The Journal of Risk and Uncertainty, 30:3; 195–209, 2005

The Gambler's Fallacy and the Hot Hand: Empirical Data from Casinos

RACHEL CROSON crosonr@wharton.upenn.edu
The Wharton School, University of Pennsylvania, Suite 500, Huntsman Hall, 3730 Walnut Street, Philadelphia, PA 19104-6340, USA

JAMES SUNDALI jsundali@unr.nevada.edu
Managerial Sciences/028, University of Nevada, Reno, Reno, NV 89557

Abstract

Research on decision making under uncertainty demonstrates that intuitive ideas of randomness depart systematically from the laws of chance. Two such departures involving random sequences of events have been documented in the laboratory, the gambler's fallacy and the hot hand. This study presents results from the field, using videotapes of patrons gambling in a casino, to examine the existence and extent of these biases in naturalistic settings. We find small but significant biases in our population, consistent with those observed in the lab.

Keywords: perceptions of randomness, uncertainty, field study

JEL Classification: C9 Experimental, C93 Field Experiments, D81 Decision Making under Risk and Uncertainty

The emerging field of behavioral economics uses regularities from experimental data to predict and explain real-world behavior. However, few studies demonstrate the persistence of experimentally-observed biases in natural settings. This study uses data from patrons gambling in a casino to test the robustness of two biases that have previously been observed in the lab: the gambler's fallacy and the hot hand.

The gambler's fallacy is a belief in negative autocorrelation of a non-autocorrelated random sequence. For example, imagine Jim repeatedly flipping a (fair) coin and guessing the outcome before it lands. If he believes in the gambler's fallacy, then after observing three heads his subjective probability of seeing another head is less than 50%. Thus he believes a tail is "due," that is, more likely to appear on the next flip than a head.

In contrast, the hot hand is a belief in positive autocorrelation of a non-autocorrelated random sequence. For example, imagine Rachel repeatedly flipping a (fair) coin and guessing the outcome before it lands. If she believes in the hot hand, then after observing three correct guesses in a row her subjective probability of guessing correctly on the next flip is higher than 50%. Thus she believes that she is "hot" and more likely than chance to guess correctly.

Notice that these two biases are not simply inverses of each other. In particular, the gambler's fallacy is based on beliefs about outcomes like heads or tails, the hot hand on beliefs of outcomes like wins and losses. Thus someone can believe both in the gambler's fallacy (that after three coin flips of heads tails is due) and the hot hand (that after three correct guesses they will be more likely to correctly guess the next outcome of the coin toss). These biases are believed by psychologists to stem from the same source, (the *representative heuristic*) as discussed below and formalized in Rabin (2002) and Mullainathan (2002).

The prevalence and magnitude of these biases extend into our economic and financial lives. For example, it has been argued that the disposition effect in finance (the tendency of investors to sell stocks that have appreciated and hold stocks that have lost value) is caused by gambler's fallacy beliefs. In particular, the reasoning goes, if a stock has risen repeatedly in the past, it's due for a downturn and thus it's time to sell. Similarly, stocks that have lost value are due to appreciate, so one should hold those stocks (Shefrin and Statman, 1985; Odean, 1998). Other evidence demonstrates that consumers' mutual fund purchases depend strongly on past performance of particular fund managers (Sirri and Tufano, 1998), even though the data suggest that performance of mutual fund managers is serially uncorrelated (e.g. Cahart, 1997). Thus, individuals are presumably making investment decisions based upon the belief that particular funds or fund managers are "hot."

In this study we use empirical data from gamblers playing roulette in casinos to examine the existence and prevalence of gambler's fallacy and hot hand beliefs in the field. Casino data, while difficult to obtain and to code, has a number of advantages over other methods in investigating these biases. First, the researcher can be assured that the random sequences observed truly emerge from an *iid* random process.[1] Second, participants in the casinos are making real decisions with their own money on the line. Thus the observed behavior is more likely to be caused by actual biased beliefs rather than noise or a desire to please the experimenter. Third, the participants represent a more sophisticated and motivated sample than typical students at a university; gamblers have a very real incentive to learn the game they are playing and to make decisions optimally and have the opportunity to observe salient feedback from their decisions. Thus field data provides a strong test of the existence of a bias. In our study we will analyze 18 hours of roulette play during which 139 players placed 24,131 bets.

