Learning from Mistakes:
What Do Inconsistent Choices Over Risk Tell Us?

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Abstract: We implement a risk experiment that allows for judgment errors to investigate who makes mistakes and whether it matters. The experiments are conducted with a random sample of the adult population in Rwanda, and data on financial decisions are collected. We find a high degree of inconsistent choices, with over 50% of the participants making at least one mistake. Importantly, errors are informative. While risk aversion alone does not explain financial decisions, risk aversion and inconsistent choices interact in significant and sensible ways. As we would expect, risk-averse individuals are more likely to belong to a savings group and less likely to take out an informal loan. For those more likely to make mistakes, however, as they become more risk averse, they are *less* likely to belong to a savings group and *more* likely to take up informal credit, suggesting that mistakes correlate with less than optimal behavior.

1. Introduction

We all make mistakes. We take longer to complete tasks than we thought, or we make the wrong choice because we are in a hurry. Psychologists have long recognized this problem and regularly include multiple questions in surveys that ask the same thing in order to increase reliability.[1] In experimental economics, the presence of inconsistent choices is common and more so when experiments are taken to the field. The view in economics has been to either ignore subjects with inconsistent choices or to make specialized assumptions on the nature of mistakes and estimate the parameters of interests. Several researchers (Carbone and Hey, 2000; Harless and Camerer, 1994; Hey and Orme, 1994; Hey, 2005; Loomes, Moffatt and Sugden, 2002) have shown that assumptions on the source and nature of mistakes are not trivial in the identification of patterns of behavior. They also show that, by collecting repeated observations on the same individuals, the way subjects commit mistakes (or are inconsistent) is heterogeneous.[2] This paper takes the view of psychology that mistakes are potentially informative of subjects' overall decision making rules and cognitive costs. We are particularly interested in how mistakes over risk can explain financial decisions. We find that measures of error are correlated with demographics and choices. This paper shows that there is much to be learned from our own mistakes and those of others.

We use risk experiments that allow for inconsistent choice to study mistakes and then link those mistakes to financial decisions taken in the marketplace. Participants are drawn from a random sample of the adult population in Rwanda, thus providing important variation in demographics and economic outcomes to produce robust results. This setting is particularly well-suited for our study because subjects face risky decisions regularly in their daily lives and have

[1] Psychologists call this internal consistency (for an example, see Westen, 1996).
[2] Harless and Camerer (1994) assume homogeneity.

access to a variety of, mainly informal, financial instruments. The sample is typical of adults found in urban and rural areas in many developing countries. The experiment is designed so that with fairly unrestrictive assumptions on utility, choices inconsistent with theory can be clearly predicted and measured in the data. We find that risk aversion alone is a poor predictor of decisions, but mistakes *and* risk aversion correlate with the usage of certain financial instruments, notably those that serve as safety nets.

Mistakes, or inconsistent choices, have been linked to non-cognitive abilities, e.g. motivation, lack of attention, and impatience. And, both cognitive and non-cognitive ability have been linked to outcomes, such as employment, wages, obesity, smoking, and saving decisions (Heckman, Stixrud, and Urzua, 2006; Segal, 2006). The use of economic experiments to look at cognitive and non-cognitive ability is more limited. Benjamin, Brown and Shapiro (2006) find that risk aversion in small stakes gambles is less likely with high standardized test scores, and Dohmen, Falk, Huffman and Sunde (2007) find people with lower IQ's are more risk averse and impatient. Ashraf, Karlan, and Yin (2006) look at hypothetical survey questions on time preferences and find that those who make time inconsistent choices are more likely to take up a commitment savings product in the Philippines. In this research, we investigate if inconsistent choices in risk experiments relate to mistakes in financial decisions taken in the marketplace.

Decision-making inconsistencies have been observed in several experimental studies, including decisions over risk (e.g. Holt and Laury, 2002), health (Stockman, 2006), and time preferences (Castillo, Ferraro, Jordan and Petrie, 2008; and Meier and Sprenger, 2007). Prasad and Salmon (2007), using a risk experiment protocol similar to ours, find that subjects who make inconsistent decisions over risk earn less money than those who make consistent decisions in a principal-agent experiment.

In previous research, these inconsistencies have been frequently ignored, under the assumption that they are uninformative noise. Alternatively, choices are restricted so that inconsistent behavior cannot be observed. In risk experiments, this can be done by giving the subject only a single decision to make. For example, Binswanger (1980), one of the first to use such a method, gives a menu of lotteries over which the subject chooses one. Subjects can be asked to pick a point at which they switch from risky to safe lotteries (see Tanaka, Camerer, and Nguyen, 2007; Harrison and Rutstrom, 2007). Andersen, Harrison, Lau and Rutström (2006) use an iterative procedure to hone in on the subject's switch point, and, consequentially, subjects make significantly fewer unexpected choices.[3] The advantage of these methods is that they provide clear estimates of risk aversion by eliminating the possibility of mistakes.

