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THE PROCESS OF CHOICE IN GUESSING GAMES

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Abstract

This paper employs a new experimental design to provide insight into the process of choice in one shot games. We observe the provisional choices of inexperienced players in the 2/3 guessing game in the three minute period after the structure of the game is conveyed to them. We find that their average strategic sophistication rises with consideration time. While final choices average in the low thirties, initial choices average about 50, providing new insight into "level zero" play. There are significant individual differences in learning behavior that may generalize to other settings: those whose strategic sophistication grows over time also perform better at separate learning tasks. While some players ultimately converge to a fixed decision, others do not, suggesting continued reflection and/or deliberate pursuit of a mixed strategy.

1 Introduction

Little is known about how players choose strategies in unfamiliar one-shot games. Certainly, it seems unreasonable to expect them instantly to understand the full structure

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of whatever game they are playing. In part for this reason, theories of differential strategic sophistication are increasingly important in the study of such games (Nagel (1995), Stahl and Wilson (1995), Stahl (1996), Duffy and Nagel (1997), Goeree and Holt (2004), Camerer, Chong and Ho (2004)), Costa-Gomes and Crawford (2006), and Crawford (2008)). The poster child in this respect is the 2/3 guessing game, in which players select an integer between 0 and 100 with the reward going to the individual closest to 2/3 of the group average. While elimination arguments reveal the only equilibrium choices to be 0 and 1, in practice there is significant clustering around 33 and 22. According to "Level k" (Lk) theories, those who pick 22 (type L2 players) are best responding to L1 players who pick 33, who in turn are best responding to L0 players who are assumed to make a completely random selection, as a result averaging fifty.

We open a new window on how inexperienced players learn to play in one-shot games. Specifically, we observe their provisional choices in the 2/3 guessing game in the three minute period after the structure of the game is conveyed to them. Their only method of learning in this period is via contemplation. While formal game theory has nothing to say about what is learned in this process, intuition suggests that strategic sophistication may rise with consideration time. Our data sheds light on this by capturing how reflection causes the perceived optimal decision to change.

The first experimental finding is that perceived optimal choices indeed do change over time, generally reflecting ever higher levels of strategic sophistication. While the final choices at the end of three minutes are very similar to those in the classical 2/3 guessing game, earlier choices are indicative of lower strategic sophistication. Indeed, the mean of the initial choices is very close to 50 and the median is precisely 50, aligning well with the standard assumption concerning L0 play. This is of particular interest given that there is no theory of the behavior of L0 types, who are considered to be "naive" and "not strategic," concepts that are very hard to define. Our experimental data add insight in this regard by opening up to observation players' first thoughts concerning how best to play the game.

While average sophistication grows over time, there are profound individual differences. Only thirty percent of players increase in strategic sophistication over the course of the game. Not only does this group perform better in the guessing game than do other groups, but it also performs better in separate learning tasks requiring Bayesian updating. No such pattern of differential learning can be found based either on final choices alone or on standard measures of ability.

The fact that our data uncovers various forms of heterogeneity that are not revealed by final choices alone may explain the lack of generality in type classifications across games when classifications are based only on final choices (Burchard and Penczynski (2010), and Goerganas, Healy and Weber (2010)). Overall, there may be much to gain by observing more than just the final decision when players participate in unfamiliar one-shot games.

There are other intriguing features of the learning process that are not visible if one looks only at final choices. For example, while some players converge to a fixed decision, there are others whose choices fluctuate throughout the experiment. These fluctuations may indicate strategic confusion, but they may also reflect deliberate pursuit of a mixed strategy.

Background material motivating our experimental design is in section 2, with the design itself in section 3. Our data is produced in the context of a guessing game in which subjects are incentivized to record their best guesses for a full three minutes (the "strategic choice process" treatment (SCP)). In addition to the SCP treatment, we conducted standard guessing game experiments with two distinct time constraints: 30 seconds and 180 seconds. The experimental results confirm that strategic sophistication is higher when players have more time to decide, as detailed in section 4.

Results from the SCP treatment are presented in section 5. We confirm the broadly increasing pattern of strategic sophistication. In addition to focusing on initial choices, we note also that play at 30 seconds matches well that in our 30 second standard experiment, while that at 180 seconds matches that in the longer fixed duration experiment. In that sense, the SCP treatment appears analogous to an entire array of guessing games with different time constraints, with the additional feature that we observe all choices in a single three minute span for each player in the game. In section 6 we investigate whether final choice alone correlates with ability, risk preferences and other separate learning tasks.[1] We find no such correlation.

[1]The first is modeled on the "Monty Hall" game similar to Nalebuff (1987), Friedman (1998) and Avishalom and Bazerman (2003). The second is a multiple period Bayesian updating game, which we

In section 7 we establish the special characteristics of those who decrease their choices over time: they perform better than others both in the SCP treatment and in the two separate learning tasks. In section 8 we analyze further patterns in learning behavior, in particular separating out those whose decisions fluctuate for the full three minutes. Concluding remarks are in section 9.

2 Background

2.1 Guessing Games and Non-Standard Data

One of the questions that has guided research on the guessing game is the extent to which choice (say) of 33 is a sophisticated response to a fully reasoned belief that others will average 50 rather than being a reflection of bounds on rationality. In trying to understand this, various researchers have begun to explore non-standard data that may aid in the interpretation of choices. One such line of effort involves estimating subjects' levels of reasoning by analyzing verbal data associated with their choices (e.g. Sbriglia (2004), Bosch-Domenech, Montalvo, Nagel and Satorra (2002) and Arad (2009)). In particular, Burchard and Penczynski (2010) analyzed subjects' arguments while attempting to convince their "teammates" to follow their advice.

In an effort to understand boundedly rational play in games, Costa-Gomes, Crawford and Broseta (2001) and Costa-Gomes and Crawford (2006) examined data on information search behavior recorded using MouseLab. Costa-Gomes and Crawford (2006) used MouseLab to study cognition via information search in two-person guessing games. Chen, Huang and Wang (2010) used eye-tracking data to complement choice data in a modified 2/3 guessing game played spatially on a two-dimensional plane. Taken together, the above research makes it clear that bounds on rationality play an important role in explaining the behavioral patterns in guessing games.

A separate line of work uses physiological and neurological measurements to gain insight into play in the guessing game. Dickinson and McElroy (2009) find that subjects

adapted from Kahneman and Tversky (1972).

apply higher levels of reasoning when well-rested rather than sleep-deprived, and when at their peak time of day rather than at their off-peak times. Coricelli and Nagel (2009) use fMRI techniques to explore levels of reasoning in a game in which subjects play against computers. They uncover systematic differences in neurological responses of the players at different levels of strategic sophistication.

2.2 Strategic Choice Process Data

The recent expansion of the evidentiary base in studies of the guessing game mirrors a similar movement in decision theory. Many who are interested in expanding beyond standard choice data nevertheless believe that it would be of value if the additional data were to come in a form with which economists have become familiar. It was the desire for a disciplined expansion in the evidentiary base for the study of decision-making that led Caplin and Dean (2010) to introduce choice process data in the search theoretic context. This data captures the evolution of perceived optimal choices in the period that the decision maker is searching. Caplin, Dean, and Martin (2010) developed an experimental interface to capture this data, and used it to get new insights into the nature of the search process and the rules for stopping search.

The innovation of the current paper is that we use the choice process methodology to study decision-making in the strategic context. Unlike in the search theoretic context, there is literally no external information to gather that would motivate changing one's mind in the pre-decision period. Rather, the question at hand is purely how internal reflection causes the perceived optimal decision to change. Intuition suggests that it may lead to increased strategic understanding. This is the explicit motivation for Goeree and Holt (2004) in their model of "noisy introspection."

The question our SCP experiment addresses is the extent to which subjects learn to play the guessing game by turning it over in their mind. As they do this, they may reflect both on the structure of the game itself and on their own earlier thoughts. Do they gradually move to higher levels of strategic sophistication as they internalize the structure of the game? Do they use their own earlier thoughts to model the thoughts of others, as suggested by various models in social psychology (see Dawes (1990))? Our experiment gathers data on this process of learning while hewing closely to the decision theoretic tradition.

2.3 Learning by Thinking and Time To Decide

Economists have studied many forms of learning: learning by doing; reinforcement learning; and updating after receipt of new information. Our focus is on a quite distinct form of learning that involves no new external stimulus: "learning by thinking."

Once one focuses on what is learned by thinking through the structure of the game, one is naturally led to think about the dynamics of decision-making. This brings to the fore the question of how long a period of time players have been given to decide in prior versions of the guessing game. Unfortunately, the time span of the various experiments is far from uniform. Ho, Camerer and Weiglelt (1998) set an experimental time limit of 2 minutes. However this was the maximum allowed time and not the time it took for subjects to actually respond. Bosch-Domenech, Montalvo, Nagel and Satorra (2002) report results of a five minute laboratory experiment, and of other experiments conducted more remotely (e.g. via newspaper) with response times of up to two weeks.

Rubinstein (2007) explicitly explored the connection between contemplation time and choice in the context of an online version of the guessing game. There was no maximum time, but a server recorded the time a subject took to submit the answer. Rubinstein found that more "sophisticated" responses (defined as 33 and 22) took longer (126 seconds on average), while less sophisticated responses took on average less than 90 seconds.

Weber (2003) also explored the connection between contemplation time and choices in the guessing game. He had subjects play the 2/3 guessing game ten times in a row, providing them with no feedback on their performance until all ten trials had been completed. While choice in the first round was entirely as in the standard game, by round ten the average choice had fallen significantly. This suggests that further reflection on the structure of the game led many to change their minds, without any feedback from outcomes and without new external information of any kind. It is just such learning that our strategic choice process data is designed to gauge in the context of the one-shot game.

