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The impact of near-miss events on betting behavior: An examination of casino rapid roulette play

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Abstract

We examine how almost winning in roulette affects subsequent betting behavior. Our main finding is heterogeneity in gambler behavior with some gamblers less likely to bet on numbers that were near misses on the prior spin and other gamblers more likely to bet on near miss numbers. Using a unique data set from the game rapid roulette, we model the likelihood of a gambler betting on a near miss number while controlling for the favorite number bias and the likelihood of a number being a near miss. We also find no evidence that near misses in roulette leads to gamblers extending the time spent gambling or to the placing of more bets.

Keywords: judgment and decision making, gambler's fallacy, casino betting, field data, roulette.

1 Introduction

Near-miss events occur in a wide variety of domains including gambling, sports, natural disasters, and industrial accidents. Depending upon the domain there are differing definitions of a near miss. Within the gaming literature, Reid (1986) defines a near miss as "a special kind of failure to reach a goal, one that comes close to being successful (p. 32)" which Griffiths (1995) shortens to "failures that are close to being successful (p. 23)" and Harrigan (2008) interprets as a "failure that was close to a win (p. 353)". Harrigan (2008) notes that some prefer the term "near win" as it is a more logical description of the gambling event under consideration but the term near miss prevails. In the context of industrial accidents, Dillon and Tinsley (2005) suggest "an event is considered a "near-miss" if the outcome is non-hazardous, but if a hazardous or fatal outcome could have occurred" (p. 25) and in a subsequent paper they offer the definition of "successful outcomes in which chance plays a critical role in averting failure" (2008, p. 1425). Central to the definitions of a near miss is the belief and associated feelings that one almost won but didn't, or almost lost but didn't. Locke (2001, p. 6) uses the term "Aww Schucks!" to capture the feeling of almost winning to which we add "That was a close one!" to capture the feeling of avoiding an accident.

The importance of near-miss events is that they can affect decisions made subsequent to each event. For example, there is experimental evidence that near misses lead gamblers to play longer. Early research by Strickland and Grote (1967) showed that subjects exposed to a high proportion of winning symbols on the first two wheels of a three wheel slot machine tended to gamble longer, but this result could not be replicated by Reid (1986) under slightly different experimental conditions. However, subsequent studies have found experimental evidence that near misses in slot machine games lead to more games played (Kassinove & Schare, 2001) and increased playing time (Côté et al., 2003; Dixon & Schreiber, 2004).

Although most research on the near miss effect has focused on slot machine gambling, some research has examined the near-miss effect in other casino games. Dixon (2010) found that subjects playing a simulated roulette game rated losing outcomes as closer to winning both when they were close in location to the winning number and when they were numerically close to the winning number. Another study by Dixon et al. (2009) found that blackjack players rated "non-bust" losses as close to wins, with the effect decreasing as the difference in the card values between the player and dealer increased. While both of these studies found a near miss effect in non-slot machine games, a limitation of these studies was that they were not designed to study how near misses affect subsequent gambling behavior.

Near misses also affect decision making away from the casino floor. In a project management domain, Dillon and Tinsley (2008) provide evidence that near-misses are often viewed as successes, which lead managers to make subsequent riskier decisions. Specifically, Dillon and Tinsley provide experimental evidence that managers

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who make decisions that result in near misses are evaluated as highly as managers who make decisions that result in successes (and higher than those who fail without a near miss). Further, the evidence suggests that managers who experience near-miss events, but do not experience a failure, will then subjectively assess the probability of a future failure as lower than the objective probability of failure, leading these managers to choose riskier alternatives. In the domain of natural disasters, Dillon, Tinsley and Cronin (2011) provide evidence that if a house avoided flood damage in a hurricane (a near-miss) then subjects were less likely to buy flood insurance. Subjects were also less likely to evacuate a house that had survived past hurricanes without damage. Explaining this result, Dillon, Tinsley and Cronin (2011) write "People did not update given probabilities, they did not calculate new probabilities, they simply *felt differently* about the initial probabilities that were given. Thus it might be said that near-miss information changes people's frames of reference (p. 448)."

1.1 Theory on near misses

Early theorizing on near misses suggested that gambling behavior is prolonged because near misses act as reinforcements (rewards) (Skinner, 1953). The near miss is perceived as positive feedback that the gambler is learning the game, which provides reinforcement for further play. Further research explored the link between near-misses and expectancy theory, or the idea that a person's behavior is motivated by the expected outcome of that behavior. Côté and colleagues (2003) speculated that, when the first and second reels on a slot machine show the same symbol, "the gambler's expectancy of winning is momentarily increased, which may prolong gambling and increase betting (p. 437)."

