as an example). In short, in the first period of the game, risk preference directly influences the decision-maker's subjective beliefs about her partner's strategy selection. Specifically, risk-tolerance levels positively associate with the probability of believing one's partner will take the risky option. Behaviorally, lower risk-tolerance level will lead the decision-maker more likely to select the safe option.

As the decision-maker plays the stag-hunt game with the same partner repeatedly, she would update her belief according to the results from previous periods (Erev and Roth, 1998; Neumann and Vogt, 2009). To explore how risk preference affects the evolution of the subjective beliefs, we employ a particular feedback mechanism in which the strategic uncertainty can only be eliminated when the two players in a pair play the risky option simultaneously. Specifically, the decision-maker observes the payoffs she earned in each period, and then infers her partner's action. For a decision-maker who has chosen Blue, her payoffs do no vary with the other person's choice. That is to say, she can only see what her partner did if she has chosen Red. Feedback on the other person's action is not available if she has chosen Blue . If the decision-maker were able to observe the other person's action in any case, then one way to achieve the payoff-dominant equilibrium is to send my partner a signal by choosing the risky option. Such behavior would make the subjective beliefs irrelevant. Our feedback mechanism prevents signaling. A decision-maker with lower risk-tolerance level is less likely to choose Red. Accordingly, she is also less likely to observe her partner's action. Thus, the strategic uncertainty remains as long as one of the two players selects the safe option. If only one player has chosen Red, the coordination failure is still not observable to the one who has chosen Blue. Such undesired outcome creates further confusions between the two players, prevents them from achieving the payoff-dominant equilibrium.

In summary, we put forward that risk preference plays a central role on explaining the origin and the evolution of the decision-maker's subjective belief. In the first period of the game, risk preference affects the way people form the mental representation of their partners; consequently, risk-tolerance level positively correlate with the probability that believing one's partner will choose the risky option. When the decision-maker plays the stag-hunt game with the same partner repeatedly, low risk-tolerance level would hinder the elimination of strategic uncertainty, which in turn, impeding cooperation between the players.

1.2. The Operational Definition of Risk Preference

Economists generally conceive of risk preference as reflecting the shape of one's utility function. Pratt (1964) and Arrow (1965) introduced the concept of risk aversion as a quantitative measure for individual risk preference. Based on this idea, economists typically use lottery games to elicit the decision-maker's risk aversion level in laboratory experiments. For instance, Eckel and Grossman (2008) introduced a lottery game that contains a series of lotteries, each lottery is associated with a particular risky level. The lotteries are given to the participants in ascending order by their risk levels. The participants choose one lottery among all the lotteries to play. By observing their lottery selections, the experimenter will then assume a particular utility function form (for example, constant relative/absolute risk-averse utility function) and estimate the participants' risk aversion levels. Other examples include Hey and Orme (1994), Pennings and Smidts (2000), Holt and Laury (2002, 2005).

Within the psychology literature, cautiousness, as a personality trait, is seen as an indicator of one's preference toward risk. Howard A. Moss (1961) proposed "Cautiousness is regarded as the tendency to behave in a manner designed to avoid potential failure or disapproval experiences, and this goal is achieved often at the expense of other satisfactions. That is, the cautious person is more concerned with avoiding failure than with obtaining success. In order for cautiousness to be observed, there must be a basis for judging certain response alternatives as entailing less risk and less potential satisfaction than other alternatives". Operationally, cautiousness is measured using personality inventories. For example, the *International Personality Item Pool* (Goldberg, 1999) has a sub-dimension to assess people's cautiousness level.

The first conceptual distinction between risk aversion and cautiousness is that they understand "uncertain outcome" in quite different ways: whereas risk aversion considers the uncertain outcome as possible utility increase, cautiousness considers the uncertain outcome as potential event that may lead to potential negative or disapproval experience (Knowles et al. 1973; Sitkin ans Weingart, 1995; Gasper and Clore, 1998). Such dissimilarity makes cautiousness a better measure for the decision-maker's risk preference in the stag-hunt game. In our game, the main factor that prevents people from choosing the cooperative action is the fear of not being reciprocated. According to the definition of cautiousness, a decision-maker who has a tendency to avoid potential disapproval experience will give away the cooperative option and choose the safe option, as the safe option entails no risk of coordination failure. The risk aversion measure cannot capture the decision-maker's attitude toward such potential negative outcome.

The second distinction between risk aversion and cautiousness is that they make different assumptions about the decision making environment: whereas risk aversion is constructed under the assumption that each decision-maker will make the decision on an isolated island and will not be concerned about other people, the cautiousness is constructed under the assumption that the decision-maker will think through her actions in a social interaction situation. These differences may make cautiousness a more apt measure of risk preference in interdependent situations. Fischer and Smith (2004) and Nicholson et al. (2005) found empirical evidence that cautiousness negatively correlates with the tendency of involving in risky social activities. To measure cautiousness, we use the average of a five item subset of the *International Personality Item Pool* (*IPIP*), (Goldberg, 1999). Subjects indicate their agreement with statements (such as "I choose my words with care") on a 5-point Likert scale. In the current study, we measure individual risk preference using both risk aversion and cautiousness. We employ the Eckel and Grossman (2008) lottery game to estimate risk aversion[3].

2. Experimental Design and Administration

The experiment was conducted at the University of Connecticut in the fall of 2013. Participants were recruited from the undergraduate student population via a recruitment notice in a university-wide "Daily Digest" email. In total, 50 undergraduates (34 women and 16 men) participated in the experiment over seven sessions of between six and twelve participants each. The experiment lasted about an hour including check-in and payment processing. Participants earned "*points*" through the experiment which were converted into cash at the conclusion of the experiment at a rate of $1 for every five points earned. Average earnings were $15.18, including a $5 show-up fee.