Given our focus on learning, our first experimental goal was to explore the impact of decision time on the outcome of a standard 2/3 guessing game. There is one paper of which we are aware in which the time constraint in a 2/3 guessing game was manipulated. Kocher and Sutter (2006) examined the effects of time pressure and incentive schemes on choices in repeated plays of the guessing game. Surprisingly, they did not find much difference in first round play for different time constraints.

In section 4 we show that strategic sophistication increases over time by comparing choices in standard guessing games of duration 30 seconds and 180 seconds. The longer time of 180 seconds was chosen since prior work suggests that it is enough time for most subjects to reason through the game (see section 8 for more on how many players "converge" on a strategy). The shorter time was chosen to cut short such reasoning. The design appears to have been successful in that regard. The estimated distribution of types in the 180 seconds version is entirely consistent with those in Nagel (1995) and Ho, Camerer and Weigelt (1998), while the shorter version produces significantly different estimates of strategic sophistication.

3 The Experimental Design

All of the experiments were run at the laboratory of the Center for Experimental Social Science (CESS) at New York University. Our subjects were drawn from the general undergraduate population in the university by email solicitations. The guessing game experiments themselves lasted about 10 minutes. Subjects in the SCP treatment participated in a series of other tasks following the guessing game, as detailed in section 3.3 below. Average payoffs were between 10 and 15 dollars.

In all treatments, subjects were first seated at their computer terminals, and then given the experimental instructions, face down. Once everyone received the instructions, subjects were instructed that they could turn the sheets over and the instructions were read out loud. Subjects did not communicate with one other during the experiments. There was only a single play of the 2/3 guessing game in each experiment. The precise experimental instructions differed across treatments as indicated below.

Given our interest in how learning takes place in a novel one shot game, we dropped subjects who reported being familiar with the game, whether in a lab, in a classroom or in any other context. This familiarity was assessed in a questionnaire at the end of each session. Some 25% of subjects had either played the game or heard of it. The remaining sample consists of 188 subjects.

3.1 Standard Guessing Games

As indicated, we first ran two standard guessing game experiments using different time constraints. These standard experiments were included to gauge the importance of decision time in the outcome of the game, and also to provide benchmarks with which to compare the SCP treatment. Subjects had either 30 seconds or 180 seconds to play these games. In total, 66 subjects participated in the 30 seconds treatment, and 62 participated in the 180 seconds treatment. The rules of the game and the task were described as follows:

> RULES OF THE GAME: A few days ago 8 undergraduate students like yourselves played the following game. Each of the 8 students had 180 seconds to choose an integer between 1 and 100 inclusive, which they wrote on a piece of paper. After 180 seconds, we collected the papers. The winner was the person whose number was closest to two thirds of the average of everyone's numbers. That is, the 8 students played among themselves and their goal was to guess two thirds of the average of everyone's numbers. The winner won $10 and in case of a tie the prize was split.
>
> YOUR TASK: You will have 180 seconds to choose an integer between 1 and 100 inclusive. You win $10 if you are "better than" those 8 students at determining two thirds of the average of their numbers. That is, you win $10 if your number is the closest to two thirds of the average of the numbers in the past game.
>
> OR
>
> YOUR TASK: You will have 30 seconds to choose an integer between 1 and 100 inclusive. You win $10 if you are "better than" those 8 students at determining

two thirds of the average of their numbers. That is, you win $10 if your number is the closest to two thirds of the average of the numbers in the past game.

The screen displayed 100 buttons, each representing an integer between 1 and 100 inclusive.[2] Once the game started, subjects could select any number by clicking on the button displaying it. Subjects could change their selected number as many times as they wanted. Subjects could end the game earlier by clicking on a "Finish" button. There was no difference between choosing a number and staying with that number until the end of the game or instead clicking the Finish button. In the standard experiment, it was only their final choice (at 30 seconds or 180 seconds as specified in the instructions) that determined the participant's payoff from the game.[3]

Note that our experiment has the feature that a subject's number is not included in the average. This was to ensure that the strategic choice process version of the game did not have additional equilibria, as outlined in the next section. The 2/3 guessing game in which the subject's number is not counted in average is similar in spirit to the situation in which the number of participants is large and a single integer has little effect on the average (see Bosch-Domenech et al (2002)).[4]

3.2 Strategic Choice Process Treatment

While there was no change in the described rules of the game, what determined the subject's payment in the SCP treatment was the subject's choice at a random time. The experimental instructions were as follows.

When the game starts, you can select a number by clicking on the button displaying the number that you want. You may click when you want, however many times you

[2]It is common to allow also the choice of zero. Having the minimum choice be one simplifies matters slightly since the unique equilibrium, identifiable by iterated elimination of dominated strategies, is for all to select 1. When zero is included as an option, there are multiple equilibria. It is also common to allow subjects to choose any real number, as opposed to integers. Our experimental apparatus - displaying all the possible choices on the screen - makes the restriction to integers a necessary one. The equilibrium solution is unchanged by this modification.

[3]There was no incentive to finish early, since the game lasted the same amount of time regardless.

[4]Formally: suppose the group size is n and a subject believes the average of the other participants is $\bar{x}$. If that subject's number is counted in the average then that subject should choose $\frac{2(n-1)\bar{x}}{3n-2}$ so that as the group size gets larger and larger, this choice converges to $(2/3)\bar{x}$, which is what the subject should choose if his/her number were not counted in the average.

want. The computer will record all the numbers you click on, as well as when you clicked on them. After 180 seconds, or when you click the finish button, the round will come to an end and you won't be able to change your choice anymore. Just to make clear, if you choose a number and then stay with that number until the end, or instead decide to click on the "Finish" button, it will make no difference.

Only one of the numbers you selected will matter for payment. To determine which one, the computer will randomly choose a second between 0 and 180, with each second equally likely to be chosen. The number you selected at that time will be the one that matters. We will call this number **"Your Number."**

We wanted to make sure that subjects participating in SCP treatments properly understood the incentive structure. Hence when they arrived in the lab we described the experimental methodology to them *before* introducing them to the guessing game. They were told that:

1. The game that they were about to play would last 180 seconds.
2. The computer would record their choice throughout the game.
3. After the 180 seconds were over, the computer would randomly select one of the 180 seconds.
4. Their choice at that random second would be the one that mattered for their payment.

Illustrative examples were provided to illuminate the nature of the final payoff.[5] The examples illustrated that failure to pick an option would result in a certain payoff of zero. Hence subjects were incentivized to make a quick and intuitive first estimate of two-thirds of the average final number picked by the group that had played previously. Whenever further reflection causes this best estimate to change, they were incentivized immediately to make the corresponding change in their guess.

[5] Appendix A contains the complete instructions for these SCP sessions.

3.3 Other Tasks in the SCP Treatment

Subjects who participated in the SCP treatment also participated in five additional activities. The full instructions for all the games they played are in Appendix B.[6] The goal of these additional activities was both to check whether the subjects' performance in the beauty contest game was a reflection of standard measures of numeracy and to explore whether differences in learning behavior were connected with certain broader behavioral patterns.

The purpose of two of the questions was to elicit standard individualized characteristics, in particular risk aversion and various aspects of numeracy.[7] Below we describe the remaining three games. The first two were chosen to explore whether differences in the degree of learning exhibited in the SCP treatment were connected with ability to update in the face of new external information. The final problem was designed to explore a possible connection between status quo bias and the path of learning (see Samuelson and Zeckhauser (1988)).

1. **The Monty Hall Problem.** This is a classic problem in which intuition can diverge from Bayesian reasoning. We showed participants three closed doors on the screen, and let them know that there was $5 behind one and only one randomly chosen door, with nothing behind the other two. They were then asked to choose one of the doors. At that point, the experimenter announced that he or she knew the location of the $5, and opened one of two unselected doors to show that it contained nothing. The subject was then given the option either to stay with their initial choice or instead to switch to the other closed door.

2. **A Multiple Period Bayesian updating game.** This is a dynamic version of the Kahneman and Tversky (1972) Taxi Game problem. Subjects were told that 90 out of 100 cabs in a city were green, the others blue. They were also told that witnesses correctly identify the color of a cab 70% of the time. The game lasted

[6]Appendix B comprises all games with which every subject was involved.

[7]To evaluate risk aversion we used the method of Holt and Laury (2002) - See Appendix B.5. For the numeracy questions we used questions from the HRS (Health and Retirement Study), which have been used by Banks and Oldfeld (2007) and Burks, Carpenter, Gotte, Monaco, Porter and Rustichini (2008), as well as the CRT (Cognitive Reflection Test), which has been used by Frederick (2005) among others - See Appendix B.4.

seven periods. Each period a "witness" came forward and announced she had seen the cab and it was of a particular color. It was explained that each witness was independent of the previous ones. Subjects were asked to tell us what they thought the chances of the cab being green were after each new witness came forward.

3. **Status-quo lottery games.** There were two stages in these games, and each subject played three such games. In the first stage, students were faced with three lotteries and were asked to choose one of them. This lottery became the "status-quo" lottery for the second stage. In the second stage, subjects could choose to keep their first lottery or switch to a specified alternative.

Final choice and path of choices in the guessing game are compared with choices in the additional games in sections 6 and 7.2, respectively.