The paper proceeds in Section 1 with definitions of the gambler's fallacy and hot hand and a discussion of previous literature examining them. In Section 2 we present our data from the casino and analyze it for evidence of the gambler's fallacy and the hot hand. Section 3 provides a discussion and conclusion.

1. Definitions and previous research

This paper (and some of the literature reviewed below) uses data from gambling situations to test for biased beliefs. A number of other papers have used empirical gambling data to answer other questions (e.g. testing market manipulability in Camerer (1998), estimating utility of gambling in Golec and Tamarkin (1998), estimating efficiency of markets in Quandt (1986)). Below we focus on lab and field studies which seek to address the question of biased beliefs about a sequence of random outcomes.

1.1. Gambler's fallacy

The first published account of the gambler's fallacy is from Laplace (1820). Gambler's fallacy-type beliefs were first observed in the laboratory (under controlled conditions) in the literature on *probability matching*. In these experiments subjects were asked to guess which of two colored lights would next illuminate. After seeing a string of one outcome, subjects were significantly more likely to guess the other (see Estes, 1964 for a review).

Other researchers have demonstrated the existence of the gambler's fallacy empirically, in lottery and horse or dog racing settings. For example, Clotfelter and Cook (1991, 1993) and Terrell (1994) show that soon after a lottery number wins, individuals are significantly less likely to bet on it. This effect diminishes over time; months later the winning number is as popular as the average number. Metzger (1984), Terrell and Farmer (1996) and Terrell (1998) show the gambler's fallacy in horse and dog racing. Metzger shows that individuals bet on the favorite horse significantly less when the favorites have won the previous two races (even though the horses themselves are different animals). Terrell and Farmer and Terrell show that gamblers are less likely to bet on repeat winners by post position, thus if the animal in post-position 3 won the previous race, in this race the (different) animal in post position 3 is significantly underbet. In a non-gambling setting, Walker and Wooders (2002) analyze the choices of serves made by professional tennis players. These players have an incentive to be random (unpredictable) in their choices, yet the authors find evidence for negative autocorrelation in their serves, consistent with the gambler's fallacy.[2]

The gambler's fallacy is thought to be caused by the representativeness bias, or the "Law of Small Numbers" (Tversky and Kahneman, 1971). Individuals believe that short random sequences should reflect (be representative of) the underlying probability used to generate them. Thus after a sequence of three red numbers appearing on the roulette wheel, black is more likely to occur than red because a sequence RRRB is more representative of the underlying distribution than a sequence RRRR. More formalized versions of this idea can be found in Mullainathan (2002) and Rabin (2002). In Mullainathan (2002), individuals use categories to think about the world, for example, a roulette wheel can be unbiased, biased toward red or biased toward black. After a short run of one color, individuals predict the other color will appear, because this is what "should" happen in an unbiased wheel. In Rabin (2002), individuals exaggerate the likelihood that short sequences represent long sequences and thus act as though *iid* random processes are actually draws from a finite urn without replacement. This (incorrect) without-replacement assumption leads to gambler's fallacy beliefs.

We will test for the gambler's fallacy in our data by looking at the impact of previous winning outcomes on current bets at roulette. By direct analogy to the lottery results, people should be less likely to bet on an outcome that has previously won. Thus a negative relationship between previously-winning outcomes and current bets is evidence of the gambler's fallacy.

1.2. Hot hand

Many researchers describe the *hot hand* as the opposite of the gambler's fallacy; a belief in positive serial autocorrelation of a non-autocorrelated series. However, it is slightly different; individuals who believe in the hot hand believe not that a particular outcome is hot (e.g. that the roulette wheel that has come up red in the past is likely to come up red again), but that a particular *person* is hot. If an individual has won in the past (and is hot), then whatever they choose to bet on is likely to win in the future.

Gilovich, Vallone, and Tversky (1985) demonstrated both that individuals believe in the hot hand in basketball shooting, and that basketball shooters' probability of success is indeed serially uncorrelated. Other evidence from the lab shows that subjects in a simulated blackjack game bet more after a series of wins than they do after a series of losses, both when betting on their own play and on the play of others (Chau and Phillips, 1995).

