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Abstract: We examine whether prior exposure to environments with varying degrees of risk affects individuals' risk-taking behavior. In a laboratory setting, subjects were first exposed to high, moderate, or low-risk environments. We then elicited their risk aversion based on their decisions on an identical set of lotteries. We find that subjects who had been exposed to a riskier environment exhibited higher degrees of risk aversion. This effect is driven by the risk environment *per se* rather than by the realized outcomes of the risk. The finding has implications for theoretical models of decision-making under uncertainty and can speak to a few current policy debates.

Key Words: Risk; Risk Aversion; Laboratory Experiment

JEL Classification: D81, C91

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I. Introduction

> *He was haunted by a fear that the food would not last. He inquired of the cook, the cabin-boy, the captain, concerning the food stores. They reassured him countless times; but he could not believe them, and pried cunningly about the lazarette to see with his own eyes…. The scientific men were discreet. They let him alone. But they privily examined his bunk. It was lined with hardtack; the mattress was stuffed with hardtack; every nook and cranny was filled with hardtack. Yet he was sane. He was taking precautions against another possible famine - that was all.*
>
> *Jack London (1907) "Love of Life"*

In American writer Jack London's (1907) short story "Love of Life", a man named Jack set off into the wilderness alone. After he was rescued from coldness, starvation, and the threat of beasts, the man became extremely cautious about the storage of food. This anecdote in the short story showcases how the risk environment an individual is exposed to affects his or her risk attitude.

A daily life example could be drawn from financial decision-making. Picture an investor who has just experienced a period of volatile stock prices. Would he become more risk-loving and take up more small-cap stocks or become more risk-averse and increase his holdings in safe government bonds? In the domain of social policy-making, understanding this can also provide insight into important policy issues. For instance, the welfare state in many European nations significantly changes their citizens' risk environments. Through various social transfers, these societies create safety nets for their citizens. Would these welfare policies affect people's risk attitude through changes of risk environments? Similarly in China, much attention has been drawn to the only child effect in Chinese families as a result of the "one child policy" implemented since the late 1970s in China. People worry that these "little emperors and empresses" may behave differently after they grow up, as they were nurtured in an overly protective, somewhat risk-free environment (e.g. Fong, 2004). Although it might be hard to be certain of the answers to the questions stated above, it seems reasonable to conjecture that prior risk environment may impact one's risk attitudes.

However, standard economic models of decision-making under uncertainty postulate the stability of risk preferences and mainly focus on characterizing (or axiomizing) "stable risk preferences." The interaction between prior risk environments and future risk attitudes is thus neglected. In this present paper, we supply evidence on how risk environments affect subsequent risk-taking behavior.

A number of empirical studies have demonstrated the link between an individual's past experiences and his or her subsequent risk preference. Thaler and Johnson (1990) and Post et al. (2008) focus on the effect of experiencing realized lottery outcomes. They both find that individuals become more risk averse once they undergo negative outcomes and less risk-averse after positive ones. Malmendier and Nagel (2011) examine whether individuals' past experiences of macroeconomic shocks affect their risk attitude. They find that those who have experienced low stock-market returns throughout their lives either become less likely to participate in the stock market or invest a lower fraction of their liquid assets in stocks. Using financial professionals as experimental subjects, Cohn et al. (2014) document that financial professionals are more risk averse when primed with a financial bust than those primed with a boom. The authors argue that the priming procedure reminds those financial professionals of their past experiences (bust or boom), which may influence their willingness to take risk in the experiment. A growing literature has started to explore how past traumatic life experiences, including violence (Callen et al., 2014), combats (Bogan et al., 2013), conflict (Voors et al., 2012) and natural disasters (Eckel et al., 2009 and Page et al., 2014) affect an individual's risk attitude. Relatedly, Cameron et al. (2013) documents that the only children born under China's one-child policy are more risk-averse than those with siblings. Nguyen (2011) combines administrative and experimental data in Vietnam finding that fishermen, who are presumably exposed to a risky work environment, appear less risk averse than those with other occupations. All the above-mentioned studies suggest that the experiences in or exposure to certain environments may affect an individual's decision-making under uncertainty.

However, when examining the effect of an individual's prior exposure to risk environments on his or her risk preferences, a potential confound could arise because past experiences include both personal outcomes, which reflect the idiosyncratic realizations of risk, and the risk environment the individual has been exposed to.

Previous studies have investigated how past experiences influence individuals' risk preferences, however the effect of exposure to certain environments with risk or uncertainty is inherently entangled with the effect of that particular realization of risk or uncertainty.[2] Little is known of the effect prior risk environments have on an individual's current propensity for risk.[3] This paper investigates the effect of previous exposure to different risk environments on subsequent risk taking behavior in a well-controlled experiment. Subjects are first exposed to lotteries with varying degrees of risk -- high, moderate, and low. Then, all the subjects are asked to make decisions on an identical set of lotteries. To minimize the effect of positive or negative outcomes, no information regarding the realization of lotteries is revealed until the end of the experiment.

Our main result is that exposing individuals to a riskier environment would reduce their willingness to take risks. We interpret these results from both psychological and evolutionary perspectives. Stress arising from decision-making in the high-risk environment may be one contributing factor for the higher risk aversion after individuals were exposed to high risk, and we argue that these responses could be deeply rooted in the evolutionary process of mankind. We also discuss the theoretical, empirical and policy implications of our findings.

Our work also relates to a growing literature on the stability of risk preference (see, e.g. Chuang and Schechter, 2015, Section 2.2 for a survey). Existing studies examine whether and how much people's risk preference differs across time (Andersen et al., 2008), contexts (Barseghyan, Prince and Teitelbaum, 2011), elicitation methods (Chuang and Schechter, 2015; Straznicka, 2012), etc. On top of these studies, our short-run, context-free experiment with a uniform elicitation method reveals that the risk environment an individual has experienced also influences how individual will behave under risk in the future.

The rest of this paper is organized as follows: Section 2 describes our experimental design and procedures. We present and discuss the empirical results in Section 3, and the final section concludes.

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[2] For instance, in the experiment of Mengel, Tsakas and Vostroknutov (2015), the realized outcomes are revealed to subjects before they proceed to the next round's decision-making.