Another explanation is that near-misses activate an internal locus of control response, causing individuals to believe that positive outcomes are the result their improved ability or acquired skill. Clark, Lawrence, Astley-Jones and Gray (2009) provide brain imaging evidence suggesting that near misses increased the desire to continue playing when the subject had control over choosing the winning symbol in their game, as opposed to the game choosing the winning symbol. In addition, they found that near-misses significantly increased desire to keep playing, which also suggested that near misses can be interpreted as evidence that skill has been acquired at the game and motivates further gambling.

Another line of research has focused on explaining near-miss behavior through emotional and intuitive responses. Griffiths (1991) speculated that near-misses stimulated gamblers (particularly excessive gamblers) to prolong their play because they became "physiologically aroused" by nearly winning, as opposed to constantly losing. Clark et al. (2011) provided evidence of this physiological response when they found that subjects had greater heart rate acceleration with near misses than with either wins or losses. Dixon et al. (2011) also found that near misses are more physiologically arousing than wins or losses as reflected in skin conductance responses and heart rate deceleration. They reasoned that the greater response to near misses than wins was due to frustration. Dixon et al. (2011) argue that near misses result in a state of "frustrated arousal", and the desire to escape this unpleasant emotional state is the mechanism that prolongs play. Wohl and Enzle (2003) examined the connection between gamblers perception of their own "luck" and near wins/near losses in a simulated roulette game. Counterintuitively, they found that barely avoiding a big loss lead participants to feel "luckier" than if they experienced a near win. Notably, they found that participants who nearly missed a big loss bet significantly more in a subsequent game than those who nearly won. Their findings suggest that it is narrowly avoided losses, rather than narrowly avoided wins, that increase gambling.

The primary finding in gambling near-miss research seems to be that a near miss on a slot machine will lead a player to continue playing either because the player believes that the chances of winning on the next spin of the wheel have increased or because the player has become aroused and presumably wants to maintain/eliminate that feeling. A limitation of slot machine data is that no direct information can be gathered about player beliefs. That is, each spin of the slot reels only requires a player to place a bet and then pull a lever or push a button. While we can observe that a player continues to play after a near miss, we can only speculate that extended play is because of a change in outcome beliefs or arousal.

In contrast, the methodology of Dillon and Tinsley et al. (2005, 2008, 2011) provides more direct measurement of subject beliefs. The findings that project managers made subsequent riskier decisions after near-miss events and that insurance purchasers were less likely to buy flood insurance after a near-miss event suggest a revision of risk beliefs or a change in how they felt about those beliefs. Specifically, this data suggest that after a near-miss event subjects make subsequent decisions as if the likelihood of the focal event (a flood damaging hurricane) has declined. Subjects are making subsequent decisions, such as not buying flood insurance, presumably because they have altered their belief in the likelihood of the (insurable) risk.

If a near-miss event leads to a downward revision in the belief of a subsequent focal event, this would suggest a gambler's fallacy bias (e.g., if the ball just landed on this spot on the wheel it is due to land somewhere else). This bias occurs when players use the representativeness

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heuristic, and incorrectly believe that the ball should be randomly distributed across the wheel in the short run. In fact, the ball is randomly distributed across the wheel in the long run, but not the short run.

However, the application of this finding to gaming behavior leaves a puzzle. That is, if a gambler experiences a near miss on a slot machine and believes that likelihood of a subsequent jackpot has just declined, then presumably the gambler would shorten not lengthen her time of play. An alternative explanation to reconcile the empirical finding of longer play is that the near miss has simultaneously increased the arousal of the gambler but decreased the gambler's belief in hitting a jackpot and the effect of the arousal is enough to keep her playing.

To begin to sort out this puzzle, the research presented here considers the effect of near-miss events on roulette play. We have a unique data set that allows us to specifically examine whether a player is more or less likely to bet on a number that was a near-miss to the winning number on the prior spin of the roulette wheel. These data offer a more direct assessment of player beliefs by directly observing player bets. In the next section we describe the game of rapid roulette and then present the results of our data analysis. We conclude with an explanation for our results and implications for future near-miss research.

Figure 1: American roulette wheel.

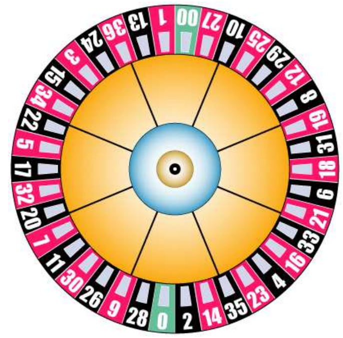
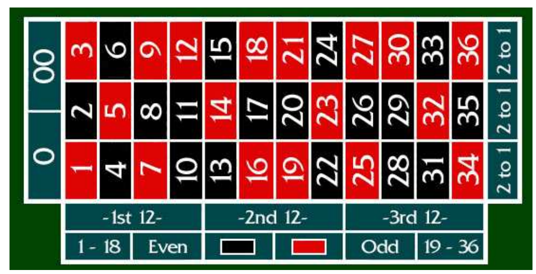


Figure 2: Roulette table.