The experiment consisted of three parts: (1) a ten period repeated coordination game with a fixed anonymous partner, (2) a survey of cautiousness, other personality factors, and demographics, and (3) a risk-elicitation procedure.

Participants were randomly assigned to one of two separate rooms upon arrival. Each participant randomly picked an experimental ID and was paired with another participant with the same ID number in the other room. Participants were introduced to the coordination game represented in Figure 1 (see Appendix for instructions) and then interacted with the same partner for 10 periods. In each period, prior to making a selection, participants first made predictions about what their partners would do (Red or Blue), and indicated how certain they were about their predictions by selecting a number between 0 (not certain at all) to 100 (completely certainty). For example, a participant can indicate a belief that the other participant will play Red, and a 30% certainty. A participant can also indicate a belief as "No idea" if she has no clue about what her partner might do. We employ the binarized scoring rule (Hossain and Okui, 2013) algorithm to make truth-telling an optimal strategy[4].

After making both the prediction and the selection, the experimenter informed each subject privately of

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3 Formally, we assume that the participant would have a constant relative risk aversion function as $U(X)=X^{(1-r)}/(1-r)$, where x denotes the expected payoffs from the lottery game. Accordingly, an extremely risk aversion participant would be characterized as $r\to\infty$. This lottery game only concerns about individual's risk aversion level, and does not incorporate a risk-seeking range. See Eckel and Grossman (2008) for more detail.

4 See the experiment instruction in appendix for more detail.

their payoff. Since payoff does not vary with partner's strategy when one selects the safe strategy (Blue), participants could infer their partner's action only when playing the risky strategy (Red). This feedback mechanism rules out potential signaling behavior (i.e., if one selects the risky option in any period of the game, she will receive the feedback on her partner's action in that period. On the opposite side, if one selects the safe option in any period of the game, she would not know her partner's decision in that period). The game was repeated for ten periods. At the end of this part, one of the ten periods was randomly selected by rolling a ten-sided die to determine participants' payment for this part. The outcome in the randomly selected period determined how many game points the participant earned for his or her decision and prediction in this part.

Next, participants completed a survey including a 30 question subset of the *International Personality Item Pool* (IPIP) (Goldberg, 1999). The 30 questions, each measured on a 5-point Likert scale, measure six personality traits with five questions each. The personality traits include our cautiousness measure, as well trust, altruism, compliance, competence, and achievement-striving, offering some controls for alternative motivations in risky coordination games. Additionally, the survey elicited demographic information, including sex, age, nationality, and education (see appendix for the complete questionnaire).

Lastly, participants completed a lottery game to measure risk aversion. The lottery is an extended (eight option) version of the procedure designed by Eckel & Grossman (2008). Participants selected from among eight different binary lotteries, each with two equally possible (50%) outcomes. The riskiness of the eight lotteries is ascending ordered with higher expected value associated with higher variance. After selecting a lottery, one of the two outcomes was randomly selected by rolling a die with the outcome determining the participant's payment for this part of the experiment. A major advantage of the Eckel and Grossman (2008) procedure is its simplicity, with 50/50 gambles being quite intuitive, and with easy-to-calculate expected values[5].

3. Results

3.1. Descriptive Statistics

Figure 2 shows the percentage of individuals and pairs playing the risky option [Red] over time. In the first period, 64% of individual participants played the risky option whereas 36% played the safe option. By the last period, 84% played the risky option whereas 16% played the safe option. In terms of pair behavior (Table 1): in period 1, 48% of pairs achieved the payoff-dominant equilibrium (Red-Red) by playing the risky option simultaneously, whereas 20% of pairs achieved the risk-dominant equilibrium (Blue-Blue). In the last period, 80% of pairs played the payoff-dominant equilibrium, whereas 12% pairs played the risk-

5 There are also other complex measures for risk aversion that might provide more refined estimates of the parameters in the utility function (e.g. Kahneman and Tversky, 1992; Hey and Orme, 1994; Holt and Laury, 2002; Barron and Erev, 2003.)—but the trade-off of a refined estimate is the increased complexity of the task. When the participants are confused by the complex task, we will see more noise in the result. Dave et al. (2010) found that failing to account for noisy behaviors (or errors) may bias the estimation of risk aversion parameter significantly.

dominant equilibrium. Subjects changed strategies fairly often in the first four periods, but little changing occurred between periods 5 and 9. Some end-game effects were observed in period 10. In general, observed behavior is similar with that observed in Al-Ubaydli et al. (2013)'s experiment.

Table 2 shows measures of risk aversion from the risk elicitation procedure. The measure of risk was calculated by assuming a constant relative risk aversion function. Table3 shows descriptive statistics of the cautiousness measurement and other personality variables. Each personality variable is formed by averaging the five Likert scale items and subtracting 3, so that each ranges from -2 to 2. Figure3 shows the scatterplot of risk aversion against cautiousness. The two measures seem largely uncorrelated (Pearson's product-moment correlation = 0.170, p=0.25, Spearman's rank correlation= 0.20, p = 0.16, Kendall's rank correlation= 0.16, p = 0.13).

Result1: The risk-averse and cautiousness measures are independent from each other.