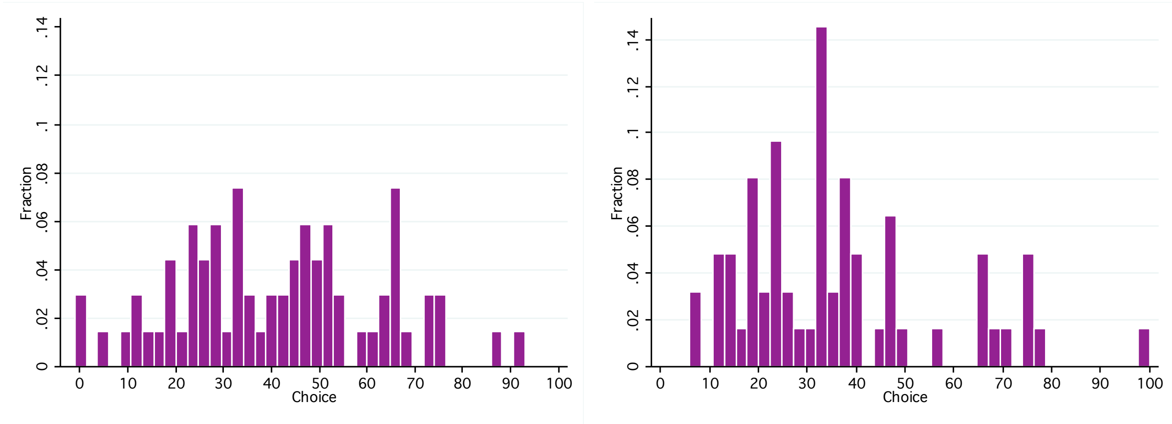
4 Standard Experiment

In Table 1 we report summary statistics for the 30 and 180 second treatments of the standard 2/3 guessing game experiments. We include corresponding statistics from the classical experiments of Nagel (1995) and Ho, Camerer and Weiglet (1998).

	mean choice	st deviation	# of obs
30 seconds	42.83	20.13	66
180 seconds	36.35	20.24	62
Nagel (1995)	37.2	20	66
Ho, Camerer & Weiglet (1998)	38.9	24.7	69

Table 1: Summary Statistics of the final choices in the Standard Experiment

As Table 1 shows, the results for the 180 second experiment are close to standard results from previous experiments. However the results for the 30 second treatment are substantially different, as further indicated by the histograms in Figure 1. The average



(a) 30 Second Treatment - Choice at 30 Seconds (b) 180 Second Treatment - Choice at 180 Seconds

Figure 1: Histogram of Final Choices in the Standard Experiment

and median choices are higher in the 30 seconds treatment than in the 180 seconds treatment. A two-sample Wilcoxon ranksum (Mann-Whitney) test shows that the samples are indeed different.[8]

We measure strategic sophistication in our standard experiments using two distinct techniques: that of Nagel (1995) and that of Camerer, Ho and Chong (2004). In Table 2 we report the classification of final choices according to Nagel's technique in the 30 and 180 seconds treatments and compare it to that obtained by Nagel (1995) in her original experiments. The results show that the distribution of types after 180 seconds is very similar to the distribution of types obtained by Nagel (1995), while the distribution of types after 30 and after 180 seconds is significantly different, with more sophisticated choices observed in the longer treatment (180 seconds).

Note that when there is more time to decide, more subjects are captured by the Nagel classification. This supports the claim that choices are more sophisticated as time goes by: being closer to uniform, many early choices fall outside the relevant intervals.[9]

[8]The p-value is 0.05, thus we reject the null that the two samples are from the same distributions. In addition, a two-sample Kolmogorov-Smirnov test for equality of distribution functions is also significant ($p = 0.032$).

[9]Nagel's classification starts from the premise that Level 0 players choose 50. Nagel then constructs neighborhood intervals of $50p^n$, where p is the multiplier used in the game ($p = \frac{2}{3}$ in our case) and n represents the level of reasoning ($n = 0, 1, 2, ...$). The numbers that fall between two neighborhood intervals of $50p^{n+1}$ and $50p^n$ are called interim intervals. To determine the boundaries of adjacent intervals a geometric mean is used. Thus the neighborhood interval of $50p^n$ have boundaries of $50p^{n+\frac{1}{4}}$ and $50p^{n-\frac{1}{4}}$ rounded to the nearest integers. The exception is Level 0, which is truncated at 50. Nagel classifies as Level 0 choices between 45 and 50, Level 1 those between 30 and 37, Level 2, and Level 3 those between 13 and 16.

Given that the Nagel (1995) classification excludes many of the early respondents, we also interpret our data through the lens of Camerer, Ho and Chong (2004), which is based on the Cognitive Hierarchy (CH) model. Levels of thinking are assumed to be distributed according to a Poisson distribution with parameter τ.[10] Following Camerer, Ho and Chong (2004), we report the best fitting estimate of τ as well as the 90% confidence interval for τ from a randomized resampling (with replacement) bootstrap procedure. We compare our results with the estimations from the Nagel (1995) and Ho, Camerer and Weigelt (1998) experiments. The results are in Table 3.

	30 Seconds	180 Seconds	5 minutes Nagel (1995)
L0	15.2%	9.7 %	7.5%
L1	13.6%	25.8%	26%
L2	10.6%	17.7%	24%
L3	4.6%	8.1%	2%
% of population captured by L0-L3 definition	43.9%	63.3%	59.9%

Table 2: Distribution of types (Nagel) in the Standard Experiment.

	# obs	Mean (Data)	τ	Bootstrap 90% C.I.
30 second treatment	66	42.83	0.5	$[0, 0.25]$
180 second treatment	62	36.35	1.1	$[0.41, 1.33]$
Ho, Camerer and Weigelt (1998) $p = 0.7$	69	38.9	1	$[0.5, 1.6]$
Nagel (1995) $p = \frac{2}{3}$	66	37.2	1.1	$[0.7, 1.5]$

Table 3: Estimating τ in the Standard Experiment, Comparison with Nagel (1995) and Ho, Camerer and Weigelt (1998).

Our estimates of τ and 90% confidence intervals from the 180 seconds treatment are close to those reported by Ho, Camerer and Weigelt (1998) and Nagel (1995). The

[10]The process begins with Level 0 players, who are assumed to play according to a uniform distribution. Level k thinkers assume that the other players are distributed according a normalized Poisson distribution from Level 0 to Level k-1. The estimation of τ involves finding the value of τ that minimizes the difference between the observed sample mean and the mean implied by τ.

estimates of τ at 30 and 180 seconds suggest that people advance in types as they have more time to think about the game. This motivates our interest in exploring *how* subjects arrive to their final choices.

5 The Strategic Choice Process Experiment

5.1 Dynamics of choices in SCP Experiment

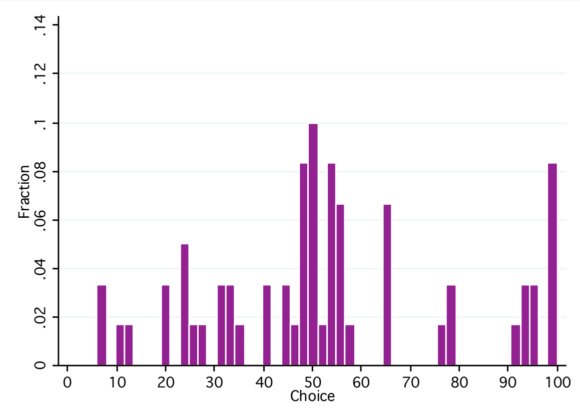
Figure 2 presents three histograms to illustrate the time path of choices in the SCP experiment: the very first choices made by subjects (which were made after an average of approximately 7 seconds), choices after 30 seconds, and choices after 180 seconds. These histograms reveal that overall choices go down as time goes by, and that subjects are less likely to make high choices after 3 minutes of thinking about the game than at the start of the game.

5.1.1 First Choices

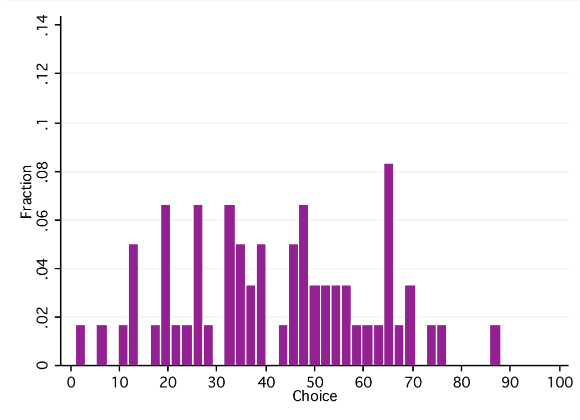
Mean	53.1
Median	50
Standard Deviation	25.57
Time of the first choice	mean: 7.2 sec st dev: 4.75

Table 4: Summary Statistics of First Choices.

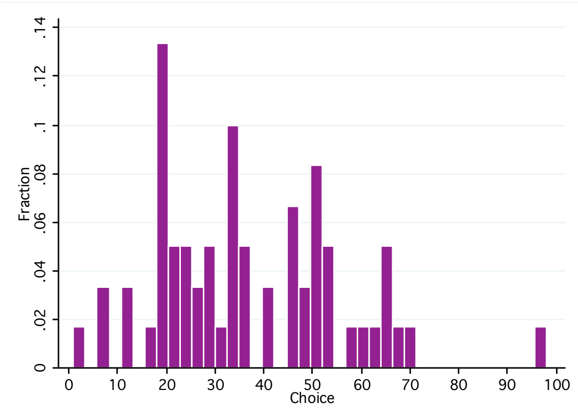
Figure 2(a) indicates the first strategic instincts that participants had after reading the rules of the game. Table 4 presents key statistics concerning these first choices. Note that the median first choice time is 6 seconds. By the 10^{th} second, 85% of our subjects had made a first choice. The average time it takes to then make a second decision is also short, about 18 seconds.