We are interested in knowing the importance of mistakes and lottery-measured risk aversion on financial decisions. Lottery-measured risk preferences have been linked to economic decisions and the results are mixed. Eckel, Johnson, Montmarquette and Rojas (2007) find that risk-averse individuals are more likely to take up experimentally-provided education financing. Bellemare and Shearer (2006) find that risk aversion is correlated with job sorting, and Dohmen, Falk, Huffman, Sunde, Schupp and Wagner (2005) find that lottery measures of risk do not relate to risky behaviors but a general risk question does. Harrison, List, and Towe (2007) argue that these mixed results may be due to ignoring background risk.[4]

Our results are surprising and may offer some insight into the existing mixed results when only controlling for risk aversion. While we find no correlation between risk aversion and

[3] Further, one may infer from the comparison of unexpected subject "switch-backs" in Holt and Laury (2002) with Prasad and Salmon (2007) that people make fewer inconsistent choices when lotteries are presented all at once, rather than sequentially. This has been found in the literature in psychology and marketing (e.g. Langer and Weber, 2001, and Chakravarti, Krish, Paul and Srivastava, 2002). Decisions made together are thought of as a "bundle," and thus reconciled with each other. Decisions made in a sequence are viewed separately, each with its own independent chance of error.

[4] We were not able to replicate background risk in this research so cannot address this hypothesis.

outcomes, we do find one when we also control for mistakes. Once we control for mistakes, as we would expect, risk-averse subjects are more likely to be in a savings group and less likely to take an informal loan. Risk preferences interact with the tendency to make mistakes in significant and sensible ways. As risk aversion increases, those who are more likely to make mistakes become less likely to belong to a savings group and more likely to take out an informal loan. Those who make mistakes seem to be missing out on potentially beneficial opportunities or taking on risks when they should not. Making mistakes in one task may to be linked to less than optimal behavior in another. Being able to observe these types of behavioral biases is essential to understanding financial decisions.

The paper is organized as follows. Section 2 describes the financial decisions people make in Rwanda. Section 3 describes the experiment and defines what an inconsistent choice is. Section 4 describes the data and presents the results. Section 5 concludes.

2. Financial Instruments in Rwanda

The formal financial sector in Rwanda is limited and is consistently rated as one of the worst in the world. Because of this, many Rwandans rely on informal channels for credit. We will look at three common types of informal credit (savings groups, insurance groups and informal loans) and formal credit offered through a bank or credit union.

Savings groups (*tontines*) are rotating credit associations that allow members to pool risk. Members deposit a fixed amount of money at a fixed interval (typically monthly), and once every interval, one member of the group receives all the money deposited by the members. Members may leave the group without penalty once a cycle in which all group members receive the pool of money is complete. Groups vary in size and in the interval length (e.g. monthly or every two months). These groups are common and popular in Rwanda. We expect risk-averse individuals to be more likely to join this group.

Insurance groups (*groupes d'entraide*) come in two general forms. The first is a rotating work group for construction or agricultural work. Members exchange labor to help other members. The second offers financial assistance in the case of a bad shock (i.e. death, illness). It functions as insurance. More generally, the group may offer moral support. These groups sometimes also have a religious component to them as many are organized by churches. Members typically pay a monthly fee to belong.[5] Since the risk-pooling nature of these groups is not only monetary, we do not expect risk aversion over money to be as strongly correlated with membership.

Informal loans are usually short-term, small, and are largely used for immediate consumption smoothing. They are widespread in Rwanda and almost never carry monetary interest. Most are store credit or cash loans from family and friends. While these loans are interest free, they do carry an expectation that the favor will be reciprocated. Default on these loans is risky since interactions with friends and family are expected to be long term. Not paying back this type of loan may imply not being able to borrow in the future. Further, taking no-interest formal loans may obligate a person to reciprocate to the lender in the future. We expect risk-averse individuals to be less likely to take out these loans.

Formal credit is not widely accessible due to large financial barriers. To be eligible to apply for a formal loan, an individual must pay an application fee and maintain an account in the bank or credit union. Minimum deposits in banks are often very high, and membership in a credit

[5] Unfortunately, the data we have do not distinguish between these two general forms.

union requires paying a small fee.[6] Formal banks and credit unions are relatively stable, however, prior to 2000, credit unions did have a reputation for making loans and not asking that they be paid back. Since 2000, regulation has made credit unions more accountable and stable.[7] Formal loans are primarily used for business and construction, rather than consumption smoothing. It is not clear how risk aversion will affect the probability of taking out a formal loan because the barriers to entry clearly select a certain segment of the population. This population might be more risk averse or more risk seeking.