This result is consistent with our discussion of the differences between risk aversion and cautiousness, as they are measuring different aspects of how people react to uncertainties

3.2. Subjective Beliefs and Decision Making

A primary research question concerns the origin of participants' beliefs. Accordingly, we examine predictions in the first period, prior to any interaction between the participants. Figure 4 shows the distribution of participants' predictions in the first period. Whereas only 6% (3/50) indicated that they have no idea about their partners' actions (by reporting a certainty of 0%), 62% (31/50) participants predicted that their partner will choose the risky option (Std.Dev. = 17.12), and 32% (16/50) participants predicted their partners will choose the safe option (Std.Dev. = 22.34).

We find that there is a clear connection between the participants' prediction and their decision in the first period of the game. Specifically, participants' decisions almost always match their prediction of their partner's play regardless of the certainty level that they have reported (Table 4). Among participants who predicted that their partners will play red, 96.77% (30/31) of them also selected red, among participants who predicted their partners will play blue, 100% (16/16) of them also selected blue. This is in line with Neumann et al. (2009), who also found that the majority of the participants chose the strategies that were consistent with their stated first-order beliefs.

Result 2: Subjective belief determines strategy selection independent of the certainty level.

This result is consistent with our discussion on the role subjective belief played in decision making. The mixed-strategy Nash equilibrium in the stag-hunt game is to play the Red with a probability of 0.75 and to play the Blue with a probability of 0.25. If the confidence level were to translate into probability and then serve as the base of decision-making as the expected-utility theory predicted, a risk-neutral decision maker will not play red unless she is at least 50% sure her partner will play red. Obviously, the externally determined probabilities cannot explain the underlying decision-making mechanism.

3.3. Origin of subjective beliefs

In section 1.1, we hypothesized that in the first period of the game, participants will make predictions using Stackelberg heuristics. Evidence from the experimental data suggests it is the cautiousness, rather than the risk aversion, that serves as the basis of such a heuristic. We first use the median value of the risk-averse measure to split the sample and find no significant difference between beliefs of the two groups (Table 5). Specifically, about the same proportion of risk-averse individuals (16/26=61.5%) and risk-seeking individuals (15/24=62.5%) believe that their partner will play the risky option in the first period. (Fisher exact test p=1.0). Conversely, a median split along the cautiousness measure shows marginally significant differences in predictions (Table 6). Less cautious individuals are more likely to believe that their partner will choose the risky option (19/26=73%) (Fisher exact test p=0.14).

To further examine the relationship between one's risk aversion/cautiousness and subjective belief in period 1, we use a probit model to predict the binary prediction (red=1, ignoring certainty) as a function of the risk aversion measure and cautiousness measure, controlling for other personality traits and demographic factors (Table 7). We also use an OLS model in which the dependent variable is the overall certainty that the partner will play red, measured from -100 (certain partner will play blue) to 100. Lastly, for comparison, we also offer a probit regression on the participant's first period choice rather than prediction.

According to table7, the estimated parameters on risk aversion on all the three regressions indicate the risk aversion measure, has negligible, statistically insignificant effects on the participants' binary prediction, precise prediction and decision. This result is consistent with findings from past studies (Neumann and Vogt, 2009; Al-Ubaydli et al., 2013, Büyükboyaci, 2014). Contrarily, the cautiousness measure has a large, statistically significant effect on the participants' binary prediction and decision. The more cautious is a subject, the more one believes that the partner, too, is cautious in the sense that the partner is more likely to play the safe strategy, blue. In addition, we notice that both the risk aversion measure and the cautiousness measure have statistically insignificant effect on the certainty level of prediction.

Result 3: The traditional measure of risk aversion cannot explain individual subjective belief and strategic selection in the first period of the game.

Result 4: The psychological concept of cautiousness correlates with one's belief that the partner will play the safe option in the first period of the game.

3.4. Evolution of beliefs

In this section, we first look at how the participants update their subjective beliefs based on the outcome of the prior period. Results are summarized in table 8. For participants who played the risky option and ended up with the payoff-dominant equilibrium, 98% of them selected the risky option in the next period. It is clear that once the two participants in a pair played cooperatively together, the strategic uncertainty between them was eliminated immediately. However, for participants who played the risky option but ended up with a bad outcome (i.e., red-blue), 46% of them predicted that the partner would switch to the red in the next period. That is to say, strategic uncertainty led to variation in next period's beliefs.

To examine whether risk aversion/cautiousness plays a role in explaining the evolution of people's subjective beliefs, we again use median splits, and classify participants as either more risk-seeking individuals or more risk-averse individuals. Accordingly, we identify three different types of pairs of partnered subjects: risk-seeking pairs (both participants are risk-seeking individuals), mixed pairs (one risk averse and one risk seeking participant), and risk-averse pairs (both are risk-averse individuals). We use the same method based on cautiousness to classify pairs as cautious pairs, mixed pairs, and less-cautious pairs. Table 9 shows for each type of pair the proportion of periods in which different equilibria were achieved. On aggregate, 81.43% of risk-averse pairs and 88.33% of the risk-seeking pairs achieved the payoff-dominance equilibrium (Fisher exact test $p = 0.3343$). 7.14% of risk-averse pairs and 3.33% risk-seeking pairs achieved the risk-dominance equilibrium (Fisher exact test $p = 0.4503$). Figures 5 and 6 show the proportion of pairs achieving the payoff-dominant equilibrium or risk-dominant equilibrium over time for each of the two groups. When we use the risk-averse index to mid-split the sample, we cannot observe any clear pattern over time. Therefore, we again confirm the findings from past studies who find that risk aversion does not explain individual behavior in this game.