(a) SCP Experiment - First Choices



(b) SCP Experiment - Choice at 30 Seconds



(c) SCP Experiment - Choice at 180 Seconds

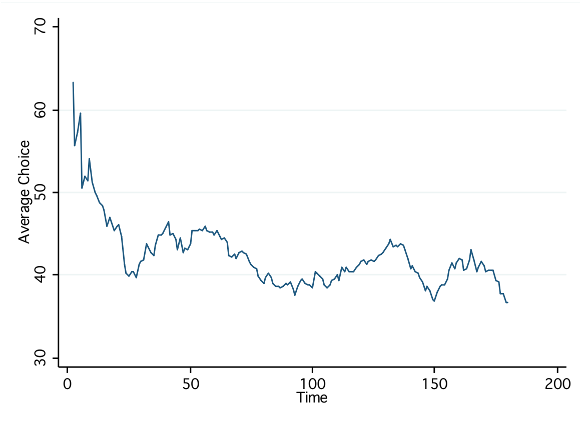
Figure 2: Histogram of Choices (1st, after 30 seconds, after 180 seconds) in the SCP Experiments

The mean first choices of our subjects is close to 50,[11] while the median and mode of first choices are exactly 50. This aligns with the standard assumption in the literature that on average people's first thought (or L0 choice) is indeed 50, or that the play is uniform over the support resulting in an average of 50. Note also from the histogram that 100 is a focal point. Finally, while the number of subjects choosing 100 declines to almost zero after three minutes, there are quite a few subjects who choose 50 even after the full 3 minutes.

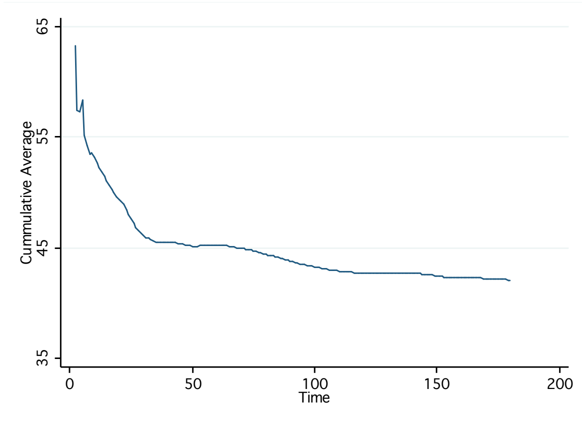
[11] A random sampling with replacement bootstrap simulation gives a mean of 49.4 and a 95% Confidence Interval for the mean of $[42.5, 56.2]$.

5.1.2 Overall Choices Diminish Over Time

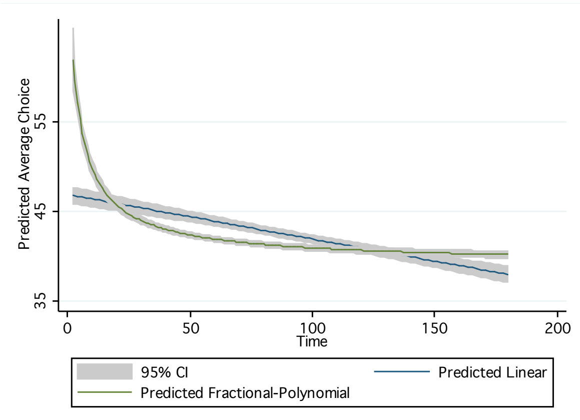
Regression analysis confirms that both the average and median choices displays diminishing time trends, using both linear and fractional-polynomial formulations. Figures 3(a) and 3(c) below presents the raw data (average choice plotted for each second) as well as the fitted regression curves and corresponding 95% confidence intervals.



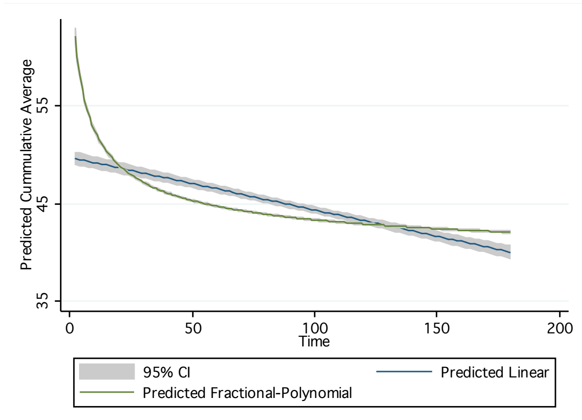
(a) Average Choices Over Time



(b) Cumulative Average Choices Over Time



(c) Predicted Average Choice Over Time



(d) Predicted Cumulative Average Choice Over Time

Figure 3: Average Choices Over Time: Raw Data and Regressions

Another way to present the dynamics of choice over time is to compute the cumulative average. Recall that in the SCP treatment each of the 180 seconds has the same probability of being chosen for payment. Therefore, the participant who chooses the same number X in all 180 seconds can be seen as choosing X 180 times. This is taken into account in Figures 3(b) and 3(d) which averages over current and past choices to arrive at the cumulative average choices over time. The figure confirms again that the average and cumulative average choices diminish over time, with the added feature that the declining pattern in the cumulative average choice is smooth and well matched by the non-linear formulation.

	mean choice	std deviation	# of obs
30 seconds - Standard	42.83	20.13	66
30 seconds - SCP	41.68	19.95	60
180 seconds - Standard	36.35	20.24	62
180 seconds - SCP	36.73	18.34	60

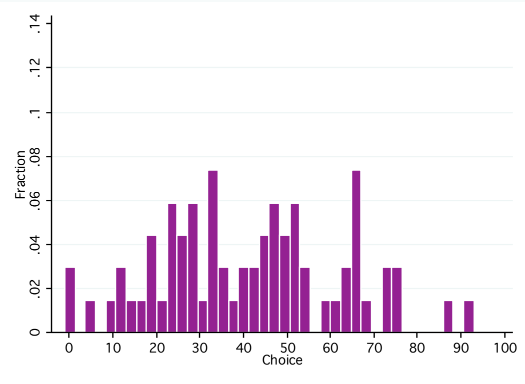
Table 5: Summary Statistics of Choices in Standard and SCP Treatments.

5.2 SCP and Standard Treatments

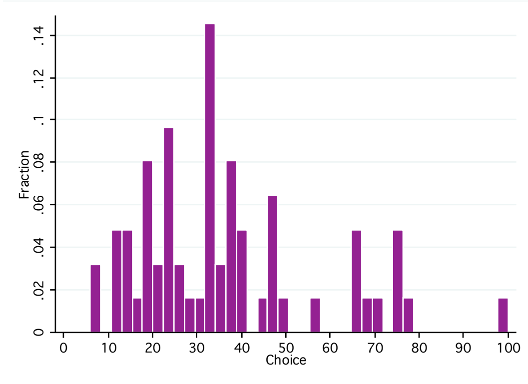
It is of interest to compare choices in the SCP treatment with play in the standard 2/3 guessing game with different fixed horizons. In Table 5 we present summary statistics of choices in the standard experiments with the 30 seconds and the 180 seconds time limits, and the choices after 30 seconds and after 180 seconds in the SCP treatment. The table shows that the main characteristics of the Standard and SCP experiments are similar in terms of means and standard deviations.

In Figure 4 we present the histograms of choices in both experiments after 30 seconds and after 180 seconds, which indicates that the changed incentive structure in the SCP treatment had limited impact on behavior.

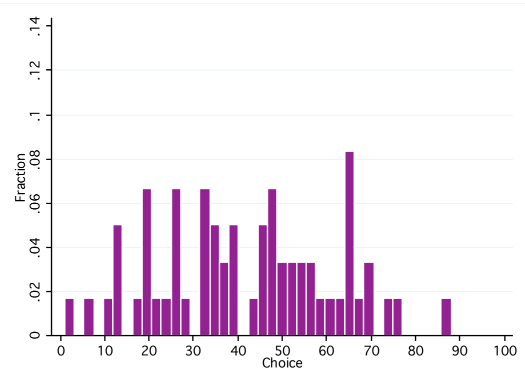
A two-sample Wilcoxon ranksum (Mann-Whitney) test comparing the 30 second choices in the SCP and in the Standard experiment shows that we cannot reject the hypothesis that the two samples are from the same distribution ($p > 0.10$). Similarly, a two-sample Kolmogorov-Smirnov test for equality of distribution functions gives us the same results ($p > 0.10$). The same holds true when comparing the 180 second choices in the SCP and Standard experiments. In principle, it appears that the SCP treatment is similar to multiple plays of the game with different time constraints, with the added feature that subjects do not have any additional time to reason once the 180 seconds have started. Moreover it provides a within subjects design for exploring the impact of decision time.



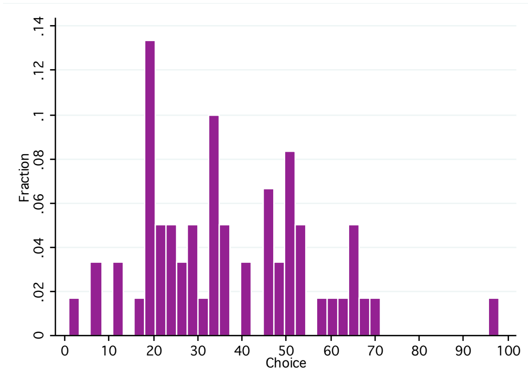
(a) Standard Experiment - Choice at 30 Seconds



(b) Standard Experiment - Choice at 180 Seconds



(c) SCP Experiment - Choice at 30 Seconds



(d) SCP Experiment - Choice at 180 Seconds

Figure 4: Histogram of Final Choices in the Standard and SCP Experiments

A random sampling (with replacement) bootstrap estimation of τ, as we performed on the data from the Standard experiments, show that the 90% Confidence Interval for τ at the 30^{th} and 180^{th} second are $[0, 0.31]$ and $[0.45, 1.72]$, respectively. This is in line with the Confidence Intervals from the Standard experiments reported in Table 3, and support the claim that as contemplation time increases, strategic sophistication advances.