3. Experiment

The experiment was conducted in conjunction with a 2002 World Council of Credit Unions survey on the economic activities and household characteristics of a random sample of credit union members and non-members in seven locations across Rwanda. In each location, fifty members and fifty non-members were interviewed, for a total of 700 survey respondents. Members were randomly selected from lists of active credit union members, and non-members were randomly selected from neighborhoods served by the credit union. Survey respondents were at least 18 years old and were asked questions about household demographics, the economic activities of household members, and credit use. Interviews were conducted in Kinyarwanda, the primary Rwandan language, by Rwandan enumerators.[8] The enumerators were trained and tested by the experimenters.

At the end of the survey, each respondent was asked to complete two lottery experiments, one with only positive earnings (the gain lotteries) and one with both positive and negative earnings (the gain-loss lotteries). We chose these two payment structures for the following

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[6] Credit unions are more accessible for the poor since the membership fee is far lower than the minimum balance at a formal bank. Many poor become credit union members precisely so they can have access to credit.
[7] Since 2000, the country has experienced relative political stability. While many still do not trust the government, the credit union and banking sector is used and somewhat trusted.
[8] For a complete description of the data and survey design, refer to Petrie (2002).

reasons. The first payment structure replicates what has been used before in lottery experiments. The second better mimics the type of outcomes an individual might face under risk. A risky decision typically will involve the chance of a gain and the chance of a loss. We will see that this latter payment structure is better able to explain economic decisions.

Of the 700 respondents, 15 received pilot treatments that were not designed to generate usable data, and another 62 were unable or unwilling to complete the full lottery experiment, so 623 individuals provided risk preference data. Of those individuals, 442 received a treatment that presented a menu of five lotteries at once and asked the subject to choose one (similar to Binswanger, 1980). This five-pair simultaneous presentation treatment, by design, did not allow the subjects to make mistakes. This will serve as an important comparison treatment when we look at how risk measures predict financial decisions. The remaining 181 subjects received sequential binary-choice lotteries that did permit mistakes. Eighty-two subjects participated in a treatment with low payoffs (55 with hypothetical and 27 with real payoffs) and 99 had a treatment with high payoffs (all hypothetical).

The 181 participants of the sequential-choice lottery game are similar on observable characteristics to the larger survey population (of 700 individuals). Both have similar gender ratios (39.0% female for the sequential-choice lottery participants and 39.4% for the survey population), average ages (36.6 and 37.2, respectively), and average monthly per capita incomes (30,897 RWF and 34,520 RWF, respectively). Like the survey population, 93% of the sequential-choice lottery participants are literate. Compared to the 2002 official Rwandan national census, the survey population is similar on many demographic dimensions. However, the survey population is slightly richer and more literate than the national average in Rwanda.

This may be because credit union members, who made up 2% of the Rwandan population at the time of the survey, were oversampled.

3.1 Experiment Design

In the sequential-choice experiment, subjects face a series of five pairs of lotteries, each with 50-50 odds, and are asked to choose one lottery (A or B) in each pair. The lottery pairs are shown in Table 1 for low payoffs and high payoffs. The gain and gain-loss lotteries are increasing in expected payoff and variance, and in each pair, lottery B has a lower expected payoff and variance. Also, in each subsequent pair, option B has the same payoffs as option A in the previous pair. If choices are consistent, this lottery exercise is equivalent to presenting subjects six lotteries simultaneously and asking them to choose one. A risk-neutral or risk-loving individual would always choose A. An individual with a concave utility function would start with option A and switch to lottery B as expected payoffs and variance increase and continue to choose option B. Since the subject's "switching point" may occur above or below the wealth range of the lotteries presented to the subjects, strongly risk-averse subjects may always choose option B, while less risk-averse subjects may always choose option A.

The format of the experiment is similar to Holt and Laury (2002), hereafter HL, but with several key differences. HL keep payoffs constant and vary the probabilities of receiving the high and low outcomes. In our experiment, the probability is always 50-50, and the payoffs are varied. Also, HL present the lotteries all at once to the subjects. In our experiment, lottery pairs are presented sequentially. Finally, in addition to lotteries over gains, we also present lotteries over gains and losses (as in Holt and Laury, 2006).

3.2 Experiment Implementation

Before making decisions, subjects are instructed that one of the five lotteries in each set will be randomly chosen for implementation by pulling a number between one and five from a hat. Then, a coin is flipped to determine payment. After the procedures are explained, the subject is allowed to practice briefly with a sample lottery pair. Then, all lottery pairs are presented one at a time and in the same order for all subjects. For example, in the gain lottery, subjects are first presented with the payoffs for G1 and are asked if they would prefer lottery A or lottery B. Next, they are presented the payoffs for G2 and asked to choose between A and B, and so on. They must choose one of the lotteries in each case. They are not allowed to declare indifference. Once subjects have made decisions for the gain lotteries, they are presented with the loss lotteries one by one and in the same order. When all lotteries have been completed, a lottery is randomly chosen from the gain sequence and another from the loss sequence. A coin is flipped for the chosen lottery in each sequence. If the coin turns up heads, the subject would earn the first number in the payoff pair for the chosen lottery. For example, if lottery G3 was randomly chosen in the low payoff treatment and the subject chose option A for G3, then if the coin flip turned up tails, the subject would earn 200 RWF.