When we use the cautiousness index to identify the pairs, we find 60% of the cautious pairs and 90% of the less-cautious pairs achieved the payoff-dominance equilibrium (Fisher exact test, $p<0.0001$). Additionally, 25% of the cautious pairs and 2.85% of the less-cautious pairs achieved the risk-dominance equilibrium (Fisher exact test $p = 0.0002$). Figures 7 and 8 show that 100% of the less-cautious pairs eventually achieved the payoff-dominant equilibrium (none of them achieved the risk-dominant equilibrium). For the cautious pairs, only 60% of them achieved the payoff-dominant equilibrium and 40% achieved the risk-dominant equilibrium. As we discussed in section 1.1, since cautious individuals are less likely to attempt the risky option in the early periods of the game, they will also less likely to update their beliefs based on positive feedback. As a consequence, the strategic uncertainty between the two players in a pair would impede them from cooperation. Observations from the experiment supported our conjecture.

Result 5: The traditional measure of risk aversion cannot explain individual subjective belief and strategic selection in the repeated game.

Result 6: The psychological concept of cautiousness negatively associates with the probability that one achieve the payoff-dominance equilibrium.

4. Conclusion

This paper seeks to provide insight into how individual characteristics influence one's decision making in a social cooperation environment. Specifically, we investigated how risk preference affects people's subjective beliefs in a repeated coordination game. Moreover, in most past studies, the decision-maker's risk preference was often solely defined by the constant relative risk aversion. Accordingly, the only measure of risk preference was one's selection in certain lottery games. In this study, we explored another aspect of risk preference beyond the traditional risk aversion measure. Integrating insights gleaned from personality psychology with the literature on decision making, we put forward that cautiousness plays a key role in determining the decision-maker's subjective belief formation and strategy selection.

We designed and conducted a laboratory experiment to test this idea. In the first part of the experiment, the participants played a simple coordination game with fixed partners over ten periods. In each period, the participants made a selection between a safe option and a risky option. In addition,

we also elicited the participants' beliefs by asking them to make predictions on their partners' possible actions. We employed the binarized scoring rule (Hossain and Okui, 2013) to provide incentive to report one's subjective belief truthfully. In the second part of the experiment, we used a subset of the *International Personality Item pool* (Goldberg, 1999) to measure the participants' cautiousness level. In addition, we also assessed some other personality traits that might affect decisions in the game. Following the personality survey, the participants were asked to complete a demographic survey. In the last part of the experiment, we used the Eckel and Grossman (2008) lottery game to elicit the participants' risk aversion, as in many past studies.

Based on the data generated from our laboratory experiment, results from previous studies are replicated: the risk aversion measure cannot explain the participants' behavior in the simple coordination game. Nevertheless, evidences that are original from this paper suggest that cautiousness influences the participants' subjective beliefs and decisions through two mechanisms: 1. in the first period of the game, cautiousness affects the way a decision-maker forming mental representations of her partner. Higher score on cautiousness leads the decision-maker more likely to believe her partner will play the safe option. Behaviorally, cautiousness negatively associates with the probability of playing the risky option. 2. in the repeated game, since higher score on cautiousness makes the decision maker less likely to try the risky option in early periods of the game, she would not have enough feedbacks to update her subjective belief effectively. Consequently, the uncertainty concerning her partner's next move would make her less likely to achieve the payoff-dominance equilibrium.

There are several limitations to the current study that ought to be addressed in future work. First, whereas an experimental design that does not have feedback to the participants who have chosen the safe option, it does not capture the full picture of belief formation and strategy selection. One-shot game design and random-partner design could be helpful extensions of this study. Second, it is also worth to take other popular measures of risk preference (e.g. Zukerman sensation seeking, *Domain-specific Risk-taking scale*, Impulsiveness in the big five. etc) into consideration, as we are still far from achieving a sophisticated understanding on how individuals think, feel, and act under uncertain situations. Third, as in most past studies, the lottery game we used in this study was designed on the base of expect-utility theory, regardless of the fact that many experimental studies have shown that human decision making under uncertain situations are systematic deviations from the prediction of the expected-utility theory (Loewenstein et al. 2001). A possible alternative is to measure the decision-maker's risk preference using instruments that are designed relying on prospect theory (Kahneman and Tversky, 1979; Mishra et al., 2012). For example, Barron and Erve (2003) and Abdellaoui et al. (2008) are all possible candidates.

Our investigation contributes to several literatures. Our findings contribute to decision making literature in that we emphasize not only on strategy selection, but also on the importance of subjective judgment during decision making. We contribute to the behavioral game theory literature, by examining how individual characteristics, especially risk preference, influence the equilibrium selection in a repeated coordination game where multiple equilibria could be recognized simultaneously. We identify cautiousness as an important, but previously unexamined, aspect of risk preference that affects the game outcome. Our work also speaks to the learning literature by demonstrating how cautiousness affects the way people react to past experiences, which have not been directly investigated in a coordination game context.

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Appendix A. Tables and Figures

Table1. Detailed descriptive statistics in each period

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8	Period 9	Period 10
Percentage of Individual Select the Red	0.64	0.86	0.74	0.84	0.82	0.86	0.84	0.84	0.78	0.84
Percentage of Pairs Achieve the Red-Red	0.48	0.72	0.60	0.76	0.76	0.80	0.76	0.84	0.76	0.80
Percentage of Pairs Achieve the Blue-Blue	0.20	0.00	0.12	0.08	0.12	0.08	0.08	0.16	0.20	0.12

Table2. The descriptive statistics of the estimated risk aversion

Lottery	Payoffs	Prob.	Risk*	CRRA**	Selection
1	$6.0 $6.0	50 50	0.00	r>2.5	3 (6%)
2	$7.6 $5.2	50 50	0.28	0.96<r<2.5	5 (10%)
3	$9.2 $4.4	50 50	0.57	0.75<r<0.96	9 (18%)
4	$10.8 $3.6	50 50	0.85	0.54<r<0.75	9 (18%)
5	$12.4 $2.8	50 50	1.13	0.41<r<0.54	3 (6%)
6	$14 $2.0	50 50	1.41	0.31<r<0.41	13(26%)
7	$15.6 $1.2	50 50	1.70	0.22<r<0.31	3 (6%)
8	$17.2 $0.4	50 50	1.98	r<0.22	5 (10%)

# of Observations = 50, Standard Deviation = 2.02

Male = 16 (32%), Female = 34 (68%),

*Risk is measured as standard deviation of expected payoff.