[3] Besides, Mengel, Tsakas and Vostroknutov (2015) argue that for those field studies demonstrating the link between macroeconomic shocks or financial crises and risk taking behavior, it is difficult to establish whether such effects are due to an increase in risk aversion or to updated priors or other reasons.

II. Experimental Design and Procedures

All subjects participated in the main experiment for a total of 12 rounds. We employed the multiple price list format popularized by Holt and Laury (2002).[4] In each round, subjects were presented with a menu of 13 choices (rows) between a lottery (option Left) and a sure outcome (option Right), as shown in Figure 1. The options on the left were identical, while options on the right increased by rows. Across rounds, the left options differed.

To examine how an individual's attitude towards risk reacts to various prior risk environments, we manipulate the magnitude of risk to which subjects are exposed. Subjects are randomly assigned to one of the three treatment groups: HM, LM and the control treatment MM. In the first 6 rounds, subjects in treatment HM, MM, and LM were exposed to a set of 6 lotteries with high risk (set H), moderate risk (set M), and low risk (set L), respectively, with one lottery in each round. In the last 6 rounds, subjects in all treatments were exposed to the set of 6 lotteries with moderate risk, set M. That is, subjects in all the different treatment groups made decisions on an identical set of lotteries in the second half of the experiment. Thus we can make between-subject comparisons to identify the causal relationship between prior risk environments and one's subsequent risk attitude.

In every round, subjects chose between a lottery and a sure outcome in each of the 13 rows. If the subject chose the lottery, he or she would obtain x experimental tokens with half probability and obtain *400-x* tokens with half probability. Specifically, the 6 lotteries' outcomes are (400, 0), (395, 5), (390, 10), (385, 15), (380, 20), and (375, 25) respectively in set H, (310, 90), (305, 95), (300, 100), (295, 105), (290, 110), and (285, 115) respectively in set M, and (230, 170), (225, 175), (220, 180), (215, 185), (210, 190), and (205, 195) respectively in set L. Note that all lotteries have an equal mean of 200 with a 50% probability of receiving the better outcome (x) and a 50% probability of receiving the worse outcome (*400-x*). The standard deviation for any lottery with x is *x-200*. In row i, if the sure outcome was chosen, the subject received z_i tokens, for any $i \in \{1,2,\dots,13\}$. Given x, the better outcome of the lottery in the round, the following equation shows how the values of $z_i's$ are determined.

[4] In Holt and Laury (2002), subjects choose between a riskier lottery and a less risky lottery for each row. In our experiment, subjects choose between a lottery and a sure outcome.

$$z_i = \begin{cases} 400 - x + \frac{200-(400-x)}{10} \cdot i, & if\ i \leq 10 \\ 200 + \frac{(x-200)}{5} \cdot (i-10), & if i > 10 \end{cases}$$

Therefore, $z_i's$ are listed in an ascending order, with $z_i \leq (\geq) 200$ for $i \leq (\geq) 10$.[5] As a result, a risk-neutral individual would have chosen the lottery in rows 1-9, the sure outcomes in rows 11-13, and have been indifferent in round 10. Risk-averse individuals would have switched to sure outcomes earlier than risk neutral individuals.

A few other experimental particulars of interest are worth mentioning. First, subjects were presented with lotteries and sure outcomes algebraically without any specified values in the instructions to mitigate possible expectation effect. (See the experimental instruction in the Appendix for details.) Second, in the main task of the experiment, for each subject, the order of the 6 lotteries in one set (set H, M, or L) is randomized to counterbalance the order effect. Finally, subjects were paid by one randomly selected decision to avoid both the portfolio and the wealth effect.[6]

A total of 179 undergraduate students at Nanyang Technological University, Singapore participated in the experiment, during the period of September 2014 to October 2015. 66 subjects participated in the HM treatment, 42 participated in the MM treatment and 71 participated in the LM treatment.[7] No subject participated in the experiment more than once. Each session lasted for roughly 30 minutes and proceeded in the following manner. Once subjects arrived at the computer lab, experimenters assigned them a random seat. After all subjects signed the consent form, they were given computerized instructions while the experimenter read them aloud. Then, the main experiment began. A post-experiment questionnaire was given to collect information on demographic characteristics. The outcomes of the lotteries chosen by the subject were not disclosed to the subject until the end of the experiment. Subjects were paid in cash before they left the lab. The average monetary

[5] For instance, given x=210, the $z_i's$ are 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 202, 204, 206, respectively.

[6] Each subject makes a total of 156 decisions (13 decisions in one round×12 rounds). Laury (2006) shows that whether to pay all decisions in a round or to randomly pay one decision in a round does not make a difference.

[7] Our aim is to identify whether high-risk or low-risk prior environment has an effect on subsequent risk-taking behaviors. Thus, we recruited more subjects for the HM and LM treatments than MM treatment.

earning was S$16.25 (roughly equivalent to US$11) including the guaranteed S$3 participation fee. The experiment was programmed using Z-tree (Fischbacher, 2007).

III. Experimental Results

This section will proceed as follows. We first present the main results which are mainly based on subjects' decisions in the last 6 rounds of the main task. Then, we explore two alternative explanations for our main results. Lastly, we discuss possible mechanisms driving these findings in Section III.2.

III.1 Main Results

For each round, if he or she prefers receiving the outcome z_i to the lottery, a *rational* individual should prefer receiving any other sure outcome $z_j > z_i$ to the lottery.[8] Therefore, in each round, any rational choices would exhibit a pattern like *Lottery*,…, *Lottery*, *Safe*, …, *Safe* where *Lottery* indicates that the individual chose the lottery while *Safe* indicates that the individual chose the sure outcome. In other words, there should be no more than one switch point in each round: the choice of *Lottery* should not reappear after the first occurrence of the *Safe*.[9] Overall, 92.7% of the observations are considered "rational". By Fischer's exact test and chi-squared test, the frequency of "rational choices" is not significantly different among the three treatment groups (92.4% in HM, 92.5% in MM and 93.2% in LM).