Subjects in the real-payment treatment were given 500 RWF as a show-up fee and paid the outcomes of the coin tosses over gains and over gain-losses. They were paid in cash. Subjects in the hypothetical treatments were not paid. After the two coin flips, they were told what they would have earned had they been paid.[9]

The majority of the subjects received a hypothetical-payment treatment because of limited funding. There is some debate in the literature as to whether real payoffs are necessary to incentivize choices in lottery experiments. Camerer and Hogarth (1999) note, in a review of 74

[9] While they were not paid, subjects in the hypothetical treatments were interested in the outcome of the coin toss. That is, they were interested in the outcome of their decisions. This suggests they paid attention to what they chose.

experiments, that the effect of real payoffs in risk experiments is unclear—in some cases there is no effect, and in some cases subjects appear more or less risk averse. We test if there is a significant behavioral difference in subject choices between the real and hypothetical treatments, and there is not.[10] Therefore, we pool the data.

3.3 Defining Anomalous Choices

In the sequential-choice experiment, the pattern of predicted choices for any theory of choice under uncertainty where utility is increasing in money and there is no inflection point in the wealth range of the lotteries under consideration is as follows. A risk-neutral or risk-seeking subject would always choose lottery A. A risk-averse subject may choose one of six lottery patterns, AAAAA, AAAAB, AAABB, AABBB, ABBBB, or BBBBB, in order of increasing risk aversion.

If a subject ever chooses B (the safe lottery) in one lottery pair and then subsequently chooses A (the risky lottery), his choice pattern is inconsistent with theory. Relative to a given lottery X, he has now expressed a preference for both a safer lottery and a riskier lottery. If this choice represents true preferences and utility is increasing over money, there must be an inflection point in the range of these lotteries. Such a pattern of choices is not predicted by Expected Utility theory. The pattern is also not predicted by Rank Dependent Theory, Prospect Theory or Cumulative Prospect Theory. The Dual Theory, which transforms probabilities but not wealth, is even more restrictive, only allowing the patterns AAAAA and BBBBB.[11] Expected value theory only allows AAAAA.

[10] Ortmann and Hertwig (2006) state that financial incentives *may* be important in motivating economic behavior. Importantly, they emphasize the importance of a "do-it-both-ways" rule, so that experimenters can compare results of financially motivated and non-motivated treatments. This is what we do in this paper.

[11] There are two aspects of the experiment that could cause some unexpected behavior, but neither should cause inconsistent "switching-back." First, since two decisions will be implemented, subjects could make their decisions as if putting together a risk portfolio. This should make subjects choose riskier options, but consistently. Second, since one gain and one gain-loss lottery is implemented at random, errors may occur due to faulty compounding of

4. Results

We look first at inconsistent choices. Then, we examine measurements of risk aversion and estimations of mistakes, and finally, we relate risk aversion measures and inconsistent choice to financial decisions.

4.1 Inconsistent Choices

Of the 181 people who completed the sequential choice lottery treatment, roughly 55% made at least one inconsistent switch over gains or losses. This is a similar percentage to that found with the same instrument in a random sample of adults in Peru.[12] Table 2 illustrates the distribution of lottery choices across predicted patterns and inconsistent switches. Because the real and hypothetical distributions for low payoffs are not significantly different, we pool these two treatments.[13] Mistakes do not seem to be due to lack of financial incentives. There is, however, a significant difference between high and low payoff treatments. High stakes may be easier to focus on or may be a cognitively easier task. HL also found that higher-stakes lotteries resulted in a lower tendency to choose inconsistently (5.5%).

4.2 Risk Aversion

The overwhelming presence of inconsistent choices makes a risk measure based on a switching point from risky to safe lotteries in our data problematic, as many subjects have

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lotteries. However, that should simply make people behave in a consistent, but more risk-averse, fashion (Holt, 1986).

[12] The percent of inconsistent choices in the Peru sample is similar in both hypothetical and paid lotteries. The instrument in Peru allowed for indifference, and subjects reviewed their choices and were allowed to change them before the coin toss. In the hypothetical lotteries, around 52% made inconsistent choices over gains and 44% made inconsistent choices over gain-loss. In other research, Holt and Laury (2002) found 13% in hypothetical choices with students, Stockman (2006) found 11% in hypothetical choices with adults, Meier and Sprenger (2006) found 12% in paid choices with adults, Castillo, Ferraro, Jordan and Petrie (2008) found 33% in paid choices with 13-year olds, and Prasad and Salmon (2007) found 30% in paid choices with students (presenting lotteries sequentially as we did).