** Assuming a contant relative risk avere utility function $U(X)=X^{(1-r)}/(1-r)$

Appendix A. Tables and Figures

Table3. The desriptive statistics of the personality survey

Variable	Mean	Std.Dev.	Min	Max	No. items
Cautiousness	0.28	0.64	-1.40	1.40	5
Trust	0.63	0.50	-0.90	1.60	5
Altruism	1.28	0.56	-0.40	2.00	5
Compliance	0.72	0.67	-0.60	2.00	5
Competence	1.12	0.59	-0.60	2.00	5
Achievement	1.24	0.68	-0.80	2.00	5

Table4. Subjective beliefs determine strategy selection

	Select Red	Select Blue
Believe my partner will select Red	98.25%	6.32%
Believe my partner will select Blue	1.75%	93.68%
# of Observations	401	95

Table5. The estimated risk aversion cannot explain the predictions in period

Subjective beliefs in period1	Risk-averse	Risk-seeking
predict Red	16 (61.5%)	15 (62.5%)
predict Blue or No Idea	10	9
# of Observations	26	24

Table6. Less-cautious indiviuduals are more likely to predict the risky option in period 1

Subjective beliefs in period1	Risk-averse	Risk-seeking
predict Red	12 (50%)	19 (73.7%)
predict Blue or No Idea	12	7
# of Observations	24	26

Table7. The cautiousness explains the origin of the subjective belief

	(1)	(2)	(3)
Model	Probit	OLS	Probit
Dependent Variable	Predict The Other Person Will Play Red (dummy, predict red =1)	Precise Predictions Range from -100 (blue for sure) to +100 (red for sure)	Play Red (dummy, play red=1)
Risk Aversion	0.06	3.76	0.15
	(0.11)	(4.96)	(0.11)
Cautiousness	-0.95***	-22.31	-1.02***
	(0.38)	(15.98)	(0.41)
Trust	0.41	30.24	0.68
	(0.48)	(21.18)	(0.52)
Altruism	-0.05	-1.07	-0.15
	(0.40)	(19.70)	(0.46)
Compliance	0.36	7.65	0.67*
	(0.38)	(20.53)	(0.37)
Competence	0.23	6.32	-0.16
	(0.63)	(32.45)	(0.65)
Achivement-Striving	0.36	9.84	0.67*
	(0.33)	(15.11)	(0.36)
Male (dummy)	0.99*	38.67	1.14*
	(0.58)	(25.87)	(0.62)
Age	-0.01	0.97	-0.23
	(0.28)	(13.94)	(0.27)
Education	-0.17	-8.40	0.07
	(0.30)	(14.44)	(0.31)
Constant	-0.40	-41.03	3.12
	(0.54)	(60.21)	(3.55)
Pseudo R-sqaure	0.18	0.19	0.24
Observation	50	50	50
Robust Std. Error (cluster on individuals)	YES	YES	YES

***p < 0.01, **p<0.005, *p<0.1

Table8. Positive feedback effectively eliminate strategic uncertainty

	Positively Feedback (Red-Red)	Negatively Feedback (Red-Blue)
Believe my partner will select Red in the Next Period	97.83%	45.95%
Select Red in the Next Period	96.60%	51.35%
# of Observations	324	37

Table9. Less-cautious pairs are more likely to achieve the payoff-dominant equilibrium

	Mid-split participants with Risk aversion		Mid-split participants with Cautiousness	
	Risk Averse Pairs	Risk Seeking Pairs	Cautious Pairs	Less-Cautious Pairs
% of pairs achieved Red-Red	81.43%	88.33%	60%	90%
% of pairs achieved Blue-Blue	7.14%	3.33%	25%	2.85%
# of Observations	7 x 10	6 x 10	6 x 10	7 x 10