Following Holt and Laury (2002), the number of *Safe* choices chosen in a round will be used as an indicator of risk aversion. Given rational choices, this also indicates the unique switch point chosen. Table 1 gives an overview of the average and median numbers of *Safe* choices throughout the experiment. Note that the values in Rounds 1-6 are not comparable as the *Lottery* and *Safe* choices differ largely among treatments.

Our primary interest lies on decisions made in the second half of the main task during which subjects in all three treatment groups were exposed to the 6 common lotteries in a random order. According to standard economic theory, there should be no difference in subjects' risk aversion among treatment groups. Figure 2 reports the

[8] Otherwise, at least one of the following properties for rationality is violated: (1) completeness, (2) transitivity, and (3) more is better.

[9] Experimental studies which use the multiple price list method to elicit risk and/or time preferences find that some subjects switch back and forth from row to row, known as the multiple switch points (e.g. Andersen et al., 2006). Holt and Laury (2002) document around 10 percent multiple switching from undergraduate student subject pool and more irrational decisions in the hypothetical treatments.

average number of *Safe* choices in each of the set M lotteries during Rounds 7-12. Figure 2(a) includes all observations while Figure 2(b) includes "rational" observations only. In both sub-figures, the average numbers of *Safe* choices under the HM treatment appear to be higher than those under the MM and LM treatments, under each lottery; meanwhile, in 4 out of the 6 lotteries, where x=290, 295, 305, or 315, the average numbers of *Safe* choices under the MM treatment are higher than those under the LM treatment.

Table 2 summarizes the results of the Mann-Whitney tests. We partitioned the dataset for Rounds 7-12 by lottery. When all observations are included, the number of *Safe* choices in the HM group is higher than that of the LM group for each lottery at the 5% significance level, and is higher than that of the MM group in decisions involving lotteries 300, 305, 310 and 315 at the 10% significance level; the number of *Safe* choices in the MM group is higher than that of the LM group for lottery 290 at the 10% significance level. If we exclude observations with multiple switch points, all these results persist.

The above results suggest that exposure to a higher risk environment reduces an individual's subsequent willingness to take risk. Note that the results are free from the effect of the realization of lottery outcomes, as subjects did not receive feedback on the lottery's realized outcome until the end of the experiment.

Regression analysis

Given that our multiple-round experiment generated a balanced panel dataset and that other independent variables may disturb our results, we conducted a regression analysis to further investigate the effect of prior exposure to risk environments on subsequent risk-taking behavior. In doing so, we focused solely on rational choices in Rounds 7-12. Recall that the standard deviation of lottery x is x-200. Therefore the average standard deviation of the lotteries in Rounds 1-6 is 17.5 in treatment LM, 102.5 in treatment MM, and 187.5 in treatment HM. The increment of lottery risk, measured by average standard deviation, is 85 between LM and MM as well as between MM and HM. We thus created a discrete variable, *PriorRisk*, indicating the magnitude of prior risk an individual is exposed to. It takes the values of 0, 1, and 2 for treatments LM, MM, and HM respectively.

Table 3 presents the regression results using data with "rational" choices.[10] The dependent variable is the number of *Safe* choices chosen in a round. In column (1), we regressed it on *PriorRisk* as well as x of the lottery on which the player was making a decision, with robust standard errors reported. Column (2) further controls for demographic variables including gender (*Male* equals 1 if the subject is male and 0 otherwise), ethnicity (*Chinese* equals 1 if the subject is Chinese, the main ethnic group in Singapore, and 0 otherwise), major (*Econ* equals 1 if the subject is an Economics or Business major and 0 otherwise), and experience (*Experience* equals 1 if the subject has previous experience in financial investment and 0 otherwise).[11] Column (3) further includes dummy variables capturing round fixed effects.[12] Column (4) is the same as Column (3) except that standard errors are clustered at the individual level. Column (5) employs random effect panel model estimation instead of OLS estimation, controlling for individual effects. In all these regressions, the coefficients for the variable *PriorRisk* are positive and statistically significant at conventional levels. The coefficients suggest that previous exposure to higher risk reduces individuals' willingness to take risk and increases the number of *Safe* choices. On average, prior exposure to the set H lotteries leads to about one half more *Safe* choice in subsequent decision-making over a lottery compared to prior exposure to the set M lotteries, and prior exposure to the set M lotteries increases the number of *Safe* choices by about one half in a subsequent decision compared to prior exposure to the set L lotteries.

The coefficients of *PriorRisk* capture the effect of prior exposure to risk on individuals' willingness to take risk, while the coefficients of x capture the effect of the "present" lottery risk. We can thus compare the effect of past risk and that of present risk quantitatively. The coefficients of x are about 0.016 across different specifications and statistically significant in Columns (4) and (5), implying that one unit increase of standard deviation in the present lottery increases the number of *Safe* choices by 0.016. The coefficients of *PriorRisk* imply that 85 units of increase in standard deviation in the previous lotteries will on average lead an individual to

[10] The regression results persist qualitatively even if we include data with multiple switch points. The only exception is that the effect of *PriorRisk* becomes more statistically significant in some of the specifications.
[11] Of our subjects, 59% are male, 92% are Chinese, 18% are Economics or Business majors, and 17% have previous experience in financial investment.
[12] Including a variable indicating time trend instead does not qualitatively change the results in Table 3.

choose an additional half *Safe* choice. A simple calculation suggests that the magnitude of the effect of prior risk is thus roughly one third of the effect of present risk.[13]

We also found some additional results from Table 3. Firstly, consistent with the findings in the literature on gender differences in risk aversion (e.g. Sapienza et al., 2009), female subjects are generally more risk averse than their male counterparts. Secondly, Chinese subjects appear to be less risk averse compared to other ethnic groups (Malay, Indians and Eurasians) but this effect becomes statistically insignificant if we cluster standard errors at the individual level or control for individual random effects.

To complement the above analysis, we computed and created one additional dependent variable, *CE* (certainty equivalence) to check the robustness of our results. Suppose, in a round, a rational individual chooses the lottery for any $z \leq z_k$, and the sure outcome z for any $z \geq z_{k+1}$. If $k \in \{1, 2, \ldots, 12\}$, let $CE = \frac{z_k + z_{k+1}}{2}$; if *k=0*, let $CE = \frac{(400-x)+z_1}{2}$; if *k=13*, let $CE = \frac{x+z_{13}}{2}$. Therefore, *CE* indicates the *expected* certainty equivalence of the lottery for the individual.[14] Analysis on certainty equivalence is commonly used in the literature (e.g. Goeree et al., 2002, 2003). Again, we focus on subjects' "rational" decisions in the second halves of the main task (with moderate-variance lotteries).