1.2 Roulette

1.2.1 Description of the game

Rapid Roulette (RR) is similar to the classic table game of roulette with the addition of computer terminals for player betting. In the classic version of roulette (CR) a wheel is spun by a croupier and then a ball is released in the opposite direction of the spinning wheel. As the wheel slows the ball will land on one of thirty eight slots on the wheel; the slots are numbered from 0 to 36 and in the American version of the game a double zero (00) is added to the wheel.[1] Players bet on which number(s) the ball will land on within the spinning wheel. A typical wheel and betting table for American roulette are shown in Figures 1 and 2.

1.2.2 Types of bets in roulette

Depending on the bets allowed by the casino, there are approximately 158 unique bets that can be made on the single spin of the wheel. The simplest bet is a bet on a single number; this bet provides a payout of 35 to 1. Other examples of possible bets include a split (any two adjoining numbers; payout of 17 to 1), a street (any three horizontal numbers such as 1, 2, 3 or 31, 32, 33 etc.; payout of 11 to 1), six line (1 to 6 or 28 to 33 etc.; payout 5 to 1), column (1, 4, 7, 10, 13, 16, 19, 22, 25, 28, 31, 34; payout 2 to 1), any even/odd or red/black number (payout 1 to 1), and 1 to 18 (payout 1 to 1). When the ball lands within the wheel the croupier marks the spot on board with a token and then settles all bets. Players then place new bets and the wheel is spun again.

1.2.3 Description of rapid roulette

In Rapid Roulette each player occupies an individual touch-screen station. A touch-screen monitor displays a picture of the roulette table. A wager is placed via the touch-screen terminal. On each player's screen, the last 20 winning numbers are shown sequentially across the top. Players are given 30 seconds to place their bets in each round. With approximately 5 seconds of betting time remaining, a ball is put into play on an actual roulette wheel located in the middle of the terminals. The spin takes approximately 20–30 seconds, so each round is approximately 1 minute. Once the ball settles, the croupier enters the winning number into the computer system and all bets are settled electronically. An individual cash-in ticket machine handles the buy-in and pay-out of each player.

The RR stations are typically arranged in a circle or semicircle around the wheel and the croupier station. At the casino where this data was collected there were

[1] The French/European version of roulette has no double zero on the wheel. The elimination of the double zero gives only 37 possible outcomes and thus results in slightly better odds of winning (1/37 vs. 1/38) for the player.

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twelve rapid roulette terminals. In addition to the individual player terminal, there was a large overhead screen and two smaller screens. These "public" screens show several pieces of data including: a) the last 14 winning numbers, separated into red and black columns; b) two horizontal bar graphs on the bottom showing percentages for Red/Black/Green/Even/Odd/(0&00) in the last 50 spins; c) a graphic of a roulette wheel spinning (not actual wheel); d) a screen with the "Hot 4" and "Cool 4" numbers.[2] The seating configuration prevented players from seeing other players' screens. The players could easily see the ball being put into play and bouncing on the wheel but likely were challenged to see the ball settling into a specific number in the actual roulette wheel.

Several distinctions are noteworthy in comparing RR with CR. First, in RR the placing of wagers occurs largely anonymously. In CR all players place their bets on a public table and all can see where all bets are placed. In RR player bets are significantly more anonymous thus reducing the social atmosphere of the game. Second, the computerized settling of bets in RR will decrease the amount of time necessary to collect and pay off of bets thus increasing pace of play of the game. And third, the amount players bet, win, or lose is largely anonymous.

2 Field data

The data were collected from a large casino in Reno-Tahoe region of Northern Nevada. A computer printout was provided to the researchers documenting the play that took place on five RR stations. The time period of play was Saturday night, April 26, 2006 from approximately 9:00 pm. to 1:00 am.[3] During this time period 401 unique games or spins of the wheel were recorded and analyzed. From the data it was estimated that 36 unique players were observed.[4] The average (median) number of games played by a player was 28 (19) with one player wagering on 132 spins and another only wagering on one spin. The total number of unique bets in the data set is 6,390.

