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FEAR AND LOATHING IN LAS VEGAS: EVIDENCE FROM BLACKJACK TABLES

Bruce Ian Carlin
David T. Robinson

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Bruce Ian Carlin
Anderson Graduate School of Management
UCLA
110 Westwood Plaza, Suite C519
Los Angeles, CA 90095-1481
and NBER
bruce.carlin@anderson.ucla.edu

David T. Robinson
Fuqua School of Business
Duke University
One Towerview Dr.
Durham, NC 27708
davidr@duke.edu

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Bruce Carlin
UCLA

David T. Robinson
Duke University

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Abstract

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1 Introduction

Much of modern economics is built on the premise that people maximize their expected utility for wealth when making decisions under uncertainty. In contrast, psychologists argue that people often act not so much to maximize their expected utility, but instead to minimize their expected regret—that is, people make choices to minimize their expected feeling of remorse when an action

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turns out badly compared to other alternatives (Loomes and Sugden, 1982, 1983; Bell, 1982; Larrick and Boles, 1995). In some decision environments, this can lead people to favor inaction over action, inducing what is known as the omission/commission bias (Gilovich and Medvec, 2001; Kahneman and Tversky, 1982).

Psychologists primarily study regret by performing laboratory experiments testing hypotheses about attitudes and mechanisms underlying the emotion of regret. But they do not measure how regret alters actions in market settings.[1] This limits our ability to draw economic inferences from these findings: starting with LaPiere's (1934) classic work over seventy years ago, and continuing in more recent work (Eagly and Chaiken, 1993), psychologists have repeatedly demonstrated a range of important gaps between attitudes and behaviors.[2] The disconnect between attitude and action raises a fundamental question: how does expected regret affect real economic choices made in the field?

In this paper, we use a large dataset describing actual play at a Las Vegas Blackjack table to answer this question. This allows us to provide some of the first field evidence that expected regret affects decision-making under uncertainty. Moreover, ours is some of the first evidence—field evidence or otherwise—that measures the omission/commission bias from an anticipated regret perspective. We not only measure the economic impact of expected regret on peoples' actions when their own money is at stake, but also show how the fear of regret evolves through dynamic play.

The major challenge to measuring expected regret in market settings is the fact that evaluating most choices made under uncertainty requires parameterizing a complex set of beliefs, measuring risk aversion, controlling for other behavioral biases, *and* measuring omission/commission bias. This is usually an insurmountable task.

[1]While a number of papers that focus on the role of feedback on regret, such as Larrick and Boles (1995) or Zeelenberg and Pieters (2004), draw on real life scenarios, they do not directly measure regret in market settings. There is no work that studies the omission/commission bias from an expected regret standpoint. We review this literature in Section 2.

[2]An early survey of the attitude-behavior inconsistency is found in Wicher (1969). Lowenstein (1996), Lowenstein, O'Donahue and Rabin (2003) and Van Boven and Lowenstein (2003) describe a related empathy gap. Similarly, Gilbert and Ebert (2002) demonstrates the gap between the perceived intensity of expected regret and the actual intensity of experienced regret, further calling into question the validity of using attitudes as a proxy for actions.

The game of Blackjack has two important features that make it ideal for this purpose. First, setting aside the issue of card counting, it is easy to categorize optimal play in every conceivable situation and document departures from optimal play in an unambiguous way. This is because there is a well-publicized solution to the game, known as the Basic Strategy, that has been widely accessible to card players since the 1950s. Indeed, many card playing guides offer steps for learning the basic strategy. Second, and more importantly, blackjack players place bets in the game before they make strategic decisions. Therefore, in all but a few situations, the bet is essentially a sunk cost once play begins, and the optimal strategy is independent of a player's level of risk aversion.[3] This fact allows us to identify the role of regret avoidance independent of other behavioral biases, such as risk aversion, status quo bias, or other common explanations for the behavior we document.