In Table 4, the dependent variable is the natural logarithm of *CE*.[15] The specifications of the regression models follow those in Table 3. In column (1), we regressed the natural logarithm of *CE* on *PriorRisk* and *x* of the lottery. Column (2) controls for the demographic variables. Column (3) further controls for round fixed effects. Column (4) takes into account potential clustering of standard errors at the individual level. Column (5) estimates the individual-level random effect model. The regression results are consistent with those in Table 3. In all the specifications, the

[13] Figure 2 suggests that the effect of treatment HM relative to treatment MM is more prominent than that of treatment LM. However, in the regressions of Table 3, if we replace *PriorRisk* with a dummy variable indicating the treatment LM, the coefficients of this dummy variable are negatively significant in all the regressions except the one in Column (4). This suggests that prior-exposure to the low risk environment leads to more subsequent risk-taking behavior relative to the moderate/high risk environment. On the other hand, if we replace *PriorRisk* with a dummy variable indicating the treatment HM, the coefficients of this dummy variable are positively significant in all the regressions in Table 3, showing the robustness of the effect of treatment HM.

[14] The mean and standard deviation of *CE* are 173.9 and 42.1 respectively.

[15] Using *CE* as the dependent variable instead does not change the regression results qualitatively.

coefficients of *PriorRisk* are negatively significant, implying that on average previous exposure to the high-risk environment (set H lotteries) reduces certainty equivalence of a subsequent lottery by about 3% relative to previous exposure to the moderate-risk environment (set M lotteries), and so does the moderate-risk environment relative to the low-risk environment (set L lotteries). Combining the results in Tables 3 and 4, our main finding is summarized as follows.

Main finding*: Individuals with previous exposure to a riskier environment appeared to be more risk averse than individuals with previous exposure to a less risky environment.*

We interpret the larger number of *Safe* choices in the treatments with higher risk as an indication that exposure to a high-risk environment increases risk aversion. Two other possibilities may also have the potential of explaining our findings. Firstly, subjects may have been on autopilot in the latter rounds of the experiment. If this was in effect, the subjects in the HM treatment group, who chose more *Safe* options in the first 6 (riskier) lotteries (as shown in Table 1), also chose more *Safe* options in the last 6 rounds. It is difficult to explicitly test whether subjects came up with a rule in the earlier rounds which they would then apply to the rest of the experiment without much further thought. However, data on subjects' reaction times helps to partially refute this possibility. Intuitively speaking, if an individual is on autopilot, the time needed for decision-making would be short. Figure 3 presents average reaction time throughout the experiment. The downward trend suggests that subjects spent less and less time making decisions on similar lotteries as the experiment proceeded. However, when they perceived sharp changes in the lottery risk (Round 7 in HM and LM), the subjects' reaction times spiked significantly. This implies that they stopped responding without much forethought (if they were even on "autopilot" to begin with) and reconsidered how best to respond to the new environment. In contrast, the reaction time kept declining over time in treatment MM, where subjects experienced the same set of lotteries in first 6 rounds and the last 6 rounds.

The second possibility is that subjects in the MM treatment group, who made decisions on the same set of lotteries (set M) in the second half of the experiment as they did in the first half of the experiment, may have behaved differently (inconsistently) when they played the set M lotteries for the second time. However, we found that, for a given lottery, on average about 72% of the subjects in treatment

MM made nearly identical decisions (i.e. the difference in the number of *Safe* options chosen is equal to or less than 1). Also, for all the lotteries in set M except the one with x=300, the Wilcoxon signed-rank test fails to reject the null hypothesis that a subject chose equal numbers of *Safe* choices in the first half of the experiment and in the second half of the experiment (at the 5% significance level), suggesting that MM subjects behaved consistently most of the time.[16] Moreover, as a robustness check, we ran regressions in Tables 3 and 4 replacing the data of treatment MM in the second half of the experiment with those in the first half of the experiment in treatment MM. Hence, in the observations used in these regressions, the subjects all experienced the set M lotteries for the first time. These regressions give us qualitatively the same results: Previous exposure to a riskier (less risky) environment leads to less (more) risk taking behavior and lower (higher) certainty equivalence for lotteries.

III.2 Discussion

We found that exposure to a riskier environment increased an individual's risk aversion in later decision-makings. One factor possibly accountable for this change in behavior is the stress or fear that may arise under a high-risk environment. Psychological literature shows that uncertainty constitutes a powerful stressor (e.g. Monat, Averill and Lazarus, 1972; Zakowski, 1995) and stress modulates risk behavior (e.g. Porcelli and Delgado, 2009; Mather, Gorlick, and Lighthall, 2009; Buckert et al., 2014). Kandasamy et al. (2014) suggest an underlying physiological mechanism, linking elevated levels of Cortisol, a stress hormones, to people's risk-aversion: they found that increased stress (Cortisol) level that was comparable to that of real traders when faced with uncertainty and market volatility made subjects less willing to take risk. In our experiment, the high-risk environment may have made subjects feel more stressed and possibly even fearful about the outcome. Such emotional reactions may have been carried over into the second half of the main task. This explanation is in line with Callen et al's (2014) findings that the combination of prior exposure to a violent (risky) environment and fearful recollections will cause ones' preference for certainty. They name this phenomenon "certainty premium."