2.1 Roulette near-miss definition

We define a near-miss bet in roulette as a wager placed on a number that is "near" the winning number. In roulette, "nearness" to the winning number can be defined in one of two ways:

1. A near miss table bet. As described earlier, a typical roulette bet is achieved by a player placing a chip(s) on a number(s) on the roulette table. When the ball settles within the roulette wheel and the winning number is identified, the croupier then places a token on the winning number on the roulette table. A number that is adjacent to the winning number on the roulette table is considered to be a "near-miss bet". For example, assume the winning number for a particular spin is the number 13. On the roulette table the numbers adjacent to the number 13 include 10, 11, 14, 16, and 17. Thus a bet on 10, 11, 14, 16, or 17 would be considered a "near-miss bet" to the winning number 13. If Rachel placed a bet on number 11 and the croupier placed the token on the number 13, Rachel may experience the feeling that she "almost won".
2. A near miss wheel bet. A near miss bet can also be defined as a bet placed on a number near the winning number on the wheel. For example, the numbers in adjacent slots on either side of number 13 on the wheel include 36 and 1. A wager placed on the number 1 may be considered a near miss to the winning number of 13 based upon number 1 being next to number 13 on the roulette wheel. If Jim had placed a bet on number 1 and the ball landed on number 13 on the wheel, Jim may have experience the feeling that he "almost won".

Our approach to measuring a near miss in roulette defines a near miss in terms of the physical distance between one number and another either on the wheel or table. While we believe this to be a sensible and straightforward method of measuring near misses in roulette, we also recognize that a near miss is a psychological construct in the mind of the gambler. For example, if the ball landed in the wheel two (or three or four) slots from a winning number a player might perceive this outcome to be a near miss. An alternative approach to measuring a near miss would be to ask the subject the degree to

[2] The hot and cool number list shows the number of times that number has been a winning number but does not provide a time frame or number of spins reference. When queried, the croupier did not have additional information on how the hot and cool numbers were determined.

[3] The time period of the data collected from the five RR stations ranged from 3:26 p.m. to 4:42 a.m. All five stations reported data during the period from 9:00 p.m. to 1:00 a.m. which is typically a casino's highest volume time period.

[4] Since the data obtained recorded the play that took place on a RR station, a player sitting or leaving a RR station was not observed. To estimate when a player arrived or departed a RR station, the following rules were applied to the data: 1) If a player's cash balance goes to $0 and a new buy-in occurs within five minutes from the time of last play, it is assumed to be the same player and it is a re-buy; 2) If a player cashes out and a new buy-in occurs within five minutes of the last play, it is assumed to be a different player. Note that the data were also screened based on whether the gap-in-play was five spins of the wheel rather than five minutes and the coding of players was the same. Increasing the gap-in-play filter from five to ten minutes lowers the number of estimated players from 36 to 28. While the exact number of unique players from the RR station data cannot be known definitively, from observing a sample of actual rapid roulette players a gap in play of five minutes or five spins seems a reasonable assumption, and thus for the purpose of this analysis it is assumed that there are 36 unique players.

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which an outcome constitutes a near miss (as suggested by Dixon et al., 2009), but this approach is not possible in a natural casino environment. While recognizing these issues, we believe the most sensible and conservative definition of a near miss is a bet on a number that is immediately adjacent to the winning number on the wheel or table.

3 Results

3.1 Do near misses affect players' betting behavior?

The first question we address is what effect does a near miss have on a players' subsequent betting behavior? This analysis considers whether a player is more or less likely to bet on a number that was a near miss on the prior spin of the wheel. To answer this question, we proceeded in the following manner.

First, all the possible near miss numbers to a winning number are specified. These numbers include those numbers on either side of the winning number on the wheel (e.g., 1 and 36 are on either side of 13 on the wheel) and all adjacent table numbers to the winning number (e.g., the numbers adjacent to the number 13 on the table include 10, 11, 14, 16, and 17).

Second, all of the possible bets that included one of these near miss numbers were identified. There are 158 possible bets in roulette. This set includes possible bets on a single number (S1; 1 only), two numbers (D1; 1 and 2), three numbers (T13; 1, 2 and 3), etc. For the purposes of this analysis we exclude all bets that include more than six numbers in the bet such as bets on Odd/Even or Red/Black which reduces the set of possible bets to 148.[5] For each possible bet we determined whether one of the numbers included in that bet was a near miss to the winning number. For example, Table 1 shows the 148 possible bets and whether each bet included a number that was a near miss to the number 13.

Table 1 identifies the near miss bets to a winning number 13. For example, the bet D1415 is a split bet on the numbers 14 and 15. Since the number 14 is adjacent to the number 13 on the roulette table, the bet D1415 is coded as a near miss bet to the winning number 13 in the expansive set. The bet SX2833 is a six number bet on the numbers 28, 29, 30, 31, 32 and 33. Since none of the numbers from 28 to 33 are adjacent to the number 13 on the table or wheel, the SX2833 is not coded as a near miss bet to the winning number 13. Based on this coding, there are 40 possible bets out of 148 total possible bets that could be considered near miss bets to the number 13.