Our data consist of over 4,300 hands played in over 1,300 rounds of actual play in a Las Vegas casino. The data for our study were obtained from a pilot study of the Bally MP-21 Card and Chip Recognition System, originally designed by Mindplay Intelligent Games. The MP-21 system is optically-based and tracks all bets and choices during play, capturing data in a covert and non-intrusive way. This allows us to record essential features of the game in a manner that leaves the natural play of the game is unaltered.

Using this novel data source, we find strong evidence that the classic omission bias is present in the ex ante choices that card players make, not just in their ex post attitudes about the course of play at the table. When players make mistakes, they are much more likely to do so by making an error in which they fail to act, as compared to making an error in which they take an unnecessary and suboptimal action. Indeed, passive mistakes are four times more likely than aggressive mistakes. If there were no omission bias, we would expect passive and active mistakes to be about equally likely, since the distribution of cards places players at decision points requiring aggressive action and passive action about equally often.[4] This omission bias is robust to the size of the player's bet, as well as features of play such as the number

[3]This is true for the majority of decisions in the game, but as we discuss in detail below, it is not true when a player doubles down or splits a hand. In that case, the bet size is increased so we cannot disentangle risk aversion from other biases. We make this distinction in our empirical analysis.

[4]In unreported simulations, we determined that basic strategy prescribes passive action 46% of the time. This implies that passive mistakes should occur 53% of the time if passive and active mistakes were equally likely.

of other players at the table and the running count of the deck (a tally of high cards versus low card remaining in the deck).

The economic magnitude of these mistakes is large. In aggregate, players in single-hand deals who followed the basic strategy won 48.1% of the time, very close to the theoretical win rate reported in Blackjack guides. Deviators won only 36.6% of the time, which is statistically significantly lower. A total of about $123,000 changed hands during the pilot study. Players that followed the basic strategy won a total of over $60,000, while they lost only about $56,000 following the basic strategy. In contrast, only $3,000 was won, and over $6,000 lost in hands that deviated from the basic strategy. Of these, passive mistakes lost over $2 for every dollar won, while aggressive mistakes lost only about $1.50 for every dollar won. Therefore, passive mistakes are not only more common, they are more costly.

The data not only allow us to document the magnitude of the average omission bias, but also to study how it evolves in repeated play. We find evidence of a *rebound effect*. That is, if aggressive play occurred in the prior round, it is less likely to occur in the current round. To be precise, conditional on an error occurring, sins of omission are roughly ten percent more likely following aggressive play than on average. This feedback between past and current play comports with models of learning through reinforcement and repetition, where subjects learn to be more cautious (March, 1996, Camerer and Ho, 1999, Roth and Erev, 1995, Erev and Roth, 1999).

We are careful to consider alternative explanations (other than omission bias) for the choices that we observe in our data. The first explanation is that card counters are responsible for the deviations from basic strategy. On its face this is an unlikely explanation, since the win rates among basic strategy deviators are so low, and the economic losses are so high. But to explore this explanation further, we systematically examine deviations from basic strategy, and find no evidence that the deviations vary with the count in a manner prescribed by card counting strategies.[5]

The second is that limited cognitive ability is driving our results. Indeed, it may be that some players find it difficult to remember the optimal choice in all situations. To control for this, we account for the strategic difficulty of certain situations (e.g. playing hands with soft versus hard totals, opportunities to split hands, doubling their position). The idea here is that if cognitive limitations make omission bias more prevalent, then it should be more pro-

[5]For brevity, this analysis is omitted from the paper but is available from the authors.

nounced among more difficult hands. We find, though, that the omission bias is not more pronounced among hands in which higher order thinking is required.[6]

The third possible explanation is that players derive utility from continued play, and are thus reluctant to take an additional card if doing so might exclude them from the thrill of participating in the rest of the round. To control for this possibility we account for the position of the player at the table and the number of players seated at the table. While we do find that passive mistakes are more common at larger tables, there is no evidence that passive mistakes cluster disproportionately more among those who are high in the seat order of the table. Moreover, the large table effect is small relative to the rebound effect.[7]

The fear and loathing that we document in this paper builds on previous work in psychology and economics, which we describe in Section 2. In Section 3, we review the rules of blackjack, discuss the Basic Strategy, and describe the data that was collected and used in the analysis. In Section 4, we provide the baseline findings. Section 5 provides a variety of robustness checks to support the idea that the omission bias reflects regret and not some other behavioral tendency. Section 6 studies how regret evolves through repeated play. Section 7 concludes.