Our findings on the effect of prior exposure to risk on risk preference may have roots in the evolution of mankind. The higher level of risk aversion observed in

[16] For the lottery with x=300, subjects chose slightly more "*safe"* choices in the first 6 rounds than in the last 6 rounds (on average 6 vs. 5.4).

the high-risk environment might reflect a *survival strategy* developed in the highly risky environments during the evolutionary process of humans. Recall that in our treatment HM, the first 6 high-variance lotteries mimic situations of very high risk: subjects had a 50% chance of receiving nearly zero in their payoffs. The degree of risk in this environment depicts that of the *jungle as* described by English philosopher Thomas Hobbes -- where men have to protect themselves from losing their lives as beasts in the jungle do. In the dangerous jungle, survival, rather than expected return maximization, is the top priority for individuals. A higher level of risk aversion, which prevents individuals from risking their lives, would be a better survival tactic in the presence of very high risk.[17] In contrast, subjects in the LM and MM groups faced a less risky environment in the first 6 rounds; the lower outcome ranges from 85 to 195, 42.5%-97.5% of the expected return (i.e. 200). In a less risky environment, threat to one's survival is not such a looming concern. In such situations, expected return maximization may have more priority. High levels of risk aversion, which will keep subjects away from risky options, are not as necessary for those looking to maximize their returns, when compared to those facing a high-risk situation.[18]

The above discussion provides an explanation for the effects varying degrees of risk had on subjects' risk aversion. We are not arguing that a few rounds of decision-making within the context of an experiment would permanently affect subjects' risk attitudes. Nevertheless, our experimental findings suggest that when subjects have experienced a high-risk environment, they tend to exhibit more risk-averse behavioral patterns in later decisions. This "behavioral anomaly" may be deeply rooted, stemming from the evolution of mankind where human beings had to struggle for survival in very dangerous environments.

Our findings also point to the main motivation of this paper – the importance of disentangling the effect of the risk environment *per se* from the effect of the idiosyncratic realizations of outcomes garnered from such risk environments. As discussed in the Introduction, a growing line of literature focuses on how individuals'

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[17] Relatedly, from a functional-evolutionary perspective, Ohman (1986) shows that fear originates in a predatory defense system whose function is to allow animals to avoid and escape predators. This suggests that the emotions associated with high risk, like fear and stress, are also evolutionarily adaptive strategies conducive to survival in a high-risk environment.

[18] Of course, the subjects in the HM group were not presented with threats to their survival. However, we argue that the pattern they exhibited in the experiment may have origins in the evolution of mankind.

past experiences in financial crises, violence, combats, etc. shape risk attitude. The effects of personal experiences suggest that individuals are able to "learn" from outcomes, the realizations of such risk. However, this may not be sufficient for survival in highly dangerous (risky) environments where one singular bout of bad luck may lead to the end of the game (e.g. *death*). By contrast, the ability to learn from and adapt to the environment itself would be more crucial for survival in a highly dangerous (risky) environment. In our experiment, subjects did not observe the realizations of their decisions until the end of the session. Therefore, they were unable to learn from their personal idiosyncratic realization of outcomes. The effect we report from the experiment is thus suggestive of the subjects' capability to learn from the environment *per se*; the riskiness of an environment itself could directly influence one's risk attitude.

IV. Conclusion and Implications

In the present study, we experimentally examined the effect of prior risk environments on people's subsequent risk-taking behaviors in laboratory settings. We found that subjects appeared to be more risk averse after they were exposed to a relatively high-risk environment. Our experimental design allows us to conclude that the effect comes from the risk environment *per se* rather than the realized outcomes.

Before we extrapolate implications from our results, the external validity of our experiment needs to be discussed. The risk involved in the experiment is limited to the uncertainty of the lottery outcomes. Not only were the incentives involved rather small but the subjects were also exposed to the environment for a very short time period. These settings may lack some elements of real-world risk environments. Nevertheless, we were able to observe changes in subjects' risk behaviors even within a short-lived, laboratory setting. Thus we can surmise that the impact of risk environments on risk-taking behavior may be even larger in a real-world environment.

Our main finding identifies a direction that future research could pursue. In the models of decision-making under uncertainty, risk aversion is typically exogenously determined and independent of the volatility of the risk environment an individual is exposed to. (For example, the expected utility theory assumes that risk aversion is only determined by the curvature of the utility function.) However, our key finding suggests a potential link between these two variables: experiencing a high-risk environment may directly influence attitudes toward risk. Theoretical economists may consider incorporating this relationship in models involving decision-making under uncertainty. Additionally, this interaction may provide insights into one of the major puzzles of financial economics--that equity premium varies strongly and systemically over time. In particular, the equity premium rises during recessions and declines in booms (Harvey, 1989; Bekaert and Harvey, 1995).[19] Our results suggest that individuals may become more risk-averse and require a higher equity premium after experiencing a volatile environment, which is more likely to occur during economic downturns (Manda, 2010).

Our finding can also speak to policy debates concerning the consequences of the welfare states in western and northern European countries as well as the "one-child" policy in China, a radical approach to limiting population growth. A welfare state provides a safety net for its people, significantly reducing risk in many aspects of life. One may thus wonder how the policies of the welfare state would change people's attitude towards risk. In China, due to the "one-child" policy, the "only" children are typically overprotected against risk. Although this may be optimal decisions for their risk-averse parents, many worry about the potential adverse effects that may result with such "little emperors and empresses". Cameron et al (2013) reports that only children in China are more risk averse and less competitive than those with siblings. Although it may be appealing to attribute their results to the environment in which the only children grow up, their study unavoidably compounds the effect of risk environment with the effect of realized outcomes as discussed previously in this paper. Our findings suggest that a low-risk environment *per se* is not sufficient to induce risk aversion of the only children in the Chinese families. Adversely, a low-risk environment may mildly increase the willingness to take risk. In this sense, we contribute to the policy debates by providing a relevant finding.

[19] Some asset pricing models assume countercyclical risk aversion to account for this pattern (Campbell and Cochrane, 1999; Pastor and Veronesi, 2005).