We use a logistic regression model to analyze the probability of a bet being placed on one of the 148 possible bets. Our dependent variable, BPB_{it} is binary; if a bet was placed on possible bet i on spin t, we record a success (1). If no bet was so placed, we record a failure (0). Independent variables include an intercept, a binary measure of whether the possible bet included a number that was a near miss to the winning number on trial t-1 (NM_{it}), and two control variables. The first control variable is a binary control measure for the whether a player placed a bet on a specific number on the previous trial (FAV_{it}). This control measure accounts for the tendency of players to bet on the same numbers from trial to trial, which we term a favorite number bias. For example, if a player bet on black 13 on the prior trial then $FAV_{13,t\text{-}1} = 1$ otherwise it equals 0. This dummy variable will thus pick up on a tendency of a player to consistently bet on black 13 and should allow us to separate out whether a player bet on black 13 because it was a favorite number or because it was a near miss to the winning number on the prior trial. The second control variable is a count of the total possible near miss numbers for a possible bet ($TNMPB_i$). Because possible bets differ in the quantity of numbers included in the bet and the spacing of numbers on the table and wheel, some possible bets have significantly more near miss numbers than other possible bets. For example, for a bet on the single number 0, there are four numbers (00, 1, 2, 28) that would be coded as near misses to a bet on 0. In contrast, for a six-way bet on the numbers from 19-24 there are 18 numbers that would be coded as near miss numbers to this bet. This control variable thus accounts for the differential likelihood of a possible bet having near misses. This control variable thus accounts for the differential likelihood of a possible bet having near misses. Thus we will try to predict whether a player placed a bet on a possible bet conditional on whether the possible bet included a number that was a near miss to the winning number on the prior trial while controlling for the favorite number bias and controlling for the total number of near miss numbers associated with the possible bet. Our final model is:

$$BPB_{it} = \alpha_0 + \alpha_1 \, FAV_{it} + \alpha_2 NM_{it} + \alpha_3 TNMPB_i + \varepsilon$$

A logistic regression equation was then estimated for each player. Table 2 provides a breakdown of the data and the 36 gamblers in the data set. The breakdown of the number of "near miss" bets and numbers of spins of the wheel each gambler experienced is shown. Four gamblers placed bets only on the Red/Black, Even/Odd etc. type and thus had no "near miss" bets.

[5] The exclusion of bets with more six numbers such as red/black, even/odd, etc. was done for two reasons. First, it seems psychologically implausible that a player who bet on red could believe that a winning number such as black 13 was a near miss to red. Second, the inclusion of bets with more than six numbers would result in almost every number on the table qualifying as a near-miss bet.

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Table 1: Is possible bet a near miss bet to 13?

S37	No	S29	No	D1112	Yes	D2930	No	Q812	Yes
S0	No	S30	No	D1114	Yes	D2932	No	Q1014	No
S1	Yes	S31	No	D1215	No	D3033	No	Q1115	Yes
S2	No	S32	No	D1314	No	D3132	No	Q1317	No
S3	No	S33	No	D1316	No	D3134	No	Q1418	Yes
S4	No	S34	No	D1415	Yes	D3233	No	Q1620	Yes
S5	No	S35	No	D1417	Yes	D3235	No	Q1721	Yes
S6	No	S36	Yes	D1518	No	D3336	Yes	Q1923	No
S7	No	D037	No	D1617	Yes	D3435	No	Q2024	No
S8	No	D01	Yes	D1619	Yes	D3536	Yes	Q2226	No
S9	No	D02	No	D1718	Yes	T012	Yes	Q2327	No
S10	Yes	D372	No	D1720	Yes	T0372	No	Q2529	No
S11	Yes	D373	No	D1821	No	T3723	No	Q2630	No
S12	No	D12	Yes	D1920	No	T13	Yes	Q2832	No
S13	No	D14	Yes	D1922	No	T46	No	Q2933	No
S14	Yes	D23	No	D2021	No	T79	No	Q3135	No
S15	No	D25	No	D2023	No	T1012	Yes	Q3236	Yes
S16	Yes	D36	No	D2124	No	T1315	No	SX16	Yes
S17	Yes	D45	No	D2223	No	T1618	Yes	SX49	No
S18	No	D47	No	D2225	No	T1921	No	SX712	Yes
S19	No	D56	No	D2324	No	T2224	No	SX1015	No
S20	No	D58	No	D2326	No	T2527	No	SX1318	No
S21	No	D69	No	D2427	No	T2830	No	SX1621	Yes
S22	No	D78	No	D2526	No	T3133	No	SX1924	No
S23	No	D710	Yes	D2528	No	T3436	Yes	SX2227	No
S24	No	D89	No	D2627	No	Q15	Yes	SX2530	No
S25	No	D811	Yes	D2629	No	Q26	No	SX2833	No
S26	No	D912	No	D2730	No	Q48	No	SX3136	Yes
S27	No	D1011	Yes	D2829	No	Q59	No		
S28	No	D1013	No	D2831	No	Q711	Yes		