2 Related Literature

Psychologists and economists broadly define regret to be the negative emotion associated with comparing an actual, realized outcome to a counterfactual one that could have been realized if a different choice had been made. For example, consider two risk-neutral people who are offered a lottery in which a fair coin is flipped. The coin pays $1 million dollars if it shows heads, and nothing otherwise. In one case, the person is simply offered the chance to play the lottery—they can accept the lottery or refuse to play. In

[6] As we note, passive mistakes are more costly than active mistakes. If limited cognition were indeed at the heart of our findings, we would expect people to spend more of their cognitive resources avoiding the more expensive mistakes. This is clearly not what we find in the data.

[7] It is also noteworthy that this alternative explanation is another form of expected regret. Specifically, people not only consider the expected remorse from potential monetary losses, but also take into account the expected remorse from losing the thrill of entertainment.

another case, the person is offered a choice between the lottery and a sure payment of $100,000.

Suppose both subjects choose the lottery, and in both cases the coin turns up tails, so that neither person wins any money. In the first case, the person is certainly disappointed, but does not experience regret, since there was no other choice that could have offered a better outcome. The second case, however, lends itself to the possible comparison of the failed lottery to the certain $100,000 payment. This feeling—that a different course of action *could* have yielded a better outcome—is regret.

Two fundamental assumptions about human nature lie at the core of regret theory (Larrick and Boles, 1995). The first is that people compare an experienced outcome to a psychologically available outcome and experience negative emotions when the counterfactual outcome is favored to the actual outcome. The second is that people anticipate this emotional state and take actions ex ante to avoid it, tilting their decision-making toward actions that minimize the scope for experiencing regret.

There is overwhelming evidence in psychology that individuals experience this emotional state after an action, and that the intensity of this emotional state is more severe when the action is attributable to one's own choice. For example, Kahneman and Tversky (1982) famously propose a vignette in which two investors, Paul and George, experience losses to their stock portfolios. Paul loses money because he did not sell his shares, while George loses money because he did sell his shares. Respondents overwhelmingly feel that George, who has experienced a loss attributable to his own action, experiences greater regret than does Paul, whose losses stem from an action he did not take. Many other such vignettes characterize how people feel in other "close call" situations, including people who choose a class in college (Landman 1987), change airplane schedules but miss their flight, or make purchases when discounts are offered randomly (Simonson 1992).

This literature relies on retrospective evaluations of imagined scenarios to establish the omission/commission bias. Kahneman and Miller (1986) argue that the underlying psychological mechanism is availability: after taking an action it is easier to imagine the outcome of *not* having taken that action than vice versa. This relative ease in producing counterfactual imagined outcomes makes errors of commission more painful than errors of omission.

Related to this, another strand of the literature focuses on the availability of feedback about unchosen alternatives and regret, and does so using real, as opposed to imaginary, scenarios. Zeelenberg and Pieters (2004) use the fact that the Dutch lottery contains two lottery systems—one that provides feedback about counterfactual outcomes regardless of whether one plays the lottery, and one that does not—to show that anticipated knowledge about counterfactual outcomes alters a subject's beliefs and attitudes ex ante choices. In the postcode lottery, anyone with a chosen postal number (like a zip code) who has purchased a lottery ticket wins the lottery, whereas the national lottery provides no feedback about what would have happened. They show that regret is intensified by the feedback that others in the same postcode won the lottery. Similarly, Larrick and Boles (1995) show in the context of a negotiation game that negotiators who know they will receive feedback about the path not taken in negotiation will negotiate more aggressively and reach impasses less often. Both these papers analyze regret from a risky choice paradigm, since in both cases a subjects' risk aversion directly links one's actions to the salience and availability of the counterfactual.