Figure1. The Stag-hunt game

		Player 2	
		Red	Blue
Player 1	Red	**60, 60**	0, 45
	Blue	45, 0	**45,45**

Figure2. Percentage of individuals/pairs select the risky option

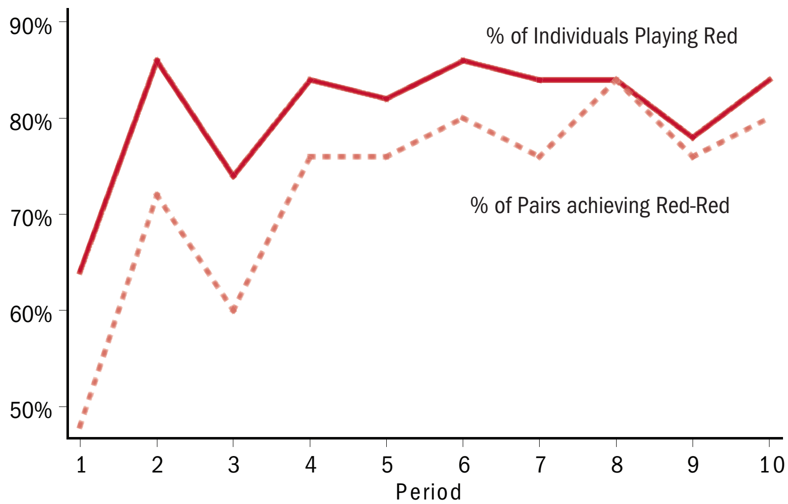


Figure3. The estimated risk aversion and the cautiousness are not correlated

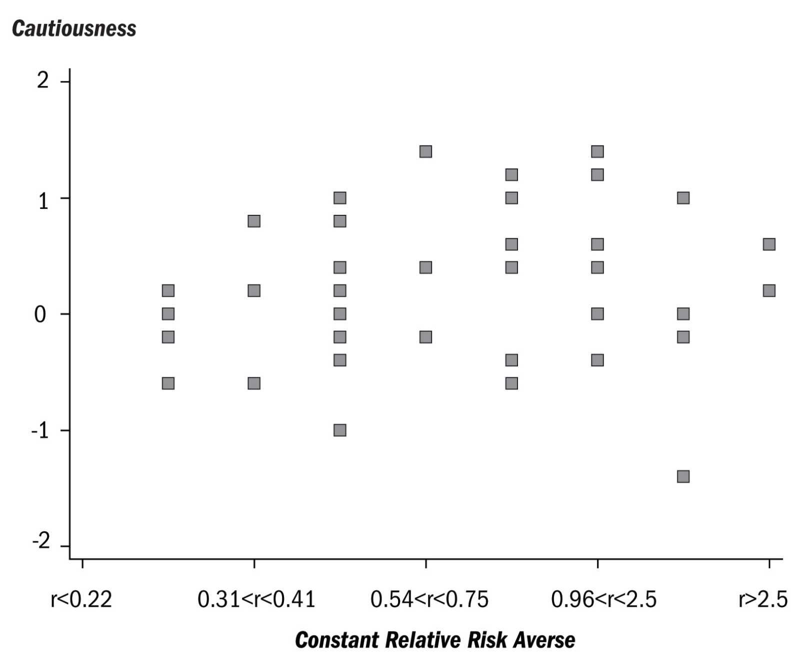


Figure4. Subjective beliefs in period1 are highly polarized

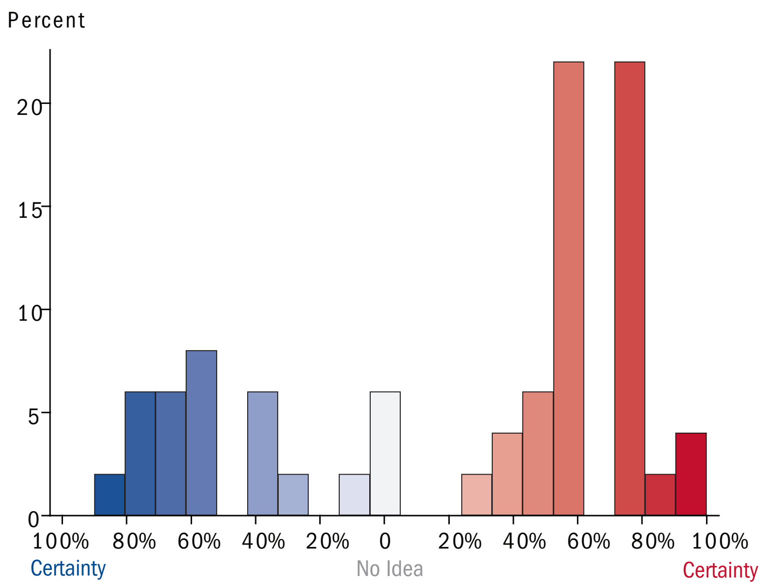


Figure5. The estimated risk aversion cannot explain why people coverge to Red-Red

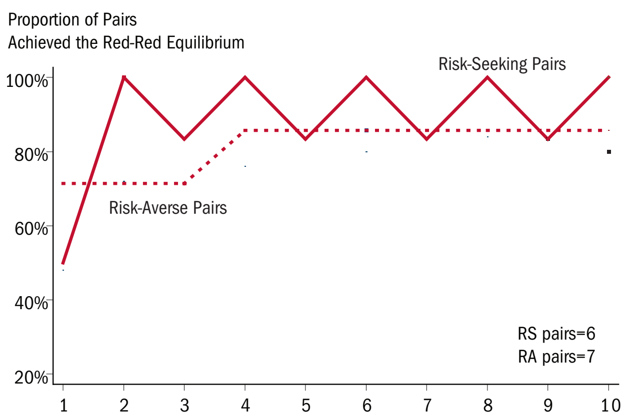


Figure6. The estimated risk aversion cannot explain why people coverge to Blue-Blue