We first summarize the results of the logistic regressions run by subject. Table 3 shows the individual parameter estimates for each player where a model could be fit. As expected, the control variables for the favorite number bias (FAVit) and for the total possible near miss numbers for a possible bet (TNMPBi) were statistically significant in the vast majority of models. As for the quantitative effect of the control variables, the median odds ratio on FAVit was 18.7, suggesting that the median gambler was 18.7 times more likely to bet on a number he had previously bet on, and the median odds ratio on TNMPBi was 0.92 suggesting the median subject was slightly less likely to bet on numbers that had a high number of near miss numbers.

The parameter estimates for the near miss (NMit) variable are shown in the far right column in Table 3. The median odds ratio estimate on the NMit variable was 0.937 suggesting that there was about a 94% probability of the median player betting on a number that had been near miss number on the prior trial. However, there was considerable diversity in the sign and quantitative magnitude of the NMit variable across subjects. The sign on the parameter estimate indicates whether the player was more likely (+) or less likely (−) to wager on a possible bet that was a near miss on the prior trial. A count of the signs on the NMit variable shows that is was negative for twenty gamblers and positive for ten gamblers. The parameter estimates were statistically significant ($p < 0.05$, two-tailed) in 30% (9/30) of the models, with four positive parameter estimates significant and five negative parameter estimates significant. The total number of significant results exceeds the expectation of 5% ($p < .001$,

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Table 2:
A. Breakdown of data set used in logistic regression.

Player number	Number of "near miss" Bets	Number of wheel spins	Player number	Number of "near miss" bets	Number of wheel spins
1	479	54	19	902	41
2	206	27	20	298	31
3	99	15	21	538	56
4	1	1	22	38	5
5	127	23	23	0	0
6	131	23	24	353	45
7	47	8	25	232	20
8	82	15	26	0	0
9	863	52	27	250	50
10	141	22	28	33	8
11	81	11	29	0	0
12	43	9	30	0	0
13	5	5	31	127	8
14	251	20	32	14	6
15	7	3	33	45	8
16	68	13	34	97	19
17	5	1	35	753	96
18	55	8	36	20	5

Total number of player wheel spins included in data set	708
Total number of bets possible per wheel spin	148
Total number of possible near miss bets (708·148)	104,784
Total number of bets dropped due to regression lag structure ((1st spin of each player) 32 players·148)	4,736
Total number of bets included in most expansive regression data set	100,048

B. Summary of bets.

Type of bet	Number of bets on table	% of possible bets	% of possible bets · 100,048	Cumulative
Single	38	25.7%	25,688	25,688
Double	62	41.9%	41,912	67,600
Triple	15	10.1%	10,140	77,740
Quad	22	14.9%	14,872	92,612
Six	11	7.4%	7,436	100,048

binomial test), and the total of 5 negatives and 4 positives were also significant ($p < .01$, assuming an expectation of .025).

The individual regression results show heterogeneity across subjects. As might be expected, some subjects are less likely to bet on near miss numbers and other subjects are more likely to bet on near miss numbers. These subjects are split about 67%/33% between less and more likely to bet on a near miss number. To provide an estimate the overall effect size of the near miss variable, we ran a logistic regression again this time collapsing the data across subjects. By collapsing the data across sub-

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Table 3: Individual parameter estimates from logistic regressions.