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Figures and Tables

Figure 1: A screenshot of one round in the main task

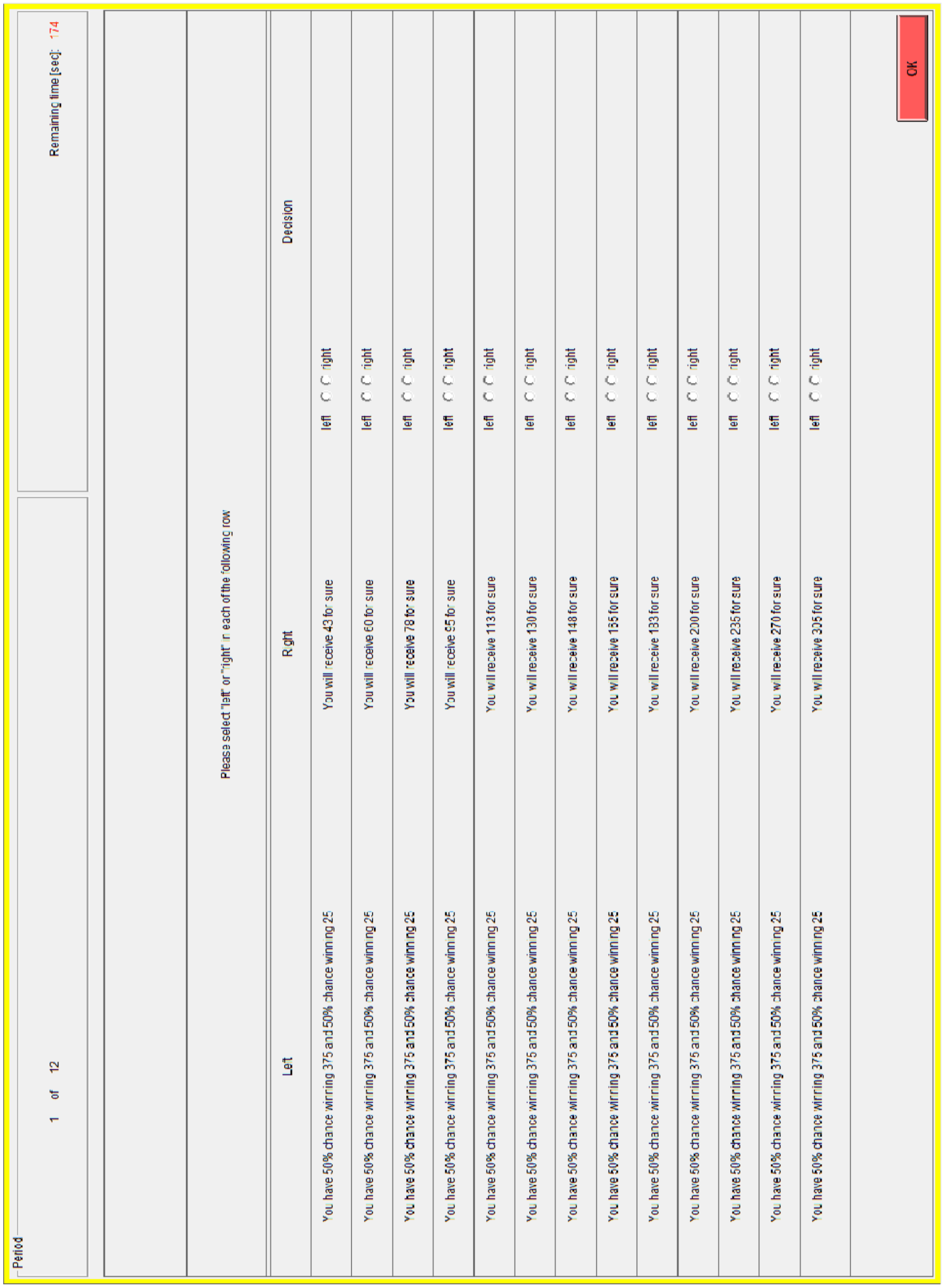


Figure 2: Choices of *Safe* options in rounds 7-12 by treatment

Figure 2(a): All choices

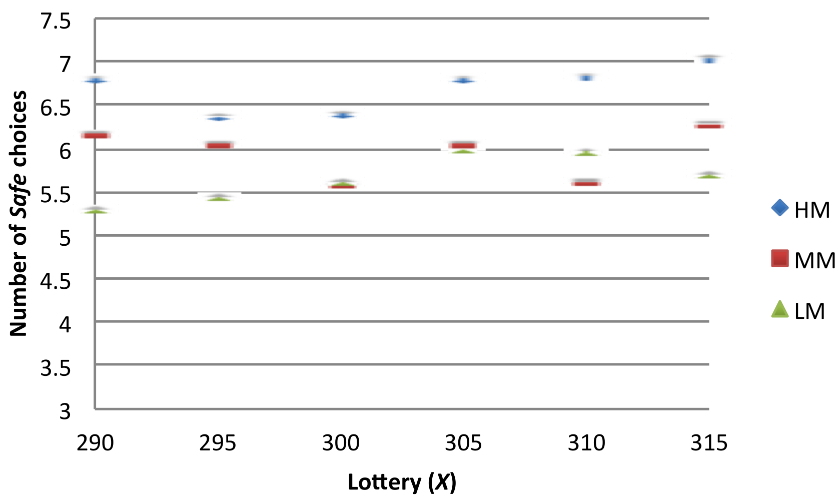
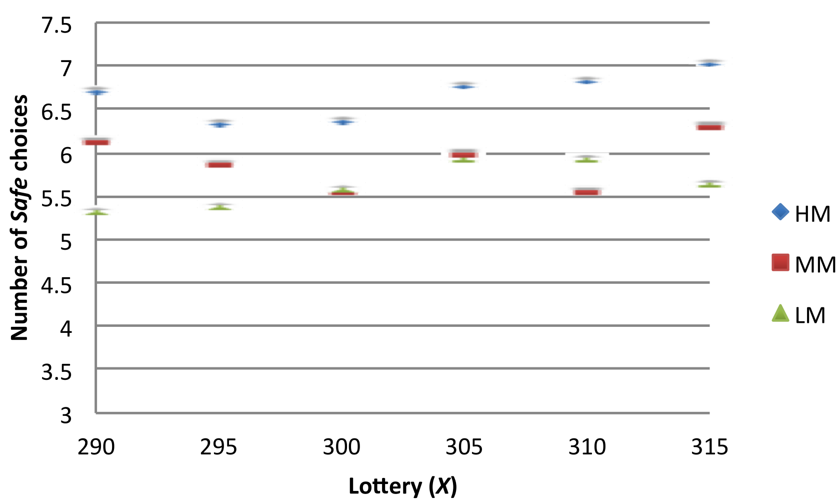
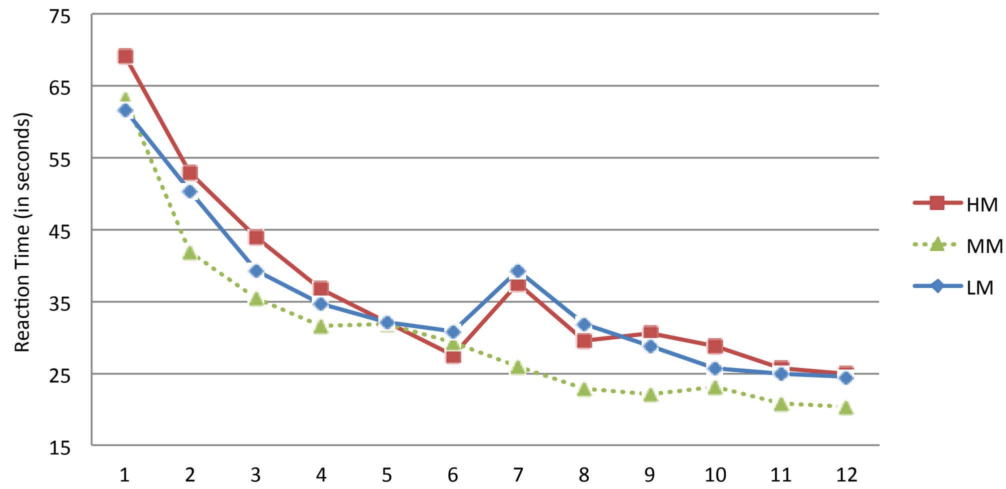