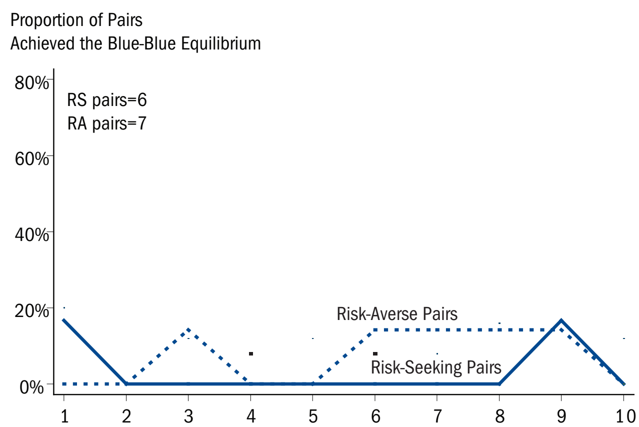


Figure7. Less-cautious pairs are more likely to converge to Red-Red over time

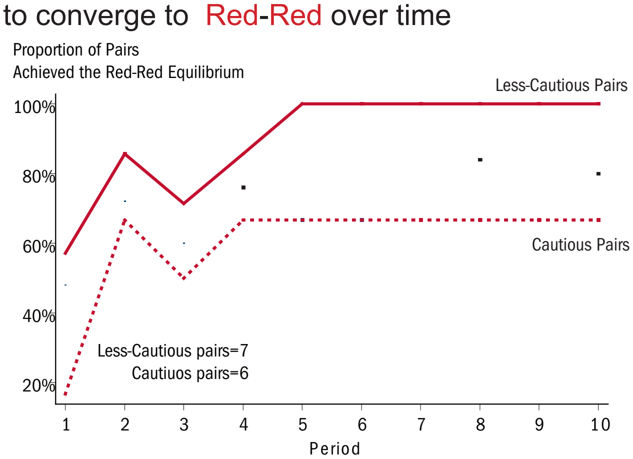
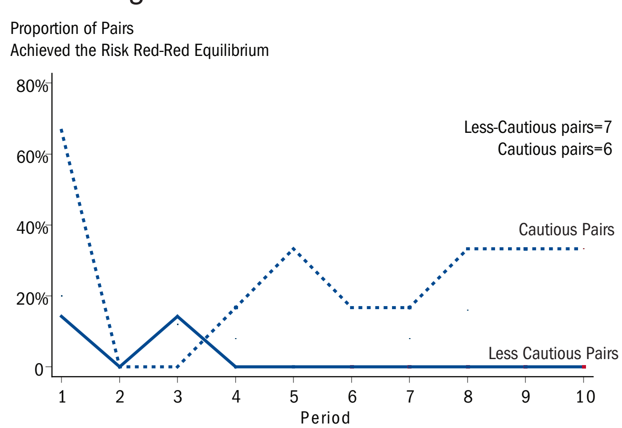


Figure8. Cautious pairs are more likely to converge to Blue-Blue over time



Appendix B. Experiment Instruction

Experiment Instructions

The purpose of this experiment is to study how people make decisions under uncertain situations. The experiment will be done on papers. You each have a printed copy of the instruction. I will now read the instruction in front of you.

Today's experiment will take approximately 60 minutes. You will finish three different parts through the experiment.

If you pay attention and make good decisions, you may earn a considerable amount of money. Just for showing up, you have earned $5. All earnings for today's tasks will be in addition to the $5. You will earn "Points" through the experiment. At the conclusion of the experiment, you will be paid $1 for every five points you earned. The more points you earn the more monetary payment you can get. At the end of the experiment, you will be paid your earnings privately and in cash. You will not be paid if you leave before you conclude the experiment.

There are three parts to today's experiment. In part 1 and part 3, the choices that you make will determine your earnings. However, you will only be paid the earnings that correspond to one of the two parts. At the end of the experiment, I will flip a coin to determine which of these two parts will be used to determine your earnings. You will have the same chance of being paid for each of these two parts. There is no direct payment for part 2.

There are some cards in this box. Please pick one randomly. The number on that card will be your EXPERIMENT ID.

For the remainder of this experiment, please refrain from any communication with other participants. Please put away your cell phones.

When you finish reading the above material, please wait for others. When everyone is ready, we will distribute and read through instructions for part 1.

Part1:

Introduction to the procedures:

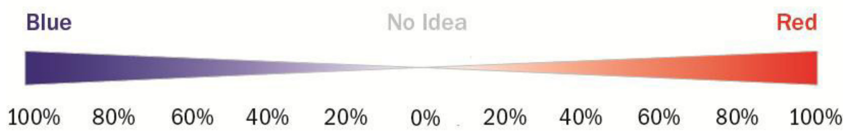
In this part, you will be paired with one other participant. Each of you will be matched with another person with the same ID number as you in the other room. You will interact with the same person over 10 rounds. In each round, you will make a choice between two actions—either Red or Blue.

The Other Participant ⇓

You ⇒	Red	Blue
Red	60, 60	0, 45
Blue	45, 0	45, 45

- If you select Blue, then you earn 45 points regardless of what the other participant selects.
- If you select Red, then:
  - If the other participant also selects Red, then both of you earn 60 points;
  - If the other participant selects Blue, then you will earn 0, and the other participant will earn 45 points.

In addition, in each round, you will make a prediction about the other participant's selection, and indicate how confident you are in your prediction. For example, you can indicate "I think the other participant will select Red, and I'm 30% sure about this." You would indicate this prediction by drawing a vertical bar on the picture below (on your answer sheet):



The other participant faces exactly the same decision and earnings. You will interact with the same person over 10 rounds.

How you will be paid in Part1:

At the end of this part, one of the ten rounds will be randomly selected to determine your payment.

A. *Payment for your decisions*

After you finish all the ten rounds, I will roll a ten-sided die to decide which round will be used to determine your payment in this part. The outcome in the randomly selected round will determine how many points you earn for your decisions in this part.

B. *Payment for your predictions*

Your payments for the predictions depend on three things: 1.you prediction, 2.the other participant's choice, 3. a random number from 0 to 100%.
You will earn 5 points if:

- Your prediction is correct with a sufficient large confident level.
- Your prediction is wrong with a sufficient small confident level.

You will loss 5 points if:

- Your prediction is correct with a sufficient small confident level,
- Your prediction is wrong with a sufficient large confident level,

Define vector V_{red} and V_{blue} :

If you report red with a positive confidence level p, then $V_{red} = \frac{1+p}{2}$.