The evidence for the hot hand from the field is weaker. Camerer (1989) compared odds in the betting market for basketball teams with their actual performance and finds a small hot hand bias. Bettors do appear to believe in the "hot team," but the bias is small, not enough to overcome the house edge in sports betting. Brown and Sauer (1993) use a different dataset and analysis, but confirm the main findings of Camerer (1989).

In more compelling evidence from the field, Clotfelter and Cook (1989) note the tendency of gamblers to redeem winning lottery tickets for more tickets rather than for cash. This behavior is also consistent with hot hand beliefs; since the individual has won previously they are more likely to win again.

The hot hand is thought to be caused by the illusion of control (Langer, 1975). Individuals believe that they (or others) exert control over events that are in fact randomly determined. We will test for hot hand beliefs in our data by looking at how betting behavior of individuals change in response to wins and losses in roulette. In particular, hot hand beliefs predict that, after a win, individuals will increase the number of bets they place and after a loss, decrease them.[3]

2. The data

In this study we use data from the field; individuals betting in a casino. In particular, we will analyze bets placed at the game of roulette. Roulette is a useful game to use: it is serially uncorrelated, unlike other casino games like blackjack or baccarat where previous realizations influence future likelihoods. Also, roulette is an extremely popular game, thus there is no shortage of data and the game is familiar to those playing it.

2.1. Roulette

Roulette is played with a wheel and a betting layout. The wheel is divided into 38 even sectors, numbered 1–36, plus 0 and 00 (in Europe, the wheel is divided into 37 sections, 1–36 plus 0). Each numbered space is colored red or black, with the exception of the 0 and 00, which are colored green. The wheel is arranged as shown in Figure 1, such that red and black numbers alternate. The numbering on the wheel is not in numerical order but instead the order as shown.

Players arrive at the roulette table, and offer the dealer money (either cash or casino chips). In exchange, they are given special roulette chips for betting at this wheel. These chips are not valid anywhere else in the casino, and each player at the table has a unique

Figure 1. The wheel.

color of chips. Players bet by placing chips on a numbered layout, the wheel is spun and a small white ball rolled around its edge. The ball lands on a particular number in the wheel, which is the winning number for that round, and is announced publicly by the dealer. Next, the dealer clears away all losing chips, players who had bet on the winning number (in some configuration) are paid in their own-colored chips and a new round of betting begins.

Figure 2 shows a typical layout. Unlike the wheel, the layout is arranged in numerical order. Players can place their bets on varying places on the layout, covering a single number or a combination of numbers located next to each other. All these bets pay the same, 36 for one (35 to one) divided by the number of numbers covered by the bet. We count all these betting combinations as "inside bets," as they are bets placed inside the layout.

In addition, bets like red/black, even/odd and low (1–18) and high (19–36) which pay even money (2 for 1) and the thirds (1–12, 13–24 and 25–36) which pay 3 for 1 are outside bets. If either 0 or 00 comes up, these outside bets lose.[4]

Notice that all these bets have the same expected value, −5.26% on a double-zero wheel.[5] If the wheel had no zeros, only 36 red or black numbers, the bets would be perfectly fair.

Figure 2. The layout.

The zeros are thus sometimes referred to as the "house numbers," even though players can (and often do) bet on them.

Since the house advantage on (almost) all bets at the wheel is the same, there is no economic reason to bet one way or another (or for that matter, at all).[6] In this sense our data suffer from a similar limitation as Clotfelter and Cook's (1991, 1993) who observed lottery number choice in a fixed-payoff lottery. In this paper, we will compare the betting behavior we observe against a benchmark of random betting and search for systematic and significant deviations from that benchmark.

2.2. Data and descriptive statistics

2.2.1. The data. The data was gathered from a large casino in Reno, Nevada.[7] Casino executives supplied the researchers with security videotapes for 18 hours of play of a single roulette table. The videotapes consisted of three separate six-hour time blocks over a 3-day period in July of 1998.[8] The videotapes provided an overhead view of the roulette area. The camera angle was focused on the roulette table, the roulette wheel, and the dealer. The videotape was subtitled with a time counter. Note that while many casinos employ electronic displays showing previous outcomes of the wheel, this casino had no such displays at the time the data was collected. A research assistant was employed to view and record player bet data from these videotapes.