Figure 2(b): Rational choices



Notes: Figure 2 displays the average number of *Safe* choices under each lottery (characterized by its *x*) in rounds 7-12 by treatment. Figure 2(a) includes all observations; Figure 2(b) includes only choices with no more than one switch point.

Figure 3: Average reaction time by treatment



Notes: Figure 3 illustrates the average reaction time in each round of the main task. Reaction time is the elapsed time between the presentation of the lottery and sure outcome options and the submission of the final decisions. The average reaction time gradually declines over rounds; however, a significant jump occurs in round 7 of the LM and HM groups.

Table 1: Average and median numbers of *Safe* choices by treatment

Panel 1(a): All choices

	Rounds 1-6						Rounds 7-12					
HM	**375**	**380**	**385**	**390**	**395**	**400**	**290**	**295**	**300**	**305**	**310**	**315**
Mean	7.17	6.82	7.06	7.18	7.52	6.95	6.67	6.23	6.26	6.65	6.68	6.89
Median	7	7	7	7	7.5	7	7	6	6	7	7	7
MM	**290**	**295**	**300**	**305**	**310**	**315**	**290**	**295**	**300**	**305**	**310**	**315**
Mean	5.67	6.1	6.02	6.43	5.9	6.31	6.02	5.9	5.43	5.9	5.45	6.12
Median	5.5	6	6	7	5.5	6	5	6	5	5.5	5	6
LM	**205**	**210**	**215**	**220**	**225**	**230**	**290**	**295**	**300**	**305**	**310**	**315**
Mean	5.96	5.46	5.31	5.06	5.66	5.59	5.15	5.3	5.46	5.85	5.8	5.55
Median	5	4	5	4	5	5	4	4	4	5	6	5

Panel 1(b): Rational choices

	Rounds 1-6						Rounds 7-12					
HM	**375**	**380**	**385**	**390**	**395**	**400**	**290**	**295**	**300**	**305**	**310**	**315**
Mean	7.21	6.79	7.07	7.25	7.46	6.92	6.56	6.18	6.22	6.62	6.68	6.89
Median	7	7	7	7	7.5	7	7	6	6	7	7	7
MM	**290**	**295**	**300**	**305**	**310**	**315**	**290**	**295**	**300**	**305**	**310**	**315**
Mean	5.47	6.08	6.03	6.39	5.87	6.24	6	5.72	5.4	5.85	5.4	6.15
Median	5	5.5	6	7	5	6	5	5	5	5	5	6
LM	**205**	**210**	**215**	**220**	**225**	**230**	**290**	**295**	**300**	**305**	**310**	**315**
Mean	5.89	5.36	5.17	5	5.55	5.42	5.16	5.22	5.44	5.79	5.79	5.5
Median	5	4	4	4	4	4	4	4	4	5	5.5	5

Notes: Table 1 presents the average and median numbers of *Safe* choices for each lottery in each treatment. Panel 1(a) includes all observations while Panel 1(b) excludes observations with multiple switch points.

Table 2: Difference in the average number of *Safe* choices between treatments in Rounds 7-12

	Lottery (x)					
	290	295	300	305	310	315
All choices						
HM-MM	0.64	0.32	0.83*	0.75*	1.23**	0.77**
HM-LM	1.51***	0.93**	0.79***	0.81**	0.88**	1.34***
MM-LM	0.87*	0.61	-0.04	0.06	-0.35	0.57
Rational choices						
HM-MM	0.56	0.46	0.82*	0.77*	1.28**	0.74*
HM-LM	1.39***	0.95**	0.78***	0.82**	0.89**	1.39***
MM-LM	0.84*	0.49	-0.04	0.05	-0.39	0.65

Notes: The values indicate the difference in the average number of *Safe* choices between two treatment groups under each lottery in Rounds 7-12. For example, 0.64 on the left top corner of the table means that, given choices in Lottery 290 in the second half of the main task, the average number of *Safe* choices in the HM group is higher than that of the MM group by 0.64. *, **, and *** represent significance at 10%, 5%, and 1% levels, respectively, under the two-tailed Mann-Whitney test. The upper panel includes all observations while the lower panel excludes those with multiple switch points.