6 What Can We Learn From Final Choice?

Given that lower numbers in the guessing game are usually interpreted as an indication of a higher cognitive level of the participants, the natural hypothesis is that the participants who chose lower numbers in the guessing game will also score better in different cognitive tasks. To test this hypothesis, participants were asked to answer a number of questions taken from the Health and Retirement Study (HRS) and the Cognitive Refection Test (CRT) after participating in the guessing game.[12] An Ordered Probit regression where a subject's ability measured by the number of correctly answered questions is the dependent variable shows that our measures of ability do not correlate with final choice. Further, being cast as a Level 0, 1, 2 or 3 as defined by Nagel (1995) also does not correlate with ability. In summary, our data suggest that ability and final choice are not correlated.

We also investigated whether the choices in the guessing game are correlated with the risk-preferences of the participants. To address this hypothesis, we used the standard experimental technique developed by Holt and Laury (2002) in which subjects are asked to answer 10 questions. Each question is actually a choice between two gambles, A (less risky) and B (more risky). In the first question, the probability for a high payoff for both gambles is 1/10, so that only a risk-seeker would choose the risky gamble. As the subjects answer more and more questions, the probability of the high payoff increases, so that at some point subjects who started with gamble A should cross over to gamble B. This technique allows the experimenter to categorize the subjects depending on when they switch to gamble B. This indicates the level of risk-aversion of a subject, with a higher switching point corresponding to higher risk aversion.[13] An ordered probit regression where the dependent variable is a subject's switching point show that final choice does not correlate with risk preferences.[14]

Finally, it is conceivable that the final choice of subjects may indicate how they will perform in other learning tasks. To test this hypothesis, participants in the experiment were also asked to play two other individual learning tasks (after they finished the guessing game). These two learning tasks were a Monty Hall game and a multiple period Bayesian updating game.[15] In both the Monty Hall and multi-period Bayesian updating game, subjects were given initial information about the state of the world and then received new information over the course of the game. A natural question is whether those participants that chose lower numbers in the guessing game were also better at these two completely independent learning tasks.

[12]See section 3 for more details and Appendix B.4 for the specific questions.

[13]See Appendix B.5 for full instructions.

[14]Available upon request from the authors.

[15]See section 3 for a detailed description of these games and Appendix B.1 and B.3 for the instructions.

In the Monty Hall game, appropriate updating indicates that the respondent should switch doors, yet it is intuitively plausible that it is equally good to stick with the initial choice. Table 6 presents two Probit regressions for the Monty Hall game. In both regressions the dependent variable y_i equals 1 if participant i kept the initially chosen door and 0 otherwise. The regressions differ in their explanatory variable(s): regression 1 uses the final choice of subjects; regression 2 uses dummy variables for the L1 and L2 types as defined by Nagel (1995), leaving the L0 type as the control group.[16] The hypothesis is that a higher final choice for regression 1, or a lower cognitive level for regression 2, correlates with a lower probability of switching doors.

	Regression 1	Regression 2
Final choice	0.0128 (0.009)	
Level 1 (Nagel)		0.4745(0.682)
Level 2 (Nagel)		−0.6980(0.572)
Constant	0.1680(0.366)	0.9085**(0.440)
# of obs	60	35
Log Likelihood	−33.8016	−16.8079
Pseudo R^2	0.0285	0.1066

Coefficient and standard deviation is reported in the parenthesis
** - significant at 5%

Table 6: Predicting behavior in the Monty Hall Game.

Table 6 clearly shows that regressions that use final choice or Nagel's categories as predictors do not have statistically significant coefficients. In other words, the final choice of subjects in the guessing game does not correlate with behavior in the Monty Hall game.

The same conclusion is drawn by looking at the behavior of subjects in the multi-period Bayesian updating game. Ordered Probit regressions indicate that the final choice as well as Nagel's categories do not correlate with the sum of the squared errors over the 7 rounds of the game.[17]

Our overall results suggest that final choice alone has little relation to the behavior in learning games as well as ability and risk measures.

Regarding the existing literature, there is some evidence that at the *population* level the distribution of types across games may be stable (see for example Camerer, Ho and

[16] There was only one subject in the L3 category. This observation was dropped from the analysis.
[17] This result also holds true for 6 of the 7 periods if we look at errors in each period separately.

Chong (2004)). At the *individual* level, Goerganas, Healy and Weber (2010) find that though there is a correlation of types within guessing games, choices in the guessing games fail to correlate with behavior outside the guessing game family. Burchard and Penczynski (2010) reach similar conclusions.

The SCP data allow us to go beyond final choice. Given the failure of final choice to identify linkage of types across games, in the next section we start by defining behavioral types based on the intermediate choices of individuals, and then explore whether this provides insight into behavior in other games.

7 Learning Types

As seen in section 5, the data show that the population as a whole advances in type as time goes by. However, a look at individual behavior shows that a significant segment of the population in fact does not. The declining path of aggregate behavior over time at the population level covers up profound individual differences. In fact, the group that systematically reduces choices over time is in the minority. To identify this group, we classify subjects into types by comparing the first half of their choices with the second half. If an individual makes an odd number of switches, we compare the average number associated with the first half with the corresponding average in the second half, weighting by the amount of time spent on each number. With an even number of switches we arbitrarily assign the additional choice to the first half (this distinction is irrelevant in practice). We then define three behavioral types, as follows:

- **Constant**: Those for whom the 2^{nd} half average is within 20% of the 1^{st} half average: there are 34 such subjects (56.7% of the population).[18]
- **Decreasing**: Those for whom the 2^{nd} half average is 20% or more below the 1^{st} half average: there are 18 such subjects (30% of the population).
- **Increasing**: Those for whom the 2^{nd} half average is 20% or more above the 1^{st} half average: there are 8 such subjects (13.3% of the population).

[18]The qualitative results do not change if we use cutoffs of 10, 15, 25 or 30% instead of 20%.

Table 7 below presents some statistics concerning these behavioral types.

	Constant	Decreasing	Increasing
Time of first choice	7.73 sec	6.72 sec	6 sec
First choice (mean)	50.88	56.61	54.74
1^{st} half average	44.08	43.36	42.53
2^{nd} half average	43.71	27.05	56.38
Last choice (mean)	38.68	25.1	57

Table 7: Summary Statistics of behavior of three behavioral types.

There are several dimensions along which these behavioral types are indistinguishable. First, they do not differ in our measures of risk attitudes or numerical ability.[19] In terms of behavior in the 2/3 guessing game, mean and median first choices are close to 50 for all behavioral types. Statistically, types do not differ in their first or second choices (p-values for ranksum and Kolgomorov-Smirnov tests are greater than 0.10). There is also no difference in terms of how long it takes different types to make their first or second choices. It is only as time progresses that the types separate out. As a result, the average final choices for the Decreasing types are lowest, while those for the increasing types are highest. A two-sample Wilcoxon ranksum (Mann-Whitney) test on the final choices of the Constant, Decreasing and Increasing types shows that pairwise these behavioral types are statistically different.[20]

7.1 Differences in Performance

The data above suggest that the Decreasing group performs best in the experimental task. Indeed this is the case: the group of 8 students that played the game before the Standard and SCP Experiments had an average of 38, which makes the best choice 25. Table 8 presents the summary statistics of the absolute value of deviations from this ideal

[19] See Appendices C.2 and C.3 for the results.

[20] The p-values are 0.0019 for the test on the Decreasing type versus Constant, 0.0007 for Decreasing versus Increasing and 0.0292 for Constant versus Increasing. Thus we can reject the null that the pairwise comparison come from identical distributions.

score. It is clear from Table 8 that Decreasing types as a whole were the closest to the targeted number.[21]

	Constant	Decreasing	Increasing
Mean	17.15	9.5	32
Median	15	7.5	31.5
Standard Deviation	12.36	7.38	22.1

Table 8: Performance of behavioral types: deviations from the winning number.

The superior performance of the Decreasing types is robust to changes in the average choice. While there is some variance in results, averages in the beauty contest games have generally been between 22 and 38: Rubinstein (2007) found an average of 36.2 in his internet experiment; subjects in Nagel (1995) average 37.2; they average 23 in the Bosch-Domenech, Montalvo, Nagel and Satorra (2002) newspaper experiment. Camerer, Ho and Chong (2004) report a series of papers in which different authors study the beauty contest game with different subject pools: CalTech students average 23, CEOs average 37.9, Econ Ph.D. students average 27.4; Kovalchick et al. (2005) used 80 year-olds and found an average of 37. For any of these averages, the Decreasing group would have performed strictly better than the Constant and Increasing groups. Only with an average choice above 47 would the Constant group perform better than the Decreasing group.

7.2 A Connection with Bayesian Updating?

Given the results on average choices, it is in some ways surprising that that only 30% of the subjects show clear evidence that additional thinking creates additional learning. It is also striking that the learning process rather than differences that are apparent at the beginning of the game is entirely responsible for differences in final decisions. It is therefore of interest to know the extent to which those who learn more in the guessing

[21]This is confirmed by the ranksum test for which p-values are 0.0382 for Decreasing versus Constant categories, 0.0063 for Decreasing versus Increasing and 0.0466 for Increasing versus Constant categories.

game perform better in various other tasks. As noted in section 3, all subjects were asked questions both to explore the connection with the ability to learn through updating, as well as with status quo bias. The latter revealed little, as summarized in Appendix C.1. However the connection with Bayesian updating turned out to be interesting and robust.

Table 9 below presents the results of three Probit regressions from the Monty Hall game. The dependent variable y_i equals 1 if participant i kept the initially chosen door and 0 otherwise. Regression 1 and 2 are the same as in Table 6, which we described in section 6. In Regression 3, the independent variable is a dummy equal to 1 if a subject is classified as a Decreasing type.