The videotape methodology made it possible to view all of bets made by each player with a high degree of accuracy.[9] However, while we could observe *if* a player bet on a particular number, given the angle of the camera (from above), we could not observe *how many* chips he or she bet on a particular number. Thus we simplified the data recording to code a bet being placed, without mention of how much the bet was. In addition to coding the bets placed on numbers, we separately coded for outside bets placed. After the assistant recorded all of the bets from the 18 hours of videotape, one of the principal investigators performed an audit check to insure accuracy.

2.2.2. Descriptive statistics: The wheel. Nine hundred and four spins of the roulette wheel were captured in this data set (approximately 1 spin per minute). Table 1 shows the distribution of outcomes (and bets) for numbers on the wheel.

The expected frequency of a single number on a perfectly fair roulette wheel is 1/38 or 2.6%. In this sample the most frequent outcome was number 30 at 3.7%, the least frequent outcome was number 26 at 1.7%. These data provide no evidence that the wheel is biased.[10] Figure 3 shows the distribution of outcomes and bets for outside bets. Again, we cannot conclude that the wheel is biased from this data.

2.2.3. Descriptive statistics: The bets. The data set included 139 players placing 24,131 bets. Table 2 presents some descriptive statistics of bets placed.

Table 1 describes the bets placed by number. If players bet randomly, we would expect them to bet on each number equally, thus 2.6% of the bets should fall on each number. Figure 3 describes the frequency of observed outside bets.

Table 1. Spin outcomes and player bets.

Outcome	Frequency outcome	% Outcome	% Expected	% Outcome-expected	Frequency bet	% Bet
0/0	22	0.024	0.026	−0.002	354	0.016
0	25	0.028	0.026	0.001	442	0.020
1	23	0.025	0.026	−0.001	362	0.016
2	30	0.033	0.026	0.007	450	0.020
3	28	0.031	0.026	0.005	357	0.016
4	15	0.017	0.026	−0.010	375	0.017
5	28	0.031	0.026	0.005	636	0.028
6	20	0.022	0.026	−0.004	363	0.016
7	15	0.017	0.026	−0.010	682	0.030
8	26	0.029	0.026	0.002	633	0.028
9	23	0.025	0.026	−0.001	503	0.022
10	24	0.027	0.026	0.000	484	0.021
11	26	0.029	0.026	0.002	783	0.035
12	21	0.023	0.026	−0.003	360	0.016
13	21	0.023	0.026	−0.003	525	0.023
14	27	0.030	0.026	0.004	649	0.029
15	27	0.030	0.026	0.004	340	0.015
16	25	0.028	0.026	0.001	643	0.029
17	23	0.025	0.026	−0.001	1079	0.048
18	23	0.025	0.026	−0.001	518	0.023
19	30	0.033	0.026	0.007	595	0.026
20	24	0.027	0.026	0.000	983	0.044
21	26	0.029	0.026	0.002	447	0.020
22	32	0.035	0.026	0.009	576	0.026
23	24	0.027	0.026	0.000	746	0.033
24	18	0.020	0.026	−0.006	461	0.020
25	19	0.021	0.026	−0.005	521	0.023
26	15	0.017	0.026	−0.010	703	0.031
27	22	0.024	0.026	−0.002	490	0.022
28	25	0.028	0.026	0.001	827	0.037
29	23	0.025	0.026	−0.001	878	0.039
30	33	0.037	0.026	0.010	695	0.031
31	22	0.024	0.026	−0.002	664	0.029
32	29	0.032	0.026	0.006	925	0.041
33	17	0.019	0.026	−0.008	613	0.027
34	29	0.032	0.026	0.006	597	0.027
35	22	0.024	0.026	−0.002	627	0.028
36	22	0.024	0.026	−0.002	641	0.028

Table 2. Descriptive statistics of bets.