[13] A Fisher's exact test for equal distributions over gains has a p-value=0.431 and over gains-loss, p-value=0.439.

multiple switching points.[14] We can, however, still look at a naïve measure of risk aversion (as in HL) by counting the number of B (safe) choices the person made. This gives us a risk-aversion measure over gain and one over gain-loss for each subject. The higher this measure, the more risk-averse the person is. So that the risk aversion measure for subjects who participated in sequential-choice lotteries can be compared to that of subjects who participated in five-pair simultaneous presentation lotteries, both were normalized to fall in the range from 0 to 1.[15] This allows us to see if the two methods produce different measures of risk aversion.

The treatment that forces consistency (five-pair) yields risk measures that are significantly higher than in the treatment that allows for inconsistent choices (sequential choice). To compare similar payoffs, we restrict our discussion to the five-pair treatment compared to the low payoff sequential treatment. Table 3 shows that risk measures are 0.12 points higher over gains, and 0.10 points higher over gain-loss. These differences are significant (t-test for difference in means, over gains p-value = 0.000, over gain-loss p-value = 0.076).

In the sequential-choice high payoff treatment, people are much more risk averse over losses (0.72) than any other treatments. Holt and Laury (2002) also saw an increase in risk aversion over high stakes.

4.3 Error Choice Model

While we can count the number of safe choices to derive a risk measure in the sequential choice lottery, this assumes that those who chose a predicted consistent pattern did not make a mistake. To be more precise, we need to consider that consistent choices could have also been

[14] Similarly, due to limited observations per individual, it would be difficult to derive a risk measure based on the parameterization of a utility function, so we are unable to compare risk aversion in our sample to that estimated in other experiments. We look at sample-level error estimation in the next section.

[15] For the simultaneous five-pair lottery, subjects are shown five lotteries with a 50-50 chance of either payoff and asked to choose one. The five lotteries over gains are, (500,500), (800,400), (1100,300), (1400, 200), (1700,100). The five lotteries over gain-loss are, (0,0), (300,-100), (600,-200), (900,-300), (1200,-400).

mistakes. To address this, and because we have few observations per individual, we use the error choice model proposed by Harless and Camerer (1994) to estimate the individual probability of making at least one mistake and the distribution of preferences over predicted patterns.

The basic intuition behind this approach is that, given a subject's preferences, different error structures will produce different patterns of observed behavior. Recall that, in our experimental design, expected utility theory allows only six patterns of behavior. So, for example, for pattern AAAAA, if a person makes one mistake only, possible patterns of behavior will be: BAAAA, ABAAA, AABAA, AAABA and AAAAB. If this subject makes a mistake with probability ε and the proportion of people that have preferences supporting pattern AAAAA is P(AAAAA), then the total probability of observing pattern of behavior BAAAA is $P(AAAAA)\times\varepsilon\times(1-\varepsilon)^4+(1-P(AAAAA)\times\varepsilon^4\times(1-\varepsilon)$. A well-specified likelihood function can be constructed for any theory of behavior under risk following analogous reasoning.

We estimated the distribution of preferences over predicted patterns for all lotteries pooled together, for low-stakes only and for high-stakes only. The results are shown in Table 4. The error rate, ε, is 0.222 and 0.217 for the pooled gain and gain-loss lotteries, and as expected, the error rate is higher at low stakes. The error rate estimates compare well to estimates for several experiments examined in Harless and Camerer (1994), where error rate estimates were 0.209-0.339 for Expected Utility Theory. Switching to lotteries that have a loss (gain-loss) increases the estimated proportion of people who choose all safe, BBBBB, especially for high payoffs.

Ultimately, we would like to know if making mistakes has any effect on financial decisions. Therefore, we use the error rate estimates to find the probability of making at least one mistake for each observed choice pattern in the data. This is simply one minus the probability of making no mistakes.

4.4 Inconsistent Choice and Financial Decisions

First, we look at who makes mistakes. Then, we examine how risk aversion and mistakes affect financial decisions.

Table 5 shows summary statistics for the entire sample and for those who completed the sequential choice lottery. The variables include the percent of subjects who are female, the percent married, the subject's age in years, the number of years of education the subject has completed, the subject's per capita household monthly expenses in Rwandan francs, the number of children under 18 years old living in the subject's household, the number of adults 50 years and older in the household, the percent of subjects in a savings group, the percent in an insurance group, the percent having take an informal loan in the past year, and the percent having taken a formal loan in the past five years. We can see that the entire sample and those who completed the sequential choice lottery are similar on most variables, with the exception that those in the sequential choice lottery are not as rich and are more likely to have taken a credit.

Who tends to make mistakes? We regress the estimated probability of having made at least one mistake (from the error rate model) over gain and gain-loss on demographic variables, as shown in Table 6.[16] Because no difference in choices was found between real and hypothetical treatments for low stakes, the treatments are pooled together.[17] As expected, subjects in the low-stakes treatment showed a greater tendency to make mistakes. The only other significant result is that over gain-loss women are more likely than men to make mistakes.

[16] A Tobit regression was also tried and yielded the same results. OLS results are reported for ease of interpretation.
[17] If a dummy variable for the real payment treatment is included, it is not significant, and the results do not change.