	Regression 1	Regression 2	Regression 3
Decreasing			$-0.7364^{**}(0.371)$
Final choice	0.0128(0.009)		
Level 1 (Nagel)		0.4745(0.682)	
Level 2 (Nagel)		$-0.6980(0.572)$	
Constant	0.1680(0.366)	$0.9085^{**}(0.440)$	$0.8761^{**}(0.223)$
# of obs	60	35	60
Log Likelihood	−33.8016	−16.8079	−32.8156
Pseudo R^2	0.0285	0.1066	0.0569

Coefficient and standard deviation is reported in the parenthesis

** - significant at 5%

Table 9: Predicting behavior in the Monty Hall Game.

Table 9 clearly shows that only the regression that uses our behavioral types as predictors has a statistically significant coefficient (neither of the other two regressions, which are based on final choice alone, correlate with behavior in the Monty Hall game). As apparent from Regression 3, belonging to the Decreasing type is a good predictor of play in the Monty Hall game. Further, individuals who belong to that category are more than twice as likely to switch doors after they receive new information on which door does not contain the prize money.[22]

[22]In the data, a little over 44% of those who belong to the Decreasing type switch door, while fewer than 20% of those who do not belong to the Decreasing group switch door. A test of proportions

In intuitive terms, the result suggests that Decreasing types are better than others at incorporating new information, whether this information results from internal reflection or a change in the information set on which to base a decision.

The connection with Bayesian updating was also apparent in our multiple period Bayesian updating game. In Table 10 we show summary statistics on the choices of individuals depending on whether they are of the Decreasing type.[23] The Decreasing and non-Decreasing types have strikingly different averages. Further, the error in prediction is always higher for the non-Decreasing type.

		Non Decreasing		Decreasing	
Period	Theory	Mean	Error	Mean	Error
1	20.6	53.4	32.4	43.6	23
2	37.7	64.9	27.2	55	17.3
3	58.5	70.4	11.9	63.9	5.4
4	37.7	65.8	28.1	48.6	10.9
5	58.5	74.3	15.8	61	2.5
6	37.7	63.5	25.8	45.3	7.3
7	58.5	69.2	10.7	56.1	-2.4

Table 10: Results by behavioral type.

As in the SCP treatment, the first period behavior of the various types is not easy to distinguish: a Ranksum test shows no difference between types in period 1. Yet this difference is significant for each of the ensuing periods (2 through 7).[24] While the identification of correct updating is more intricate than in the Monty Hall game, the central finding is that Decreasing types show behavior indicative of faster learning. For example, while non-Decreasing types appear never to choose in a manner that is consistent with Bayesian updating,[25] the Decreasing types do not significantly diverge from the Bayesian solution except in the first two periods.[26] In addition, the individual errors are

confirms these results. The two-sided p-value for the test of proportion is 0.0415, rejecting the null that the probability of switching door is the same for both the people in the Decreasing group and for those not in the Decreasing group.

[23]Breaking down the non-Decreasing type into Constant and Increasing does not change the qualitative results: the Decreasing types behave differently than the others.

[24]The pvalues for each of the seven periods are (in order): 0.2065, 0.0685, 0.0797, 0.0187, 0.0369, 0.0117, 0.0408.

[25]The largest pvalue is .0329. Thus, for each period we can reject the null that the mean of the subjects' answers are equal to the theoretical prediction.

[26]For periods 3 through 7, smallest pvalue is > 0.10.

significantly smaller for the Decreasing types.[27] A regression using Total Squared Error[28] as a dependent variable and Decreasing Type as an independent one, as well as ability measures, shows that being in the Decreasing group implies a signicantly lower squared error.[29,30]

One question the above raises is precisely how the non-Decreasing types come to make such large and continuing errors. One possibility would be overshooting, in which they adjust overly much to the new information that is provided by each witness. The other is under-adjustment. To identify which is the case, note that the percentage difference in mean prediction between periods is smaller for the non-Decreasing types than for the Decreasing types. For example, the difference in mean choices between periods 1 and 2 is 21.5% for the non-Decreasing types, versus 26.1% for the Decreasing types.[31] This simple examination of the evidence, together with the fact that the non-Decreasing types do not target the theory, suggests that under-adjustment may be predominant: the non-Decreasing types appear to be anchored to their previous choices to a greater extent than the Decreasing types.

Overall, the pattern of underadjustment by non-Decreasing types in this game resembles both their behavior in the Monty Hall game (in which the vast majority chooses to keep their first door), and their behavior in the 2/3 guessing game where their choices over the first and second halves of the game were very similar.

[27] This does not follow from the previous point. Indeed, if one group had half the people choosing "Theory + X" and half choosing "Theory - X", while in the other all chose "Theory - ϵ", then with the signrank test the former would on average target the theory while the latter would not.

[28] Each subject's "Total Squared Error" is $\sum_t (\text{Theory}_t - \text{Choice}_t)^2$.

[29] The Root MSE is 4417 and the coefficient on Decreasing is -4,088 with a p-value of 0.002. The adjusted R-squared is 0.1372.

[30] These results are largely confirmed when performing individual period regressions with "squared error in period t" as the dependent variable and behavioral type - and even our ability measures - as dependent variables (the ability measures are never significant).

[31] The percentage difference between periods 2 and 3, 3 and 4, 4 and 5, 5 and 6, 6 and 7 for the non-Decreasing types are 8.5%, 6.5%, 12.9%, 14.5% and 9%. For the Decreasing type they are: 16.2%, 23.9%, 25.5%, 25.7% and 23.8%.

8 The Dynamics of Learning

In this section we use the dynamic patterns in individual choices to sharpen our understanding of learning behavior. By way of background, in Appendix D we present the path of individual choices for all subjects participating in the SCP treatment.

The Constant category as we define it above masks two very different sub-categories: those that never changed their mind during the whole course of the experiment, and those that chose different numbers during their thinking process. We will call the first sub-category Fixed Constant types and the second Fluctuating Constant types. These two categories differ in significant ways. First, the mean choice of the Fixed Constant types is 29.6, and is much lower than the mean first choice of the Fluctuating Constant types (54.55), and the mean of their last choice (40.2). Moreover, fluctuating types change their decisions often during the course of the game, as we will see.

8.1 Playing Past Self

The simplest introspective reasoning is purely based on playing one's past decision, which results in selecting precisely 2/3 of the previous choice (a rapid learner might pick some power of 2/3 by skipping levels of reasoning). One subject (subject 31) fit this pattern precisely, moving from 50 to 33 to 22, and retaining this choice for the remainder of the 180 seconds. In total, 8 out of 60 subjects at some point display such two thirds thinking. Even though the percentage of such adjustments is non-negligible, it is not the dominant feature of our data.

8.2 The Number and Size of Revisions

A striking feature of the data is that many subjects changed their minds often during the course of the 180 seconds, and many of the changes were significant. We present measures of the size and number of changes for the Fluctuating Constant, Decreasing and Increasing behavioral types in Table 11.

	Constant Fluctuating	Decreasing	Increasing
# of changes (mean)	41.52	14.78	32.13
# of changes (median)	15	6	15
$\sum$ |changes|	mean 372.65 median 180	mean 161.67 median 60	mean 294.4 median 164
Convergence	37.9% (11/29)	77.8% (14/18)	37.5% (3/8)

Table 11: Additional measures of thinking process, by behavioral types.

As Table 11 also shows, the Decreasing types make fewer choices: on average about 14.8 compared to more than 30 for the Fluctuating Constant and Increasing types.[32] Further, the sum of the absolute value of the changes they make is are smaller. Not only are the Decreasing types advancing in strategic levels, but they are also making fewer changes.

8.3 Does Learning Converge?

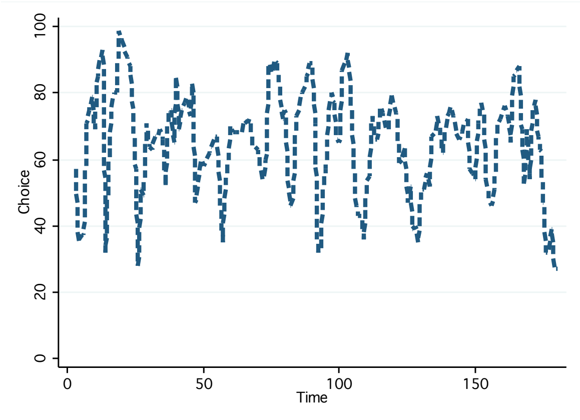
We define subjects as converging if all choices in the last 30 seconds of the game are within a 5 unit range. The first basic finding is that while the majority of subjects do converge, there is a substantial minority (45%) who are still fluctuating at the end of the game.

As we can see in Table 11, there are substantial differences in convergence behavior across learning types. Nearly 80% in the Decreasing category had converged by the end of the game. Yet for the Fluctuating Constant and Increasing types, less than 40% had converged. A test of proportions leads to the rejection of the null that the probability of convergence is the same between the Decreasing and other two behavioral types.[33]

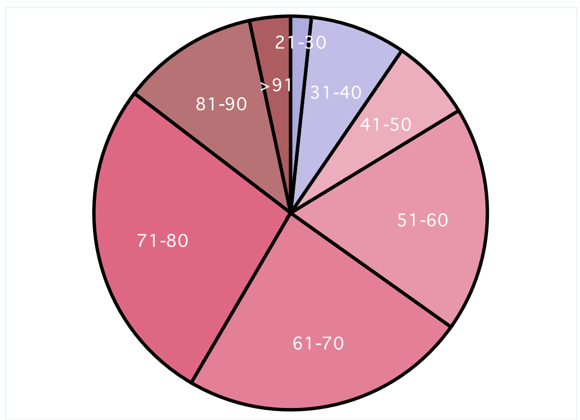
[32] A series of two-sample test of proportions rejects the null that the probability of switching numbers is the same for the Decreasing types and the Fluctuating Constant and Increasing types (both pvalues are smaller than 0.001). A ranksum test on the total number of switches gives us p-values smaller than 0.03, confirming the test of proportions.