	Mean	Median	High	Low
Number of bets per player	174	114	1,412	1
Number of spins per player	18	11	132	1
Total number of bets	22,527 Inside			
	1,604 Outside			

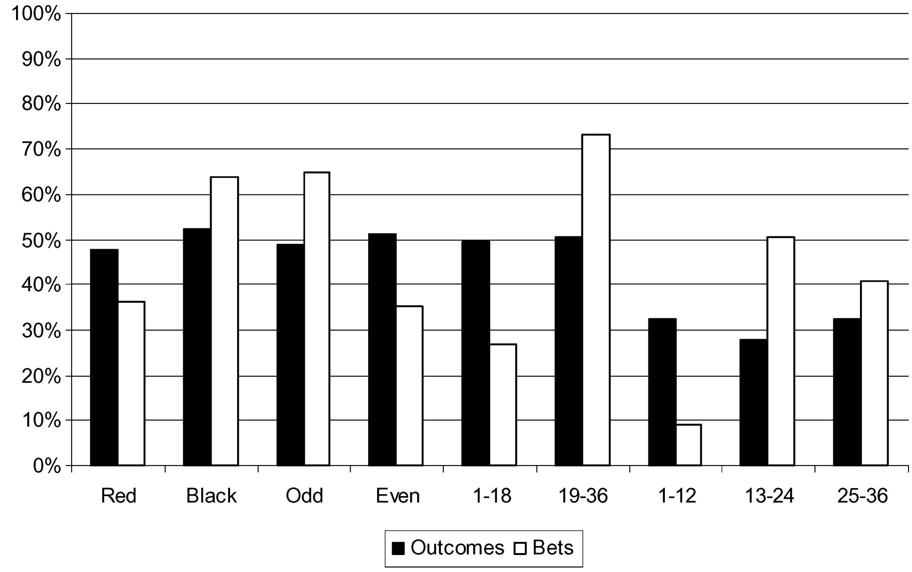

Figure 3. Outside outcomes and bets.

2.3. Gambler's fallacy

We begin our analysis looking for the gambler's fallacy, where observing a particular outcome repeatedly in the past leads individuals to believe the opposite outcome is more likely (is "due"). We focus on even-money outside bets, Red/Black, Odd/Even, and Low/High. We classify a bet as consistent with the gambler's fallacy if it was placed on an outcome that is against a streak of length n. A streak of length n is simply the number of times a particular outcome has appeared consecutively in the past.

For example, if a red number has won the last four trials, this is counted as a streak of length four. At this point, a bet on black would be counted as a gambler's fallacy bet. A similar logic would categorize a bet on an even number after four odd numbers had appeared. Figure 4 describes the frequency of gambler's fallacy bets after streaks of varying length. As shown in Figure 4, there were 531 bets placed on one of the even-money outside bets after having observed at least one spin. Of these 531 bets, 255 (48%) were gambler's fallacy

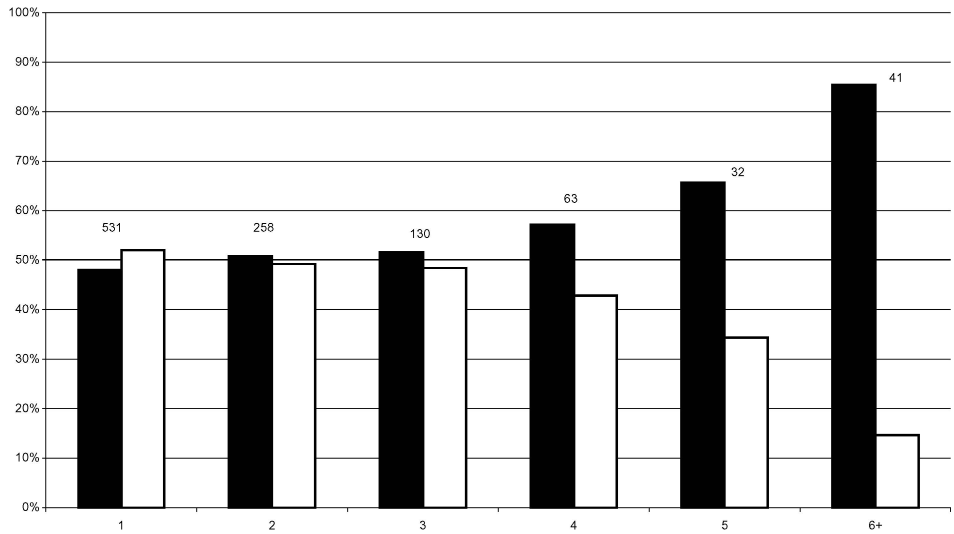

Figure 4. Proportion of gambler's fallacy outside bets after a streak of at least length N.

bets (against the previously-observed outcome) and 276 (52%) were with the previously-observed outcome. The next set of columns considers streaks of length two. Of those 258 bets that were placed on outside bets after streaks of length two, 51% were gambler's fallacy bets. A binomial test at each level of streak compares the actual bets observed with the baseline hypothesis of 50%. There are no significant differences after streaks of length one, two, three or four. However, for streaks of length 5 ($p < .05$) and for streaks of length 6 and above ($p < .01$), there is evidence consistent with gambler's fallacy play.