While these studies powerfully illustrate the psychological mechanisms that underlie regret theory, they do not provide evidence that the omission/commission bias is present in the ex ante choices that individuals make in market settings. First, the evidence on omission/commission is based primarily on experienced regret in imagined situations, rather than anticipated regret in real situations. Gilbert and Ebert (2002) show that there is a gap between the perceived intensity of expected regret and the actual intensity of experienced regret. This calls into question the validity of using ex post attitudes as a proxy for ex ante actions and choices. Moreover, there is a disconnect between attitude and action, even when measured contemporaneous with the choice being made: LaPiere's (1934) classic study of motel owners in California in the 1930s showed that they believed they would not accept Chinese guests; yet when they were approached by real Chinese guests who asked to stay in their hotel, their actions deviated from their attitudes.[8]

Therefore, the link between omission/commission bias and economic choices made in anticipation of experiencing regret is an open question, but one that is critical for gauging the economic importance of the omission/commission bias. The medical decision-making literature (e.g., Ritov and Baron, 1990; Asch, Baron, Hershey, Kunreuther, Meszaros, Ritov and Spranca, 1994) perhaps comes closest by establishing a link between ex ante beliefs about vaccination safety and ex ante statements of belief about the intention to vaccinate, but this literature does not allow us to observe the actions that people

[8]See Dockery and Bedeian (1989) for an interesting discussion.

take.

The Blackjack table provides an ideal laboratory for accomplishing this. As we discuss in the next section, the game provides a unique setting in which to study how regret affects economic outcomes, free from many other psychological biases and cognitive limitations that might otherwise generate similar predictions.

A few previous studies have used public entertainment to study human behavior and decision-making. In many of these venues, however, it is difficult to disentangle regret avoidance from other behavioral biases or cognitive limitations. For example, Tenorio and Cason (2002) derive the subgame perfect Nash equilibrium for a game segment on the television show "The Price is Right" and document systematic deviations from the optimal strategy. The deviations are indeed consistent with both an omission bias and cognitive limitations, but determining which one is responsible for the observed behavior is generally difficult.[9]

Keren and Wagenaar (1985) use the game of Blackjack as a laboratory for understanding player's attitudes about the game. They observe play in an Amsterdam casino and conduct personal interviews of Blackjack players to learn their self-perceptions of how they make decisions. Our analysis is distinct from theirs in a number of ways. We measure the economic magnitude of omission/commission bias, while they survey gamblers' attitudes and feelings about their own behavior. In that sense, their work corresponds to ex post analysis of real outcomes, with a focus on attitudes, rather than actions, while ours is an ex ante analysis. We examine how expected regret evolves through dynamic play, while they do not. Finally, they conclude that Blackjack players exhibit Simon's (1957) bounded rationality, while we link passive mistakes to the omission/commission bias.

3 The Game of Black Jack

In this section, we review the rules of Black Jack that were used in the particular casino in which the data were gathered. Then, given these specific rules we outline the optimal strategy of play (a.k.a. basic strategy) and discuss how this gives rise to a number of variables that we use in our analysis.

[9]See also analysis of "Card Sharks" by Gertner (1993), "Jeopardy!" by Metrick (1995), "The Price is Right" by Berk, Hughson, and Vandezande (1996), and "Deal or No Deal" by Post, Van Den Assem, Baltrussen, and Thaler (2008).

3.1 Rules of Play

3.1.1 Basic Setup

A Blackjack table consists of one dealer and from one to six players. In our data, there are 111 rounds involving only a single player, and 57 hands involving exactly six players. Two-, three-, and four-player rounds each occur a little more than 300 times in our data, and there are 223 five-player rounds. In total, we have 4,394 hands played in 1,393 rounds.