[33] The two-sided p-value for the Decreasing and Fluctuating Constant comparison is 0.0078; for the Decreasing and Increasing comparison is 0.0463. We cannot reject the null for the Fluctuating Constant and Increasing comparison.

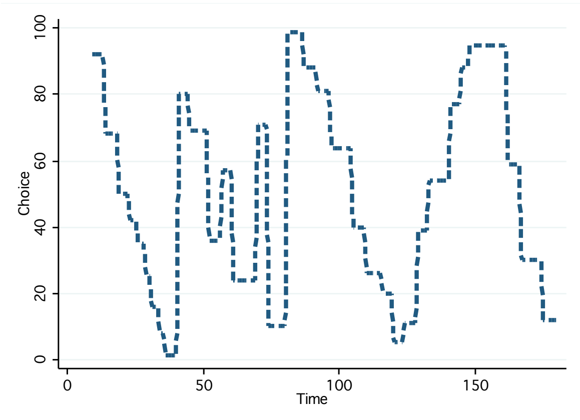
8.4 Is There Deliberate Mixing?



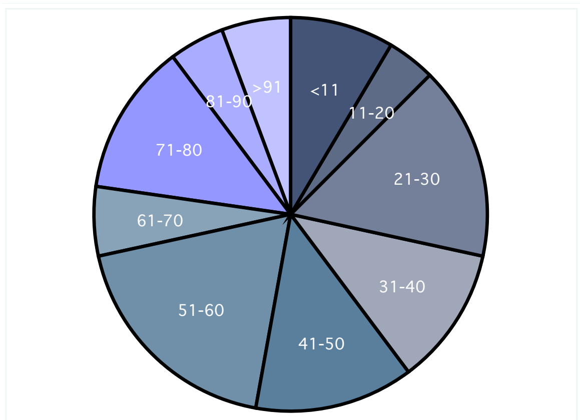
(a) Subject 7: Time Path of Choices



(b) Subject 7: Fraction of Time on Choices



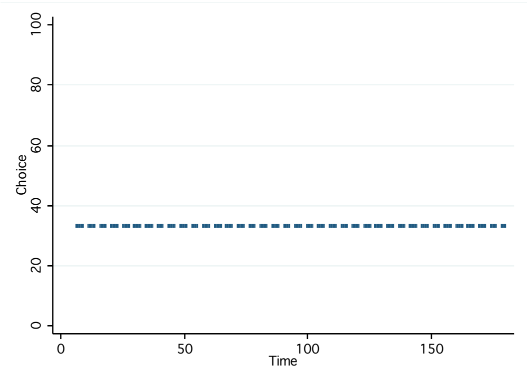
(c) Subject 51: Time Path of Choices



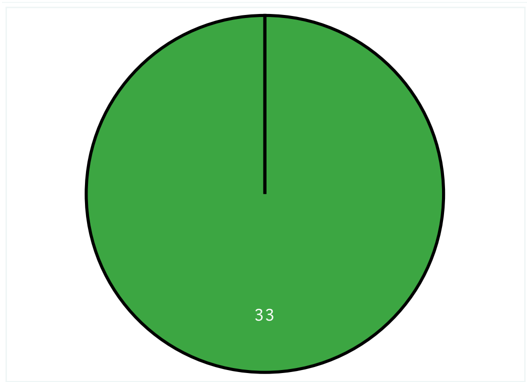
(d) Subject 51: Fraction of Time on Choices

Figure 5: Some Examples of Mixing Behavior?

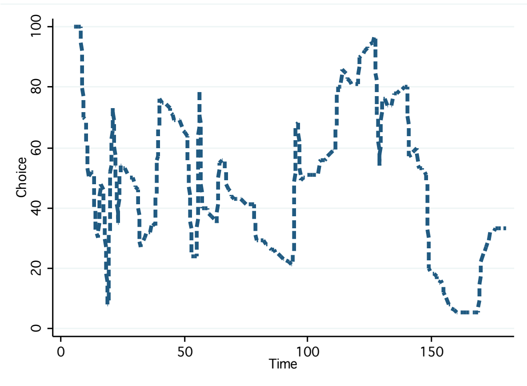
In principle, it is possible that an individual converged to a mixed rather than to a pure strategy. Indeed, the very nature of the SCP treatment creates a mixed strategy, since each second's choice has an equal chance of being implemented. While a pattern of continued fluctuations may reflect evolving understanding of the game, it may also reflect deliberate implementation of the chosen mixed strategy. Our current data do not enable us to distinguish between these two hypotheses. However it is striking how many subjects continued to change their minds throughout the game, and also fluctuated among similar choices early and late in the experiment. Figure 5 presents two examples of such behavior, along with pie charts depicting the percentage of time these subjects spent with choices in various different ranges, corresponding to the mixed strategy that they in fact



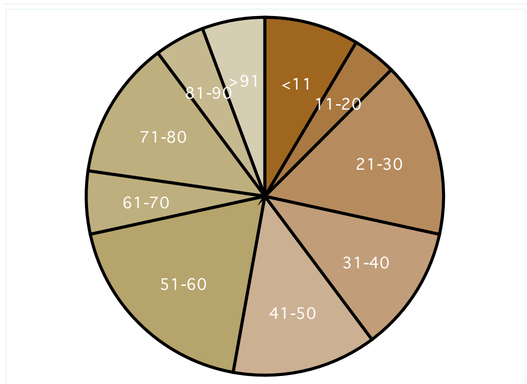
(a) Subject 57: Time Path of Choices



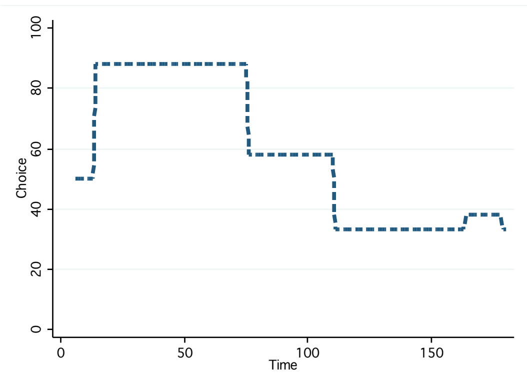
(b) Subject 57: Fraction of Time on Choices



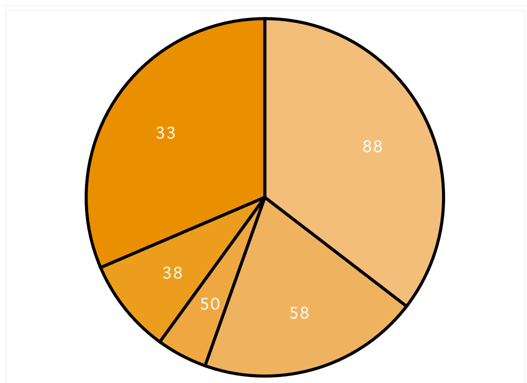
(c) Subject 54: Time Path of Choices



(d) Subject 54: Fraction of Time on Choices



(e) Subject 58: Time Path of Choices



(f) Subject 58: Fraction of Time on Choices

Figure 6: Is Final Choice Enough? Paths of Choice fot Three Individuals With the Same Final Choice

implemented in the SCP treatment.

The fact that the SCP treatment provides possible insight into mixed strategies reinforces our view that final choices do not adequately summarize strategies, particularly when learning is taking place. To further drive home this point, Figure 6 presents three individuals whose final choice is the same (33), and who would be classified as Level 1 thinkers if only their final choice was observed. However, the manner in which they arrived at this final choice is dramatically different, and may contain information of great value in understanding their behavior in various settings, as we have seen.

9 Conclusions

We introduced an experiment designed to provide new information on the process of strategic decision-making. We implemented this design in the 2/3 guessing game. We found that first guesses are close to 50, as had been assumed in specifying level zero play. Moreover, while average choices suggest that there is increasing strategic sophistication as time progresses, we identified significant heterogeneity in this regard. This heterogeneity would have been impossible to uncover using only the final choices, and appears to be relevant not only in this particular guessing game but also in various settings in which Bayesian updating is required.

The results suggest that there is much to be learned by further examining how people arrive at decisions in novel strategic situations. Strategic choice process data may shed a light not only on strategic decisions in unfamiliar games, but also on the broader process of learning.

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A Instructions for the Choice Process Experiment

We will start with a brief instruction period. If you have any questions during this period, raise your hand. Experiment consists of two parts. You will be given instructions for the next part of the experiment once you finished this part. Anything you earn in the experiment will be added to your show-up fee of $7.

PART I

We will start by describing what kinds of decisions you will be making in this game. We will then describe the rules of the game and the payments in this game.

Your task in this game is to choose a number from those presented on the screen.

The game lasts 180 seconds. At the top right corner of the screen you can see how many seconds are left. At the bottom right corner of the screen there is a "Finished" button. The rest of the screen is filled with buttons representing integer numbers between 1 and 100. They are arranged in decreasing order.

When the game starts, you can select the number by clicking on the button displaying the number that you want. You may click when you want, however many times you want.

The computer will record all the numbers you click on, as well as when you clicked on them.

After 180 seconds, or when you click the finish button, the round will come to an end and you won't be able to change your choice anymore. Just to make clear, if you choose a number and then stay with that number until the end, or instead decide to click on the "Finish" button, it will make no difference.

Only one of the numbers you selected will matter for payment. To determine which one, the computer will randomly choose a second between 0 and 180, each second is equally likely to be chosen. The number you selected at that time will be the one that matters. We will call this number **"Your Number".** Below are two examples.

Example 1

Suppose you chose the button 100 for seconds 0 to 180. Suppose the computer randomly selects second 13 to be the random second.

Since at second 13 you were at button 100, 100 is "Your Number".

Example 2

Suppose that after 10 seconds you selected the button 62. Suppose then that at second 55 you switched to button 40. Suppose that then at second 90 you switched to button 89 and then clicked on the Finish button.