Appendix B. Experiment Instruction

If you report blue with a positive confidence level p, then $V_{blue} = \frac{1-p}{2}$.

If you predicted red correctly, then you earns 5 points if $(1 - V_{red})^2$ is smaller than the random generated number k; otherwise you loses 5 points.

If you predicted red wrongly, then you still earns 5 points if $(V_{red})^2$ is smaller than the random generated number k, otherwise you loses 5 points.

If you predicted blue correctly, then you earns 5 points if $(1 - V_{blue})^2$ is smaller than the random generated number *k*; otherwise you loses 5 points.

If you predicted blue wrongly, then you still earns 5 points if $(1 - V_{red})^2$ is smaller than the random generated number *k*, otherwise you loses 5 points.

Effectively, one important thing I want to remind you is that telling the truth when reporting your prediction is optimal.

When you finish making prediction and decision in each round, please hand in your answer sheet to the experimenter. We will match your answer with the other participant's, record the other participant's answer on your answer sheet, then give the answer sheet back to you. You will find out the other participant's decision in that round. You will then proceed to the next round. In short, the procedure in each round is as follows:

		1		2		3		
Round Begin	⇒	Make Prediction	⇒	Make Decision	⇒	Learn the Other Participant's Decision	⇒	**Go To Next round**

After you finish all ten rounds, I will roll a ten-sided die to decide which round will be used to determine your payment for this part. When everyone has finished all ten rounds, we will move to part 2.

When you are finished with these instructions and are ready to proceed, please start to make your prediction and decision for Round 1.

Part2[1]

Please answer the questions carefully and truthfully. We guarantee that we will treat these surveys with the utmost confidentiality. I will now read the instruction in front of you.

This part contain phrases describing people's behaviors. Please indicate for each statement whether it is:

1. Very Inaccurate,

1 Q6, Q12, Q18, Q24, and Q30 are questions toward cautiousness. Q24 and Q30 are reverse-scoring questions.

2. Moderately Inaccurate,

3. Neither Accurate Nor Inaccurate,

4. Moderately Accurate

5. Very Accurate

as a description of you.

Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner.

STATEMENTS

Q1: I believe that people are basically moral 1 2 3 4 5

Q2: I complete tasks successfully 1 2 3 4 5

Q3: I make people feel welcome 1 2 3 4 5

Q4: I am easy to satisfy 1 2 3 4 5

Q5: I go straight for the goal 1 2 3 4 5

Q6: I avoid mistake 1 2 3 4 5

Q7: I believe that others have good intentions 1 2 3 4 5

Q8: I excel in what I do 1 2 3 4 5

Q9: I anticipate the needs of others 1 2 3 4 5

Q10: I can’t stand conforntations 1 2 3 4 5

Q11: I work hard 1 2 3 4 5

Q12: I choose my words with care 1 2 3 4 5

Q13: I trust what people say 1 2 3 4 5

Q14: I handle tasks smoothly 1 2 3 4 5

Q15: I love to help others 1 2 3 4 5

Q16: I hate to seem pushy 1 2 3 4 5

Q17: I turn plans into actions 1 2 3 4 5

Q18: I have a reserved and cautious attitude toward life 1 2 3 4 5

Q19: I suspect hidden motives in others 1 2 3 4 5

Q20: I don’t understand things 1 2 3 4 5

Q21: I make people feel uncomfortable 1 2 3 4 5

Q22: I Insult people 1 2 3 4 5

Q23: I am not highly motivated to succeed 1 2 3 4 5

Q24: I do crazy things 1 2 3 4 5

Q25: I believe that people are essentially evil 1 2 3 4 5

Q26: I don’t see the consequences of things 1 2 3 4 5

Q27: I take no time for others 1 2 3 4 5

Q28: I hold a grudge 1 2 3 4 5

Q29: I put little time and effort into my work 1 2 3 4 5

Q30: I often make last-minute plans 1 2 3 4 5

Part 3. In this part, you will select from among eight different lotteries the one lottery you would like to play. The eight different lotteries are listed below. You must select one and only one of these lotteries. To select a lottery, place an X in the appropriate box.

Each lottery has two possible outcomes (ROLL LOW or ROLL HIGH) with the indicated probabilities of occur. Your compensation for this part of the experiment will be determined by which of the eight lotteries you select; and which of the two possible outcomes occur. For example, if you select Lottery 4 and ROLL HIGH occurs, you will win 54 points. If ROLL LOW occurs, you will win 18 points. For every lottery except Lottery 1, each ROLL has a 50% chance of occur. At the end of this part, you will roll a ten sided-dice to determine which event will occur. If you roll a 1, 2, 3, 4, or 5, ROW LOW will occur. If you roll a 6, 7, 8, 9 or 10, ROLL HIGH will occur.

When you are finished with these instructions and are ready to proceed, please make your lottery selection with an X in the last box across from your preferred lottery. When you finish the selection, please notify me. You will then roll the die. After that, I will pay your earnings privately and in cash.

Choices	Rolls	Outcomes	Chances	Your Selection (Mark One Only)
Lottery1	Low	30	100%	
	High	30		
Lottery2	Low	26	50%	
	High	38	50%	
Lottery3	Low	22	50%	
	High	46	50%	
Lottery4	Low	18	50%	
	High	54	50%	
Lottery5	Low	14	50%	
	High	62	50%	
Lottery6	Low	10	50%	
	High	70	50%	
Lottery7	Low	6	50%	
	High	78	50%	
Lottery8	Low	2	50%	
	High	86	50%	