Player number	a_0 intercept estimate	$a_1 FAV_{it}$ estimate	$a_2 TNMPB_i$ estimate	$a_3 NM_{it}$ estimate
1	−5.96**	12.15**	−0.07	−1.43
2	−1.52**	2.105**	−0.17**	−0.08
3	−3.73**	20.89	−0.02**	−0.02*
5	−3.27**	2.89**	−0.02	−0.37
6	−0.99**	2.52**	−0.29**	0.58**
7	−0.89	1.69**	−0.25**	−0.43
8	−0.69	2.96**	−0.35**	0.57
9	−2.24**	2.98**	−0.05**	−0.15
10	−2.87**	19.02**	−0.09**	−0.18**
11	−3.46**	17.36**	−0.03**	0.15**
12	−4.37**	30.56	−0.01**	−0.05**
13	−3.77	−10.66	−0.25	2.42*
14	−1.93**	1.76**	−0.07**	−0.13
15	−2.69	2.77*	−0.26	1.41
16	−2.31**	1.59**	−0.11*	−0.25
18	−1.20*	1.97**	−0.21**	0.009
19	−2.38**	1.49**	0.04**	−0.33**
20	−2.39**	3.59**	−0.12**	−0.02
21	−0.36	2.65**	−0.31**	−0.12
22	−6.17**	5.81**	0.14	−0.28
24	−3.89**	19.25**	−0.001**	0.002
25	−4.25**	6.01**	−0.04	0.44
27	−8.73**	4.44**	0.37**	−0.23
28	−7.45**	2.270*	0.32**	−0.59
31	−1.55**	3.33**	−0.13**	0.07
32	−11.22	29.50	−1.10	−2.49
33	−3.43**	15.66**	−0.03**	−0.05**
34	−4.59**	1.05**	0.11**	−0.14
35	−2.21**	2.82**	−0.11**	−0.003
36	−2.38*	0.98	−0.18	1.15*

* p<0.05, ** p<0.01.

jects we are able to interpret aggregate results.

The result for the collapsed logistic regression is shown in Table 4a. The two control variables (FAVit and TNMPBi) are statistically significant (p<0.01) as is the near miss variable (NMit) (p<0.05). The odds ratio estimate on NMit is 0.912 again suggesting that the group of gamblers is less likely to bet on near miss numbers.

Table 4b shows the frequency of a bet being placed contingent on whether the bet had a near miss number on the prior trial. The ratio of a bet being placed, to not being placed, (BPBit (Yes) / BPBit (No)) given that the bet did not include a number that was a near miss to the winning number on the prior spin (NMit-1 (No)) is 0.068 (4,601/67,728). The ratio of a bet being placed to not being placed (BPBit (Yes) / BPBit (No)) given that the bet did include a number that was a near miss to the winning number on the prior spin (NMit-1 (Yes)) was 0.059 (1,552/26,167). Thus the odds are 0.87 ($0.0679 \cdot 0.8731 = 0.0593$) less of possible bet being placed if the possible bet included a number that was a near miss to the winning number on the prior spin.

4 Do near misses affect length of play?

Since prior research has shown that near misses affect length of play, we next considered if such an effect was present in rapid roulette. Several OLS regression models were used to analyze whether the percentage of near misses a player experiences affects the number of games played. For the first model the dependent variable is the total number of games played (NGP). Since each game is approximately one minute, the number of games played can be used as a measure of length of play. Independent variables included an intercept and the total percentage of near misses (TPNM) the player experienced during their play time, using the most expansive definition of a near miss. The model is:

$NGP = \beta_0 + \beta_1 \text{ TPNM} + \varepsilon$

This analysis was performed with data from each of the four near miss conditions and included all possible bets.

Next, the data set was restricted to single bets only. Due to the rapid pace of the game and the complexity of multiple number bets, players may be more impacted by near misses on single number bets. Our independent variable in this model is the percentage of near misses for all single bets (SPNM) by player. For these regressions, our model is:

$NGP = \beta_0 + \beta_1 \text{ SPNM} + \varepsilon$

For both of these models we ran a second set of regressions that excluded all players that played 5 games or fewer. This was aimed to reduce the influence of short-term players who are unlikely to display near miss effects. This resulted in four fewer players in the sample.

Across both models there was no evidence that near misses affected the number of games played. None of the coefficients of the TPNM or SPNM variables were statistically significant and the quantitative magnitude of the coefficients was very inconsistent. In addition, the models all had very low explanatory power (R^2 values less than 0.05) across all models and all near miss definitions.

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Table 4:

A. Logistic regression results across subjects.

	Parameter estimate	Odds ratio estimate
Intercept	−2.9**	
FAV_{it}	3.6**	38.1
$TNMPB_i$	0.05*	0.95
NM_{it}	−0.09*	0.912
N	100,048	

B. Bet possible bet (BPB_{it}) by near miss prior trial (NM_{it-1}).

		Was possible bet a near miss to a winning number on previous trial (NM_{it-1}):		
		No	Yes	Total
Did player bet possible bet (BPB_{it}):	No	67,728	26,167	93,895
	Yes	4,601	1,552	6,153
Total		72,329	27,719	100,048
Odds of betting possible bet given:		4,601 / 67,728 = 0.068	1,552 / 26,167 = 0.059	

4.1 Do near misses affect the number of bets placed?

An OLS regression model was used to examine how the percentage of single near misses a player experiences will affect the total number of bets placed. In order to reduce the likelihood of an issue with division bias, we limit this analysis to the percentage of single near misses versus the total number of bets placed. Using a similar method to the previous model, we ran a second set of regressions that excluded all players that placed 20 bets or fewer. This resulted in five fewer players in the sample.