In this case "Your Number" would be:

- if the computer randomly chooses a number between 0 and 9 seconds: none.
- if the computer randomly chooses a number between 10 and 54 seconds: 62

- if the computer randomly chooses a number between 55 and 89 seconds: 50
- if the computer randomly chooses a number between 90 and 180 seconds: 89

These examples are completely random and do not represent a hint at what you ought to do in this experiment. Note: once a button is clicked on, it becomes highlighted and you do not need to click on it again as it is already selected.

If you have not yet made a selection at the random second the computer chooses, then you cannot win this game.

Also, understand that if at any point you prefer a different number to the one you currently have selected, you should change the button you selected as this would reduce the chances of the less preferred number being recorded as "Your Number."

The Structure of the Game

A few days ago 8 undergraduate students like yourselves played a game. Your payoff is tied to the choices made by those 8 students, so you need to understand the game they played. We will now distribute the rules of the game these 8 students played and the rules of the game you will be playing.

Your payoff will not depend on the choices made by the people in this room. It depends only on your choice and the choices these 8 students made a few days ago.

[Distribute the second set of instructions face down now. Wait for all to receive a copy. Read it out loud.]

The PAST game the 8 people played:

Each of the 8 students had 180 seconds to choose an integer between 1 and 100 inclusive, which they wrote on a piece of paper. After 180 seconds, we collected the papers. The winner was the person whose number was closest to two thirds of the average of everyone's numbers. That is, the 8 students played among themselves and their goal was to guess two thirds of the average of everyone's numbers.

The winner won $10 and in case of a tie the prize was split.

The game YOU will be playing now:

You will have 180 seconds to choose an integer between 1 and 100 inclusive. You win $10 if you are "better than" those 8 students at determining two thirds of the average of their numbers. That is, you win $10 if **Your Number** is the **closest** to two thirds of the average of the numbers in the past game.

At any point, it is in your best interest to select the button corresponding to what you think is two thirds of the average of the numbers in the past game.

[Game starts right away.]

B Instructions for the Other Games

B.1 Monty Hall (Game 1)

Screen 1

Behind one of these doors is $5. Behind the other two is $0. So, there is only one winning door.

Please choose one of the doors.

Screen 2
You have selected Door < their choice >.

We know which door contains $5.

Before we opend the door you selected, we are going to open one of the doors that contains $0.

[We open one door that contains $0.]

Screen 3

Do you want to keep Door < their choice > or switch to Door < other door >?

B.2 Status-Quo Lotteries (Games 2-4)

The next 3 games of the experiment consist of two stages each. You will first be asked to choose one lottery from a group of alternatives (Stage 1). After you have made your choice, you will be presented with a second group of lotteries. You will have the opportunity to exchange the lottery you chose in the first stage for one of these new lotteries, or to stick with your original choice. The lottery you choose at this time will be your 'final choice' for that game.

Game 2

Screen 1

Please choose one of the following lotteries:

1. $5 for sure.
2. $0 with probability 25% and $4 with probability 75%.
3. $4 with probability 90% and $1 with probability 10%.

Screen 2

You have chosen $5 for sure.

Do you want to keep this lottery or exchange it for one of the lotteries below?

1. $13 with probability 50% and $0 with probability 50%.
2. $25 with probability 30% and $0 with probability 70%.

Game 3

Screen 1

Please choose one of the following lotteries:

1. $10 with probability 50% and $2 with probability 50%.
2. $5 with probability 25% and $1 with probability 75%.
3. $2 for sure.

Screen 2

You have chosen the lottery that pays \$10 with probability 50% and \$2 with probability 50%.

Do you want to keep this lottery or exchange it for one of the lotteries below?

1. \$14 with probability 50% and \$0 with probability 50%.
2. \$4 for sure.

Game 4

Screen 1

Please choose one of the following lotteries:

1. \$1 with probability 90% and \$3 with probability 10%.
2. \$6 with probability 90% and \$0 with probability 10%.
3. \$4 with probability 90% and \$0 with probability 10%.

Screen 2

You have chosen the lottery that pays \$6 with probability 90% and \$0 with probability 10%.

Do you want to keep this lottery or exchange it for one of the lotteries below?

1. \$10 with probability 65% and \$0 with probability 35%.
2. \$20 with probability 10% and \$2 with probability 90%.

B.3 Multi-Period Bayesian Updating Game (Game 5)

Screen 1

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

A witness identified the cab as Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

What are the changes that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 2

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness identified the cab as Blue.

A second witness comes forward. This witness is independent from the previous one. This witness identifies that the cab was Blue.

What are the changes that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 3

A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue.

A third witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Blue.

What are the changes that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 4
A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue. The third witness has identified the cab as Blue.

A fourth witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Green.

What are the changes that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

Screen 5
A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue. The third witness has identified the cab as Blue. The fourth witness has identified the cab as Green.

A fifth witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Blue.

What are the changes that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

<u>Screen 6</u>
A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue. The third witness has identified the cab as Blue. The fourth witness has identified the cab as Green. The fifth witness has identified the cab as Blue.

A sixth witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Green.

What are the changes that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

<u>Screen 7</u>
A cab was involved in a hit and run accident last night. Two cab companies, Green and Blue, operate in the city.

You know there are 100 cabs in the city: 90 of them are Green, 10 are Blue.

Witnesses correctly identify each of the two cabs 70% of the time and misidentify them 30% of the time.

A first witness has identified the cab as Blue. The second witness has identified the cab as Blue. The third witness has identified the cab as Blue. The fourth witness has identified the cab as Green. The fifth witness has identified the cab as Blue. The sixth witness has identified the cab as Green.

A seventh witness comes forward. This witness is independent from the previous ones. This witness identifies that the cab was Blue.

What are the changes that the cab involved in the accident was Blue? Enter a number between 0 and 100.

You will be paid according to how close you are to the true percentage change. You can win at most $1. You loose 10 cents for each 10 percentage points you are away from the truth.

B.4 Ability Measures (Game 6)

Game 6 consists of 9 questions. If this game will be chosen for payment, then for each correctly answered question you will be paid 50 cents.

1. If the chance of getting a disease is 10 percent, how many people out of 1,000 would be expected to get the disease?
2. If 5 people all have the winning numbers in the lottery and the prize is two million dollars, how much will each of them get?
3. Lets say you have $200 in a savings account. The account earns 10 percent interest per year. How much would you have in the account at the end of two years?
4. A store is offering a 15% off sale on all TVs. The most popular television is normally priced at $1000. How much money would a customer save on the television during this sale?
5. Which of the following represents the biggest chance of winning a lottery: a 1 in 100 chance, a 1 in 1000 chance, or a 1 in 10 chance?
6. If a customer saved $10 off a $1000 chair, what percent would the customer have saved off the original price?
7. A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?
8. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?
9. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?

B.5 Risk Attitudes (Game 7)

In game 7 you will have 10 questions. In each question (row), you will be asked to choose Lottery A or Lottery B. If this Game will be chosen for payment, then one of the questions (rows) will be chosen at random and the Lottery that you chose will be played out for you.

Option A	**Option B**	**Your Choice**
1/10 of $2 and 9/10 of $1.60	1/10 of $3.85 and 9/10 of $0.10	
2/10 of $2 and 8/10 of $1.60	2/10 of $3.85 and 8/10 of $0.10	
3/10 of $2 and 7/10 of $1.60	3/10 of $3.85 and 7/10 of $0.10	
4/10 of $2 and 6/10 of $1.60	4/10 of $3.85 and 6/10 of $0.10	
5/10 of $2 and 5/10 of $1.60	5/10 of $3.85 and 5/10 of $0.10	
6/10 of $2 and 4/10 of $1.60	6/10 of $3.85 and 4/10 of $0.10	
7/10 of $2 and 3/10 of $1.60	7/10 of $3.85 and 3/10 of $0.10	
8/10 of $2 and 2/10 of $1.60	8/10 of $3.85 and 2/10 of $0.10	
9/10 of $2 and 1/10 of $1.60	9/10 of $3.85 and 1/10 of $0.10	
10/10 of $2 and 0/10 of $1.60	10/10 of $3.85 and 0/10 of $0.10	

C Results of the Other Games

C.1 Results of the Status-Quo Games

Table 12 shows the percentage of subjects who switch to a different lottery in the second stage (virtually all subjects chose the non-dominated lottery in the first stage) of each of the status-quo games (Games 2-4).

	Non Decreasing % Keep	Decreasing % Keep
Game 2	40.5	38.9
Game 3	59.5	55.6
Game 4	59.5	61.1

Table 12: Status-quo games

Tests of proportions and Probit regressions with Decreasing and Risk-attitude as independent variables show that there the behavior of our subjects does not seem to depend on whether they are part of the Decreasing group or not.[34]

C.2 Risk Measures

Ordered Probit regressions show that Final choice or belonging to the Decreasing group do not correlate with risk preferences. The average (median, standard deviation) switching point from Lottery A to Lottery B for the Decreasing group is 6.4 (6, 1.8) and for the non-Decreasing group is 6.5 (7, 1.7). A ranksum test also show that there is no difference in the distribution of switching points between the Decreasing and non-Decreasing groups.

C.3 Ability Measures

Ordered Probit regressions show that final choice or belonging to the Decreasing group do not correlate with our ability measures. The dependent variable was a subject's score, where each subject's score was simply the number of correct answers. The average (median, standard deviation) score for the Decreasing group is 7.1 (7, 1.6) and for the non-Decreasing group is 6.7 (7, 1.6). A ranksum test also show that there is no difference in the distribution of number of correct responses between the Decreasing and non-Decreasing groups.

[34]Risk-attitude has a significant and "appropriately-signed" coefficient for Games 2 and 4. Regressions using final choice did not produce any results either.