During each round, the dealer deals from a pack consisting of six standard 52-card decks. As such, there are 24 aces, 72 face cards, and 24 of each of the numbered cards (2 through 10) in play. The numbered cards are worth their face value, the face cards are worth 10 each, and each ace is worth 1 or 11 at the discretion of the player. The entire pack is shuffled and a player is randomly chosen to insert a red plastic card within the deck, cutting the deck. The dealer then places the red card toward the bottom of the deck and play begins. During subsequent play, cards are dealt from the top until the red card is shown. When the red card is reached during a round, then that round of play completes without interruption, the deck is reshuffled and the cycle begins again.

Before any cards are dealt, each player places an initial bet. In our data, bet sizes range from $5 (occurring 381 times) to $1100 (occurring 10 times). The most common bet in our data is a $10 bet, which occurs 1,974 times.

After the initial bets have been placed, the dealer begins by dealing each player at the table (including himself) one card face up, each in turn. This is followed by a second card face up for each of the players in turn, but the dealer's second card is dealt face down. The dealer's face-down card is referred to as the hole card. At this point, each player may choose between a variety of choices, as described below.

3.1.2 Players' Behavior

The object of the game for each player is to obtain a total greater than the total of the dealer's cards in the game, but less than or equal to 21. If a player wishes to add cards, they may successively request an additional card from the dealer, which they receive face-up, for the other players to see. Each player may continue to take a hit as long as the player's total does not exceed 21, at which point they "bust" and automatically lose their bet (even if the dealer eventually busts as well). Of course, players (excluding the dealer) are not required to increase the number of cards in their hand (i.e. take a hit) and may opt to "stand" with any total less than or equal to 21.

Each player's turn is exhausted before the next player has an opportunity to take a card, and the play moves around the table until all players have had the opportunity to stand or take a hit.

This sequence of action—bets placed first, followed by cards dealt—is one of the key features that make the game of Blackjack such an attractive setting for exploring regret. In the course of play described above, there is no scope for risk aversion to factor into a player's strategy, since at the time the player chooses a course of action, the bet is fixed. Thus, the best that the player can do is to maximize the odds that he or she receives a payout conditional on the fixed bet.

There are, however, some instances in which a player can alter his or her initial bet after the cards have been dealt. After the player is dealt two cards, they may opt to "double down" and receive one more card. If they choose to exercise this option, they double their bet and must stand once they receive the extra card. Dealer play and settlement is unchanged.

The second instance occurs when a player is dealt two cards of the same value (for example, two eights). Then the player has the option to split the pair, receive another card for each, and form two separate hands. Their initial bet goes with one set, and a second bet of equal size is added to the other. The player plays each hand according to the rules already mentioned. Settlement and dealer play is unchanged, except that all naturals (see below) are treated as a normal 21 and do not payoff at 1.5 times the bet. A player splitting any pair except aces may opt to double down on either or both of their split hands.

Two other options that may exist in many casinos are the option to buy insurance and the option to surrender the hand. In the game that was played at the table at which the data were collected, there was no option to surrender the hand and there was no instance in which any of the players bought insurance. Therefore, rather than describe these options in detail here, we refer the reader to a standard book on Blackjack (e.g. Tamburin 1994).

3.1.3 Dealer's Play

In Blackjack, the dealer's play must conform to a prescribed strategy known in advance to all players. This is another reason why Blackjack is an ideal setting for identifying errors associated with regret, for there is no scope for players to hold beliefs about the dealer's strategy that deviate from one another. That is, there is no scope for appealing to a particular belief structure to determine whether a particular course of play was appropriate or not. The dealer effectively acts as an automaton, behaving as follows.