Thus we find statistical evidence that individuals bet consistently with gambler's fallacy beliefs. After streaks of 5 (or more) outcomes of a particular type, gamblers are significantly more likely to bet against the streak than to bet with it. This result is consistent with the models of Rabin (2002) and Mullainathan (2002). As can be seen in Figure 4, as the length of the streak increases the proportion of gambler's fallacy bets increases as well. After streaks of 6 or more, 85% of bets are consistent with the gambler's fallacy.

2.4. *Hot hand*

Our second set of analyses investigates whether individual's behavior is consistent with hot hand beliefs. To do this, we analyze whether gamblers bet on more or fewer numbers in response to previous wins and losses. The most extreme reduction of bets possible is to stop betting altogether (to leave the table). Of our 139 subjects, 80% (111) quit playing after losing on a spin while only 20% (28) quit after winning. This behavior is consistent with the hot hand; after a win players are likely to keep playing (because they're hot).

On the other hand, quitting is a very discrete measure of beliefs about hotness. A more continuous measure might involve the number of bets placed on a given spin as a function

Table 3. Number of outside bets placed.

	Average	St. dev.	*N*
First spin	0.48	0.71	139
Won prior spin outside	1.53	0.63	454
Lost prior spin outside	1.38	0.57	608

of the outcome of the previous spin. Table 3 presents the average number of outside bets placed by gamblers on the initial trial and after a win or loss on an outside bet on the previous spin.[11] We count the number of times these outside bets were placed, averaged over individuals and types of spins (first, previously winning or previously losing). We exclude observations when individuals remained at the table but had not previously placed an outside bet. Only individuals who placed bets are included in this analysis; individuals who left the table are not counted as having placed zero bets but instead excluded.

After an outside bet win (which occurred 454 times in our data set), individuals place on average 1.53 outside bets. After an outside bet loss (which occurred 608 times in our data set), individuals placed on average 1.38 outside bets. A regression run on the number of bets placed as a function of winning or losing shows a significant, though small, impact ($p < .05$). Thus the data provide evidence of a hot hand in betting behavior. Individuals place more outside bets when they have previously won than when they have previously lost.[12]

Table 4 presents the average number of bets placed on numbers by gamblers after an inside win or loss on the previous spin. As before, we exclude observations when individuals were at the table but had not previously placed an inside bet and only individuals who placed bets are included in this analysis; individuals who left the table are not counted as having placed zero bets but instead excluded.

There were 570 instances where an individual had won an inside bet on the previous spin. In this case, players bet on an average 13.62 numbers. There were 1487 instances where an individual had lost on the previous spin. In this case, players bet on an average of 9.21 numbers. A regression run on the number of bets placed as a function of winning or losing shows a significant impact ($p < .05$).[13] Thus the data on inside bets also provides evidence for the hot hand.[14]

We have enough observations of inside bets for a more complex regression. The dependent variable is the number of inside bets placed by person i on spin t, n_{it}. The independent variables are an indicator variable equal to 1 if the person had won on the previous spin and

Table 4. Number of inside bets placed.

	Average	St. dev.	*N*
First spin	7.63	6.12	139
Won prior spin inside	13.62	6.60	570
Lost prior spin inside	9.21	5.35	1487

Table 5. Hot hand regression.

Intercept	1.63**	−1.83
Win previous trial	1.09**	0.99**
# bets placed last spin	0.58**	0.27**
# bets placed first trial	0.23**	2.07**
Individual dummies	No	Yes
R^2 (adjusted)	.64	.64

$^{**}p < 0.01$; $^{*}p < 0.05$; $^{\wedge}p < 0.10$.