In this model our dependent variable is the number of bets placed (NBP) and our independent variables include an intercept and the percentage of single near misses the player experienced during their play time (SPNM). The model is:

$$NBP = \beta_0 + \beta_1 SPNM + \varepsilon$$

There was no statistically significant evidence that near misses impacted the number of bets placed. Coefficients of the SPNM variable were statistically insignificant and quantitatively inconsistent. In addition, across all models and all near miss definitions R2 values were less than 0.05. Overall, the results do not support the hypothesis that near miss events increase either the length of time that a player will play or the number of bets that a player will place.

4.2 Do near misses affect the amount wagered?

Our final analysis examined whether near misses affected the amount players wagered. As shown in Table 5, the average amount wagered on a bet was $1.57.

The average wager on a possible bet contingent on whether the possible bet was a near miss or not on the last trial was $1.43 vs. $1.70 and the difference was statistically significant ($t = -2.82$, $p<0.01$). Roulette players wagered less on a BPB_{it} if the BPB_{it} had been a near miss on the last trial. Thus, roulette players were less likely to bet on a BPB_{it} that had been a near miss on the prior trial and when they did bet on such a BPB_{it} they wagered less.

5 Discussion

In our sample of rapid roulette players, we find heterogeneity in gambler behavior with some gamblers less likely to bet on near miss numbers and other gamblers more likely to bet on near miss numbers. These findings suggest the effect of near misses events on subsequent decisions may not be consistent across decision makers and research results should be interpreted carefully.

Our finding that the sign on the near miss parameter estimate was negative for twenty out of thirty gamblers (but statistically significant for only five gamblers) is more consistent with the data regarding near misses and natural disasters (Dillon & Tinsley, 2008, 2011). Recall that sub-

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Table 5: Amount wagered.

	N	Mean	STD
All Bets	6388	1.57	3.6
Possible bet was *not* a near miss to winning number last trial	3572	1.70	2.9
Possible bet *was* a near miss to winning number last trial	2579	1.43	2.9

jects that had almost been hit by a flood were less likely to buy flood insurance presumably because in some manner their belief about the risk of a flood had changed. Our data suggest that some gamblers are behaving as if they believe that the likelihood of the roulette ball landing on a number that was a near miss to the winning number on the last spin has declined. Thus while the objective odds of the ball landing on any number in roulette is fixed at 1 out of 38, the subjective beliefs of gamblers appear to be affected by where the ball landed on the past trial. And specifically, rapid roulette players' betting behavior is consistent with a belief that the roulette ball is not likely to land near the same spot twice, suggesting a gambler's fallacy type bias (e.g., if the ball just landed on this spot on the wheel it is due to land somewhere else). This interpretation does not provide an explanation for the ten gamblers with positive near miss parameter estimates (four statistically significant). Gamblers that bet on prior near miss numbers are behaving as if they believe the likelihood of the ball landing on that number has somehow increased suggesting some kind of hot hand beliefs.

While a near miss affects the numbers players choose to bet on and the amount bet, there is no evidence to support that near misses lead players to gamble longer. Our evidence thus does not support prior findings that near misses lead to arousal/frustration or reinforcement which has been shown to lead to longer play. Since our field data lacks the experimental controls to appropriately measure and manipulate the length of play, we interpret this result cautiously. That said, an interesting aspect of roulette is that all bets on the roulette table have the same negative expectation of winning (-5.26%). Given this, there is no negative performance impact on a player who changes her betting pattern in response to a near miss. But given that every bet has a negative expectation of winning, the longer a gambler plays the more she is likely to lose. So if near misses change the bets that players choose but do not increase the total time gambling, the number of bets placed, or the amount bet, then the player is no worse off.

We conclude with suggestions for future research. While prior research suggests that near-miss events cause arousal and can serve as physiological and psychological/psychosocial reinforcements, our results suggest future research should also focus on how near misses change beliefs and expectancies. While a behaviorist explanation could be made to explain why rapid roulette players are less or more likely to bet on numbers that were near misses, a simple cognitive explanation in a gambling context is that gamblers believe those numbers to be cold/hot and less/more likely to win. To sort this out we suggest future research is necessary that can simultaneously control and measure both cognitive beliefs and physiological responses following near-miss events. Finally, since our results show significant heterogeneity across subjects future research should attempt to account for these individual differences.

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