Once all of the players have made their decisions regarding play, the dealer turns over their hole card. If the sum of the two cards is 17 or greater, the dealer stands without taking a card. If the sum of the two cards is less than or equal to 16, the dealer must take another card (take a hit). The dealer continues to take cards until their total exceeds 16. In the version of the game played in our data, dealers do not have the option to take more cards when their cards total 17 or greater with an ace counting as 11. That is, dealers may not hit on "soft 17".

If the dealer's total is between 17 and 21, they compare their hands with the players who are still in the game (i.e., the players who did not bust). However, if their hand total exceeds 21, they bust and lose to players who have totals of 21 or less.

This structure of play between the dealer and the players creates a situation that is naturally conducive to studying the impact of regret on decisions under uncertainty. Since any player who busts is excluded from the settlement if the dealer later busts, this creates a natural heuristic that favors errors of omission. Namely, a player who is affected by regret is concerned with two scenarios ex post: the first is that they took an extra card, busted, and then later learned that the dealer busted; the second is that they stood too soon and learned that the dealer beat them. An omission bias associates lower regret with the latter outcome, since it was not caused by the willful action of the player (i.e., to take another card).

3.1.4 Settlement

As mentioned above, if a player's total exceeds 21, they automatically lose their bet. If a player's total is less or equal to 21 and exceeds the dealer's total, they win and receive their initial bet plus an amount equal to their original bet. If a player's total is less than the dealer's total, the player loses their initial bet. Finally, if the dealer and the player have equally strong hands (equal totals not exceeding 21), the hand is called a "push" and no money exchanges hands.

If a player receives an ace and a either a face card or a ten (totaling 21) on the initial deal, they have a "blackjack". As long as the dealer does not have a natural as well, the player receives a net payout from the dealer of 1.5 times their initial bet. Otherwise, the hand is a push. Note that acquiring more than two cards that total 21 does not constitute a natural.

From the structure of settlement, it is clear that there is no direct strategic interaction between the players—the rules of the game do not pit one player against another, and one player's victory does not preclude another player from also winning (except by affecting the cards that are available to draw). That is, holding constant the sequence of cards that were dealt, whether Player 1 wins or loses has no effect on the size of Player 2's payoff. Moreover, it is never desirable to attempt to starve another player of a card, since this behavior has no impact on a player's payoff. A player's payoff is only determined by their own choices to take a hit or stand based on the cards they were dealt and their (common) knowledge of the dealer's hand. This simple game structure makes it easy to attribute the observed patterns of play to the omission bias described above.

3.2 The Basic Strategy

Given the rules of the game as laid out above, there exists a reasonably simple algorithm for maximizing one's expected return given the cards a player is dealt and the knowledge of the dealer's face-up card. This is known as the Basic Strategy. The strategy is basic in the sense that is does not require any attempt to recall the cards that have been played since the previous shuffle.

In this section, we describe the optimal play for Black Jack, given the rules listed in Section 3.1 and the absence of card counting. The optimal strategy for a one-deck game was first published by Baldwin, Cantey, Maisel, and McDermott (1956) and has since been extended to multiple decks and card-counting schemes (e.g. Thorp 1962, Wong 1994, Griffin 1999).

Figure 1 describes the optimal strategy for the game we are considering. Each panel describes one strategic situation for the player in question. The top panel describes optimal play when a player has a hard total: i.e., when the player is not dealt an Ace or a pair, and therefore has no possibility to split the hand or to otherwise reclassify the value of the Ace after receiving another card. Although the exact prescriptions of the Basic Strategy for hard totals are somewhat more complicated than this, the bulk of the Basic Strategy for hard totals can be communicated by four simple rules. The first is to never take a hit on a hand totaling seventeen or higher. The second is to never stand when the dealer shows seven or higher (provided the player's total is sixteen or below). The third is to never stand below twelve. The fourth is never to take a hit when the dealer shows two through six.