0 otherwise (won_{it-1}), the number of bets the individual had placed on the previous spin (number_{it-1}) and the number of bets the individual had placed on their first trial as a control for individual differences (first_i). As before, individuals who have left the table before spin t (who bet zero on spin t) are excluded. The regression equation is thus

$$n_{it} = \alpha_0 + \alpha_1 \,\text{won}_{it-1} + \alpha_2 \,\text{number}_{it-1} + \alpha_3 \,\text{first}_i + \varepsilon$$

Results from this regression are shown in Table 5. The second column adds individual dummy variables for each person in our dataset.

As Table 5 indicates, winning a bet in trial $t - 1$ significantly increases the number of bets placed in trial t, consistent with the hot hand bias and the results of Camerer (1989) and Brown and Sauer (1993).[15]

3. Conclusion and discussion

This paper uses observational data to investigate the existence and impact of two statistical illusions; the gambler's fallacy and the hot hand. These biases and their resulting behaviors have been observed in the lab; we find evidence for these illusions in the field using data from casino gambling. Our paper makes two important contributions to the behavioral economics literature. First, we provide field data to examine the existence of biases in the perception of *sequences* of gambles. Second, unlike previous research with field data, we have observations of individual's behavior, enabling us to test behavior directly rather than looking more indirectly at market outcomes, as in Camerer (1989) and Brown and Sauer (1993). A related paper (Sundali and Croson, 2002) provides an even more disaggregated analysis of this data and identifies heterogeneity in the existence and strength of these biases in different individuals.

Our data demonstrate that gamblers bet in accordance with the gambler's fallacy. After observing a streak of 5 or more occurrences of a particular outcome, they place significantly more bets against the streak than with the streak. This result is consistent with the models of Mullainathan (2002) and Rabin (2002). Our data also demonstrate that gamblers act in a way consistent with the hot hand; they bet on more numbers after winning than after losing.

These results are consistent with those previously observed in the lab. That these observations are robust when generalized from lab to field is reassuring. However, the limitations inherent in field data admit of alternative interpretations of some of our results. For example, the hot hand result may be explained by an income or house money effect; individuals bet on more numbers after they have won not because they believe that they (personally) are more likely to win again but because they're richer, or playing with the house's money. A similar explanation, suggested by a helpful referee, involves individuals betting some fixed fraction of the chips gamblers have in front of them. While we cannot rule out these explanations using field data, previous lab studies have controlled for them (e.g. Chau and Phillips, 1995). Future lab studies could be designed to do so as well; by manipulating the win/loss history while keeping the current income constant we could test the effect of history on behavior without the confounding factor of income. Similarly, eliciting probability judgments after each trial would provide direct evidence of biased beliefs in a way that is not possible in the field.

A second important limitation of this (and related) research has to do with the cost of exhibiting these biases. In roulette, as in most casino games, the odds of winning or losing are relatively constant independent of how you bet. For example, in craps the house edge from betting the "pass" line is 1.41% and the "don't pass" line is 1.40%. In blackjack the house advantage does not change as the size of the bet changes. Thus the decision of whether to bet pass or don't pass, or of how much to bet at blackjack, is not a costly one in terms of expected value. Thus these settings are ones where biased beliefs are most likely to develop and persist.

These limitations suggest the need for further research combining empirical and lab data in a way that we were prevented from accomplishing here. After observing individual decisions in the field, follow-up lab studies or surveys can help to tease apart these alternative explanations of behavior. Empirical data from financial decision-making could be combined with survey data in a similar way. Other future projects might involve data from other *iid* casino games (e.g. craps, slot machines) both to replicate our current findings and to identify differences between the games.

Almost every decision we make involves uncertainty in some way. It has been amply demonstrated by lab experiments (and some previous empirical papers) that we suffer from biases in uncertain decision situations. This paper uses data from individuals gambling in a casino to test for the presence of these biases in a naturally-occurring environment. The gambling biases we observe are consistent with previously-observed departures from rationality in the lab and in the field.

Acknowledgments

The authors thank Eric Gold for substantial contributions in earlier stages of this project. Thanks also to Jeremy Bagai, Dr. Klaus von Colorist, Bradley Ruffle, Paul Slovic, Willem Wagenaar, participants of the J/DM and ESA conferences, at the Conference on Gambling and Risk Taking and at seminars at Wharton, Caltech and INSEAD for their comments on this paper. Special thanks to the Institute for the Study of Gambling and Commercial Gaming for industry contacts which resulted in the acquisition of the observational data reported here. Financial support from NSF SES 98-76079-001 is also gratefully acknowledged. All remaining errors are ours.