Next, we look at how risk aversion and mistakes affects financial decisions. Before considering mistakes, however, we want to see if our naïve risk aversion measure alone can explain decisions. Table 7 shows how membership in a savings group or insurance group and having taken either a formal or informal credit is affected by risk aversion, controlling for other demographic covariates.[18] For completeness, we look at both the sequential choice lottery and the five-pair lottery (which does not allow inconsistent choice). To make these two sets of regressions comparable, we restrict the sample to the two survey locations where both types of lotteries were randomly administered.

As the table shows, there is no significant effect of risk aversion on almost every single financial mechanism. There is also no significant effect of gender. The only weakly significant relationship is between risk aversion over gains in the five-pair lotteries and taking out an informal loan. Those who are more risk averse over gains are less likely to get an informal loan.

Since risk aversion alone does not correlate with using most financial mechanisms, we ask if the tendency to make mistakes does. A person who makes inconsistent choices over risk may fail to take optimal advantage of the financial instruments available to him, or he may be less trusted by informal lenders and savings and insurance groups. On the other hand, if he is self-aware of his mistakes, he may insure against this tendency and be more likely to select into these instruments. This is the argument made by Ashraf, Karlan and Yin (2006).

Table 8 shows our results of OLS regressions with bootstrapped standard errors.[19] Being a member of a savings group or taking out an informal loan is significantly correlated with risk aversion over gain-loss lotteries and mistakes, but in opposite directions. As described earlier,

[18] Results are robust to alternative specifications, such as Logit and Dprobit.
[19] Because we are using the estimated probability of making at least one mistake as an independent variable, this gives us a generated regressor and we therefore chose not to use OLS. Instead, the estimates were done by sampling with replacement 10,000 times to generate estimates and bootstrapped standard errors. The estimates are significant if they fall within the confidence interval specified in the table.

savings groups serve as a risk pooling device, so we would expect risk-averse individuals to be more likely to be a member. They are. Also, borrowing money from informal sources (usually family and friends) involves the risk of losing face should one not be able to pay. These loans do not carry monetary interest, but they do carry an expectation of reciprocation. Default in this context can be socially costly. Therefore, we would expect risk-averse individuals to be less likely to take out an informal loan. They are.

More importantly, risk aversion and mistakes interact in meaningful and significant ways.[20] Conditional on being more likely to make mistakes, a risk-averse individual is less likely to be in a savings group and more likely to take out an informal loan. That is, those who make mistakes are less likely to choose as we would expect. These results suggest that individuals who make mistakes are not self aware, but rather do not choose optimally or are excluded from groups or informal loans.

Not all financial decisions are significantly correlated with risk aversion or mistakes. Being a member of an insurance group or taking out a formal loan is not correlated with risk aversion, tendency to make mistakes, or the interaction. This may be because insurance groups offer a variety of services, such as insurance, labor, and credit, so the correlation with risk and mistakes is not so clear. Formal loans from banks have an evaluation system in place that makes it easier to screen out bad credit risks. Those who are more likely to make mistakes may be screened out and never offered a loan.

5. Conclusions

[20] If we just control for mistakes or risk and mistakes (not interacted), there is no significant effect. That is, mistakes alone, risk alone, and risk and mistakes do not correlate with financial decisions. It is the interaction of the two that is important.

Can we learn anything from mistakes? This research suggests that we can. Using a lottery experiment designed to detect inconsistent choice in risk, we examine the correlation between risk aversion, mistakes, and financial activities that may serve as safety nets. We find that the tendency to make inconsistent choices over risk is widespread and women are more susceptible than men. When mistakes are ignored, risk aversion alone does not explain the use of financial instruments. When we control for the tendency to make inconsistent choices, however, risk and mistakes explain participation in savings groups and the use of informal credit. As we would expect, risk-averse individuals are more likely to belong to a savings group and less likely to take out an informal loan. Those who are more likely to make mistakes display opposite behavior. Mistakes in the experiment are correlated with suboptimal behavior in these financial decisions.

This research makes two contributions. First, our results may help explain the inconclusive results that relate lottery-measured risk aversion to economic outcomes. We, as some other researchers, do not find a significant correlation between risk aversion and outcomes. While it has been suggested that the lack of correlation may be because of not properly controlling for background risk (Harrison, List and Towe, 2007), our results suggest that this may also be due to not controlling for mistakes. Second, our results suggest that testing for consistent behavior in experiments may have some important implications for understanding choices in non-experimental settings. Previous work has mostly ignored inconsistent choices or designed experiments to not permit inconsistent behavior. This research suggests that important behavioral information may be embedded in mistakes, and we may want to take them seriously.

If forced consistency hides preferences and behavioral biases, to truly understand behavior, we might want to design mechanisms that allow us to detect mistakes. If risk aversion and mistakes interact such that less than optimal decisions are taken in such areas as credit or in the labor market, this is important to know. Researchers and policy makers should be interested in developing policies and institutions that can address this interaction of preferences and mistakes.