The strategy is more complicated for soft totals (that is, hands involving an ace, which can be either be counted as a one or an eleven) or pairs. With soft totals, the player effectively holds an option to convert an eleven-valued ace to a one if the card received would otherwise trigger a bust. The optimality of standing versus doubling down versus taking a hit depends on the relative value of this option as compared to the dealer's likely strategy. With pairs, optimal play likewise requires the player to weigh the expected value of splitting, taking an additional card, doubling down, or standing against the dealer's strategy. The fact that obeying the basic strategy involves both memory (the player must memorize the basic strategy table) as well as variation in cognitive difficulty (some plays are obvious, others require a more subtle appreciation of strategic play) gives rise to variation in the data that allow us to proxy for a player's skill and/or memory. We discuss these and other variables below.

3.3 Our Data

The data consists of 4,394 Blackjack hands played according to the rules defined in Section 3.1 during a pilot test of the MP-21 Card and Chip Recognition System designed by Mindplay Intelligent Games.[10] The data that we obtained are proprietary and provide only a partial glimpse into the actions of each player at the table. We have data at the player-level, where a unique round number allows us to identify how many players were seated in a particular round, but not the player's individual identities.

Table 2 provides a complete list of the variables that we can glean from the data. For each player, we know the size of their initial bet, whether they doubled down or split, and whether they won, lost, or pushed. In cases where hands were split, we know the outcome of each hand. We also whether they deviated from the basic strategy, and the nature of the deviation if it occurred. In addition, we also know the running count at the beginning of each round. Importantly, however, we do not know the cards played by each player: we only know a particular sequence of play when it resulted in a

[10] We excluded 156 hands from the initial data set that were interrupted during play. Including these hands has no effect on our analysis.

deviation from the basic strategy.

Since we do not have unique player identifiers,we do not have any information on player demographics. Without player identifiers, it is not possible to track an individual's play from one round to the next. Therefore we focus instead on whether particular types of play occurred in a particular round. This weakens our ability to identify either rebound or contagion, since we cannot be sure that a particular player did not leave the table, nor can we know if new players arrived. At the same time, it is commonplace for would-be players to observe play at a table before taking a seat. Thus, it is reasonable to assume that all players seated are at least partly aware of recent play at the table when a round begins.

Finally, although we have the running count, we do not know when the pack is re-shuffled. This makes a precise calculation of the true count from the running count impossible. (The true count is the running count divided by the number of decks remaining before the shoe is reshuffled.) Although the sine qua non for identifying card counters would be to look for variation in bet size that varied strategically with the true count, it is extremely unlikely that card counters were present in our data. We say this because, as we discussed in the introduction below, players who deviate from the basic strategy lose far more often than players who follow the basic strategy. Moreover, in unreported tables we have verified that two tell-tale signs of card counters are absent: first, variation in initial bet size is not explained by time varying features of play at the table; second, deviations from the basic strategy do not covary with the running count in a manner prescribed by card counting strategies (e.g., Baldwin et al, 1956, or Wong, 1994).

4 The Omission Bias

Table 3 begins by simply reporting the outcomes that occurred during the pilot study. In Panel A, we focus on single-hand deals: that is, deals in which players did not split their hand into two or more hands. It shows that 1,856 hands out of a total of 4,287 single-hand deals resulted in wins. Among players who followed the basic strategy, the winning percentage is 48.1%, which is statistically much higher than the 37% experienced by those who deviate from the basic strategy (the associated t-statistic for the difference in means is over 4 in absolute value).

Panel A also illustrates the first-order result: approximately 80% of all deviations from the Basic Strategy involve passive mistakes; ones in which the player should have taken an extra card and did not, ones in which the player should have split or doubled down but did not. Only one mistake in five involves players behaving overly aggressively. In panel B we no longer restrict attention to single-hand deals, but also include deals in which the player (rightly or wrongly) split. In a handful of cases, the player splits more than twice, but in general the basic fact that passive errors are much more common than aggressive errors holds regardless of the number of hands played (or won).