Notes

1. While biased roulette wheels, loaded dice and stacked decks of cards do indeed exist, major casinos in the US are heavily regulated, subject to periodic auditing and severe penalties (loss of gaming license, fines and jail time) for offering rigged games. Furthermore, gambling devices which are nonrandom (or predictable) represent financial liabilities to the casino, as informed patrons can take advantage of the better-than-expected odds.
2. Although, as one reader points out, the *production* of a random sequence is a different task than predicting or perceiving a random sequence.
3. There are alternative explanations for these behaviors. For example, wealth effects or house money effects might cause an increase in betting after a win. In our empirical data we will not be able to distinguish between these alternative explanations although previous lab experiments have done so.
4. This rule, that outside bets lose when 0 or 00 comes up, varies somewhat between casinos and, in particular, between the US and Europe. Sometimes only half of the outside bet is lost, with the remainder being paid directly to the player. In other casinos, the outside bet is held "in prison." The bet must remain unchanged until the next spin, where it then either wins or loses depending on the outcome of the wheel. These rule variations impact the house advantage in the game. In our data, outside bets are lost when 0 or 00 appears.
5. This statement is not strictly true. There is, in fact, one bet has a house advantage of 7.89%. The bet involves placing a chip on the outside corner of the layout between 0 and 1. The bet wins if 0, 00, 1, 2 or 3 appears, but pays only 6 for 1 (as though the bet were covering 6 numbers instead of 5). We observed only 75 instances of this bet being placed (out of 24,131 bets). Only 11 different individuals placed this bet (out of 139 identifiable individuals in our data), and of them, only 6 placed this bet more than twice.
6. Because of this the incentive to learn how to play roulette may be dampened. On the other hand, there remains an incentive to learn how to place the bets (the etiquette of the game) and how much each bet pays (to make sure the dealer is paying you correctly).
7. A casino in Washoe County, Nevada is classified as "large" by the Nevada Gaming Control Board if total (yearly) gaming revenues for the property exceeds $36 million.
8. The three time blocks were from 4:00 p.m. to 10:00 p.m., 8:00 p.m. to 2:00 a.m., and 10:00 p.m. to 4:00 a.m. These time blocks were appropriate since the majority of gaming business is done in the evening hours.
9. Players were identified based upon the color of the chips being used to bet, the player's location at the table, and any distinct characteristics of the player's hand or arm such as appearance, jewelry, clothing, tattoos, etc. Players who ran out of chips and immediately bought more (of the same color) were coded as the same player. Players who ran out of chips and did not immediately buy more were coded as having left the table. When money was again exchanged for chips of that particular color, we assumed a new player had joined the table.
10. Ethier (1982) calculates the number of observations necessary to detect a bias in the wheel.
11. We follow Wagenaar (1988) in defining hot hand as having won the previous spin and being otherwise independent of longer, lagged history. One might imagine extending this notion of hot hand to include (more restrictively) having won the previous N spins or (less restrictively) having won on one of the previous N spins.
12. A similar pattern can be found looking at the impact of all previous bets on current outside bets. After winning either an inside or an outside bet, individuals placed an average of 0.85 outside bets. After losing, they placed an average of 0.50 outside bets. These differences are also significant at $p < .05$.
13. A similar pattern can be found looking at the impact of all previous bets on current inside bets. After winning either an inside or an outside bet, individuals placed an average of 10.30 inside bets. After losing, they placed an average of 8.21 inside bets. These differences are also significant at $p < .05$
14. As noted elsewhere in the paper, there are competing explanations of behavior which would be consistent with this data. One such explanation, suggested by a helpful referee, is that gamblers bet a fixed percentage of the chips they have remaining in front of them. If this is the case, they would also bet more after a win

and less after a loss. A more thorough discussion of alternative explanations for our data can be found in the discussion section.

15. A similar regression of the change in the number of bets placed ($n_{it} - n_{it-1}$) on whether the individual won last spin and the number of bets they placed on the first spin also yields a positive and significant coefficient on past wins.

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