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Table 1
Lottery Treatment Payoffs
(in Rwandan Francs, 500 RWF = $1 US*)

Low Payoff Treatment (real and hypothetical)

Gain Lotteries	**A**	**B**
G1	(700, 400)	(500, 500)
G2	(900, 300)	(700, 400)
G3	(1100, 200)	(900, 300)
G4	(1300, 100)	(1100, 200)
G5	(1500, 0)	(1300, 100)

Gain-Loss Lotteries	**A**	**B**
L1	(700, -100)	(500, 0)
L2	(900, -200)	(700, -100)
L3	(1100, -300)	(900, -200)
L4	(1300, -400)	(1100, -300)
L5	(1500, -500)	(1300, -400)

High Payoff Treatment (hypothetical only)

Gain Lotteries	**A**	**B**
G1	(1650, 1000)	(1250, 1250)
G2	(2050, 750)	(1650, 1000)
G3	(2450, 500)	(2050, 750)
G4	(2850, 250)	(2450, 500)
G5	(3250, 0)	(2850, 250)

Gain-Loss Lotteries	**A**	**B**
L1	(1650, -200)	(1250, 0)
L2	(2050, -400)	(1650, -200)
L3	(2450, -600)	(2050, -400)
L4	(2850, -800)	(2450, -600)
L5	(3250, -1000)	(2850, -800)

* At the time of this research, median per capita annual income in Rwanda was 118,000 RWF, according to the US Department of State, so 500 RWF was roughly equivalent to a day's wage. From our survey data, median monthly per capita income and expense measures were between 15,000 – 18,000 RWF, and this would imply a daily wage (based on 5 working-days a week) of 691- 830 RWF in our sample.

Table 2
Distribution of Choices Over Sequential-Choice Lottery Treatments
(in percent)

	Gain Lotteries			**Gain-Loss Lotteries**		
Choice Pattern	**All**	**Low Payoffs***	**High Payoffs**	**All**	**Low Payoffs***	**High Payoffs**
AAAAA	12.7	9.8	15.2	8.8	12.2	6.1
AAAAB	11.1	2.4	18.2	2.8	3.7	2.0
AAABB	5.5	4.9	6.1	0.6	0.0	1.0
AABBB	3.3	1.2	5.1	1.7	1.2	2.0
ABBBB	6.1	3.7	8.1	4.4	3.7	5.1
BBBBB	7.7	4.9	10.1	27.1	8.5	42.4
One anomalous switch	47.0	58.5	37.4	42.0	48.8	36.4
Two anomalous switches	6.6	14.6	0.0	12.7	22.0	5.1
Total	181	82	99	181	82	99

* Real and hypothetical payoff treatments are combined.

Table 3
Mean Risk Aversion Measures by Lottery Treatment

	Sequential-Choice Low Payoff*	Sequential-Choice High Payoff	Simultaneous Five-Pair
Risk aversion over gain	0.44 (0.25)	0.43 (0.32)	0.56 (0.37)
Risk aversion over gain-loss	0.43 (0.28)	0.72 (0.32)	0.53 (0.37)
N	82	99	442

* Real and hypothetical payoff treatments are combined.
Standard deviations in parentheses

Table 4
Estimated Population Preferences for Predicted Lotteries

	All		Low Payoffs		High Payoffs	
Choice Pattern	**Gain**	**Gain-Loss**	**Gain**	**Gain-Loss**	**Gain**	**Gain-Loss**
AAAAA	0.31	0.37	0.39	0.67	0.25	0.19
AAAAB	0.31	0.00	0.36	0.00	0.30	0.02
AAABB	0.02	0.00	0.00	0.00	0.03	0.00
AABBB	0.02	0.00	0.00	0.00	0.06	0.00
ABBBB	0.22	0.04	0.11	0.07	0.22	0.06
BBBBB	0.13	0.59	0.14	0.26	0.14	0.73
ε	0.22	0.22	0.34	0.31	0.13	0.15
Likelihood function	-3.18	-3.09	-3.39	-3.34	-2.85	-2.62

Table 5
Summary Statistics

	All Lottery Subjects		Sequential-Choice Subjects	
Variable	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Female	0.39	0.49	0.37	0.48
Married	0.64	0.48	0.65	0.48
Age (years)	36.58	11.23	38.52	10.94
Education (years)[a]	8.84	3.78	8.41	3.95
Per Capita monthly expenditures (1,000 Rwandan francs)[b]	30.62	61.97	21.15	43.68
Number of children (age < 18) in household[c]	2.99	2.15	3.02	1.95
Number of elderly (age ≥ 50) in household[c]	0.30	0.60	0.35	0.64
Member of savings group (tontine)	0.18	0.39	0.22	0.41
Member of insurance group	0.20	0.40	0.20	0.40
Have used formal credit	0.24	0.43	0.36	0.48
Have used informal credit	0.48	0.50	0.55	0.50
Number of Observations	623		181	

[a] There are 14 missing observations on education, so this is based on n=609 for the whole population, n=178 for the sequential-choice subjects.
[b] Household per-capita monthly expenses in Rwandan Francs divided by 1000, range was 0 to 1007.
[c] Ages were missing for some household members for some households, so these numbers are based on n=619 for the whole population, n=180 for the sequential-choice subjects.