Table 3: : Effects of Previous Exposure to Risk on the Number of *Safe* Choices

	(1)	(2)	(3)	(4)	(5)
PriorRisk	0.5171***	0.4237***	0.4229***	0.4229*	0.4674**
	(0.1054)	(0.1054)	(0.1057)	(0.2296)	(0.2251)
x	0.0164	0.0161	0.0162	0.0162**	0.0165**
	(0.0110)	(0.0107)	(0.0107)	(0.0066)	(0.0065)
Male		-1.416***	-1.417***	-1.417***	-1.362***
		(0.1824)	(0.1829)	(0.3922)	(0.3846)
Chinese		-0.9135***	-0.9154***	-0.9154	-0.8675
		(0.3330)	(0.3334)	(0.7548)	(0.7523)
Econ		-0.3228	-0.3227	-0.3227	-0.3234
		(0.2078)	(0.2083)	(0.4662)	(0.4659)
Experience		0.4806*	0.4810*	0.4810	0.4708
		(0.2667)	(0.2674)	(0.5688)	(0.5695)
Round effects controlled for	No	No	Yes	Yes	Yes
Individual level random-effect model	No	No	No	No	Yes
Observations	1018	1018	1018	1018	1018
R^2	0.025	0.078	0.078	0.078	0.012

Note: Observations that are in rounds 7-12 and that have at most one switch point are included. Column (1) regresses numbers of *Safe* choices on *PriorRisk* and *x*; column (2) includes demographical variables; column (3) further includes dummy variables of rounds. In columns (1)-(3) and (5), robust standard errors are reported in parentheses. Column 4 reports standard errors clustered at the individual level in parentheses. Column (5) uses random effect panel data model in estimation, controlling for individual effects, with within *R* squared reported. *, **, and *** represent significance at 10%, 5%, and 1% levels, respectively.

Table 4: Effect of Previous Exposure to Risk on Certainty Equivalence

	(1)	(2)	(3)	(4)	(5)
PriorRisk	-0.0331***	-0.0268***	-0.0267***	-0.0267***	-0.0295*
	(0.0074)	(0.0074)	(0.0074)	(0.0160)	(0.0156)
x	-0.0027***	-0.0027***	-0.0027***	-0.0027***	-0.0027***
	(0.0008)	(0.0008)	(0.0008)	(0.0005)	(0.0005)
Male		0.0942***	0.0943***	0.0943***	0.0907***
		(0.0128)	(0.0128)	(0.0272)	(0.0266)
Chinese		0.0582***	0.0584***	0.0584	0.0553
		(0.0219)	(0.0219)	(0.0490)	(0.0488)
Econ		0.0171	0.0171	0.0171	0.0172
		(0.0142)	(0.0142)	(0.0314)	(0.0314)
Experience		-0.0343*	-0.0343*	-0.0343	-0.0336
		(0.0189)	(0.0189)	(0.0395)	(0.0395)
Round effects controlled for	No	No	Yes	Yes	Yes
Individual level random-effect model	No	No	No	No	Yes
Observations	1018	1018	1018	1018	1018
R^2	0.0313	0.078	0.079	0.079	0.0527

Note: Observations that are in rounds 7-12 and that have at most one switch point are included. Column (1) regresses *ln(CE)* on *PriorRisk* and *x*; column (2) includes demographical variables; column (3) further includes dummy variables of rounds. In columns (1)-(3) and (5), robust standard errors are reported in parentheses. Column 4 reports standard errors clustered at the individual level in parentheses. Column (5) uses random effect panel data model in estimation, controlling for individual effects, with within R squared reported. *, **, and *** represent significance at 10%, 5%, and 1% levels, respectively.

Appendix: Experimental Instructions

Instructions

Thanks for your participation. This session consists of the main experiment and a questionnaire. I expect the whole thing to take about 30 minutes.

Depending on your decisions and the luck, you will be able to earn money in addition to the $3 guaranteed for your participation.

Please read the following instructions carefully.

NO communication between participants is allowed at any time during the experiment. If you have any questions, please raise your hand and I will come to assist you privately.

Please now turn off your mobile phone and any other electronic devices. These must remain off until you leave this room.

During the experiment, your earnings will be calculated in "tokens." You will be paid in Singapore dollars at the following conversion rate:

15 tokens = S$1

To ensure anonymity, your decisions in this session are linked to your Participant ID number and at the end of this session you will be paid by Participant ID number. All payments will be put in an envelope. No other participants will see how much you have been paid. Please do not reveal your choices to any other participant in the experiment.

Your Tasks

The main experiment consists of 12 rounds. In each round, you will make a series of decisions on choosing between a lottery and a certain amount of tokens for sure. The following table shows an example of a round.

Each row in the table corresponds to one decision that you will make. For each row, you will choose between "Left" and "Right". For instance, in Row 1, if you choose "Left", you will receive x tokens with 50% probability and y tokens with 50% probability; if you choose "Right", you will receive z_1 tokens with certainty. After you make all 13 decisions in the table and click "Continue", you will proceed to the next round. The completion of the 12th round entails the end of the experiment. In the experiment, x, y and z will be assigned real values. Note that Left Options differ across rounds; and for each round, Right Options differ across rows. So please read carefully the options presented to you when making decisions.

	Left	Right	Decision
1	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_1 tokens for sure	Left□ □ Right
2	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_2 tokens for sure	Left□ □ Right
3	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_3 tokens for sure	Left□ □ Right
4	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_4 tokens for sure	Left□ □ Right
5	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_5 tokens for sure	Left□ □ Right
6	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_6 tokens for sure	Left□ □ Right
7	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_7 tokens for sure	Left□ □ Right
8	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_8 tokens for sure	Left□ □ Right
9	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_9 tokens for sure	Left□ □ Right
10	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_{10} tokens for sure	Left□ □ Right
11	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_{11} tokens for sure	Left□ □ Right
12	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_{12} tokens for sure	Left□ □ Right
13	You have 50% chance winning x tokens and 50% chance winning y tokens	You will receive z_{13} tokens for sure	Left□ □ Right

Your Payment

After you finish your decisions in all the 12 rounds, one round will be randomly selected as the payment round. For this randomly selected round, you will be paid by your decisions in one randomly selected row. Suppose Row 1 is chosen for payment. If you choose Right in Row 1, you will receive z_1 tokens for sure. If you choose Left in Row 1, you will receive either x tokens or y tokens with equal probability. The computer will randomly determine the outcome for this lottery.

The earnings will be transformed to Singapore dollars using the 15 tokens=S$1 conversion rate and be paid to you in addition to the S$3 participation fee.