Table 6
Probability of At Least One Inconsistent Choice
OLS Regression

	Gain	Gain-Loss
Female	0.049 (0.063)	0.164** (0.071)
Married	-0.027 (0.062)	0.063 (0.078)
Age	-0.000 (0.003)	-0.006 (0.004)
Education (years)[a]	0.009 (0.007)	0.002 (0.008)
Monthly expenses	-0.001 (0.001)	-0.001 (0.001)
Number of children (age <18) in household	0.001 (0.015)	0.010 (0.018)
Number of elderly (age ≥ 50) in household	-0.049 (0.044)	0.021 (0.057)
Low stakes treatment	0.397*** (0.054)	0.305*** (0.073)
Constant	0.442*** (0.140)	0.636*** (0.182)
R^2	0.261	0.184
N	177	177

Note: standard errors reported in parentheses. *p-value<0.10, **p-value<0.05, ***p-value<0.01. Robust standard errors are used. All regressions include village-level fixed effects.
[a] There were missing values on education for three observations, and missing household ages for another, so those observations are dropped.

Table 7
Financial Decisions without Inconsistency Measure
OLS Regressions

Five-Pair Lotteries								
	Savings Group		Insurance Group		Formal Credit		Informal Credit	
Risk Aversion (gain)	-0.025 (0.114)		-0.111 (0.132)		-0.067 (0.144)		-0.286* (0.164)	
Risk Aversion (gain-loss)		0.111 (0.101)		-0.071 (0.123)		0.193 (0.141)		-0.118 (0.177)
R^2	0.033	0.046	0.058	0.053	0.303	0.319	0.088	0.058
N	82	82	82	82	82	82	82	82
Sequential-Choice Lotteries								
	Savings Group		Insurance Group		Formal Credit		Informal Credit	
Risk Aversion (gain)	0.281 (0.191)		0.189 (0.182)		-0.347 (0.216)		0.051 (0.189)	
Risk Aversion (gain-loss)		0.111 (0.154)		-0.056 (0.163)		0.260 (0.167)		-0.211 (0.184)
R^2	0.180	0.157	0.191	0.179	0.193	0.182	0.093	0.106
N	89	89	89	89	89	89	89	89

Note: standard errors reported in parentheses. *p-value<0.10, **p-value<0.05, ***p-value<0.01. Robust standard errors are used. All regressions include the following control variables: gender, married, age, education, monthly per-capita expenses, number of children (<18 yrs), adults age 50 and older, and village-level fixed effects. There were missing values on education or on the ages of household members for 5 observations (3 from the Sequential-Choice Lotteries and 2 from the Five-Pair Lotteries), so those observations are dropped.

Table 8
Financial Decisions with Inconsistency Measure
OLS Regression with Bootstrapped Errors

	Savings Group		Insurance Group		Formal Credit		Informal Credit	
Risk Aversion (gain)	0.664* (0.421)		-0.340 (0.411)		-0.583 (0.437)		0.150 (0.478)	
Estimated Probability of Mistake (gain)	0.465 (0.283)		-0.305 (0.273)		-0.108 (0.312)		0.127 (0.336)	
Risk aversion (gain) * Est Prob Mistake (gain)	-0.820 (0.580)		1.014 (0.599)		0.443 (0.631)		-0.215 (0.749)	
Risk Aversion (gain-loss)		0.547*** (0.252)		0.096 (0.247)		0.290 (0.271)		-0.611*** (0.218)
Estimated Probability of Mistake (gain-loss)		0.515*** (0.239)		0.199 (0.237)		0.081 (0.270)		-0.606*** (0.219)
Risk aversion (gain-loss) * Est Prob Mistake (gain-loss)		-1.185*** (0.393)		-0.366 (0.361)		0.020 (0.443)		0.786*** (0.427)
N	89	89	89	89	89	89	89	89

Note: standard errors reported in parentheses. The estimates are bootstrapped 10,000 times. *coefficient falls between the [0.05, 0.95] percentiles of the bootstrapped parameter distribution, ** coefficient falls between the [0.025, 0.975] percentiles of the bootstrapped parameter distribution, *** coefficient falls between the [0.01, 0.99] percentiles of the bootstrapped parameter distribution. All regressions include the following control variables: gender, married, age, education, monthly per-capita expenses, number of children (<18 yrs), adults age 50 and older, and village-level fixed effects. There were missing values on education or household member ages for 3 observations, so those observations are dropped.