Panel C illustrates the economic consequences of winning, losing, and deviating from the basic strategy. Of the 1,872 winning hands, all but a little over 7% followed the basic strategy. $62,035 was won by players following the basic strategy, while $56,402 were lost in the 2,104 losing hands that followed the basic strategy. Thus, the ratio of monetary losses to wins is 0.9. In contrast, the 7% of hands that won while deviating from the basic strategy won a total of $3,021. About 12% of losing hands deviated from the basic strategy, losing a total of $6,387. This is a loss-to-win ratio of 2.11. Or to put it slightly differently, those who followed the basic strategy won about $1.23 per hand for every dollar lost per hand. In constrast, deviators won about 80 cents per hand for every dollar per hand lost.

5 Does the Omission Bias Capture Regret?

The remainder of Table 3 demonstrate that this basic feature of the data is robust to a variety of alternative explanations for the omission bias.

One potential explanation is that passive errors are a sign of inexperience. By examining the bet size distribution, we can see whether passive errors cluster among low-bet hands, which would corroborate this explanation. Panel D shows that this is not the case. Indeed, passive errors outnumber aggressive errors more than two to one among bets larger than fifty dollars. The handful of errors made by gamblers betting more than $100 are all passive. Thus, there is no evidence that inexperienced players who are reluctant to bet large sums of money are driving our result. The omission bias we document holds more or less evenly across the bet size distribution.

Another possible explanation for the omission bias is that it stems from bounded rationality. That is, could the omission bias be driven by hands that are in some sense harder to play because they involve a more subtle understanding of the optimal strategy? To examine this possibility, we also considered whether the omission bias is more severe among soft hands—hands in which the player is dealt an Ace, which can either be played as a high card (for a value of 11) or a low card (for a value of 1). There is no statistically discerning difference in the frequency of basic strategy deviations between hard and soft hands.

A prominent alternative explanation is that omission bias is driven by a player's desire to continue play. That is, players derive utility from the act of play and are willing to sustain passive losses more readily because they prolong play while active losses do not. There are two versions of this explanation, one that extends across rounds to the player's overall enjoyment of an evening of Blackjack, the second a narrower version that only pertains to the player's desire to stay in the game for a particular round of play. Of course, the first variant cannot explain omission bias: a player who wishes to play blackjack for as long as possible over the course of a long period of time (an hour, a day, a weekend) should follow the basic strategy and place bets in such a way to minimize the probability of ruin.

The second variant, however, provides a viable explanation for omission bias. It suggests that players may prefer sins of omission to sins of commission if they derive utility from being seated in active play at the table throughout the entirety of the round. That is, players may favor omission bias if they simply wish to be in play when the dealer plays his hand.

To test for this possibility, we begin in Table 4 by analyzing the distribution of passive and aggressive errors at different seat positions around the table. Since the total number of players varies from one round to the next, the columns of Table 4 report different table sizes. The rows of Table 4 report different seat positions. For example, the distribution of errors at four-person tables indicates that seat position 1 is associated with 20 passive errors and 6 aggressive errors. Thirteen passive and seven aggressive errors were committed at the second seat position, and so forth. If anticipation drives the omission bias, then we would expect to see passive errors cluster disproportionately among low seat positions, since these players would face the longest time to wait before learning the ultimate outcome of the game. But we do not. As the right-most column of Table 4 shows, the distribution of passive and aggressive errors is roughly uniform across seat positions.

Rather than assuming that anticipation varies across players at a particular table, it may be the case that average anticipation is higher at a larger table. The bottom row of Table 4 provides some evidence in favor of this hypothesis, since it shows that large tables contain more passive errors than small tables. Of course, since in some sense each seat represents a draw from a bernoulli distribution of passive/aggressive errors, this simply may reflect a mechanical relation between table size and omission bias. Nevertheless, we extend our analysis in Table 5 by attempting to predict passive errors by seat position alone. In the first two columns we model passive errors as a function of the seat order. Model 1 is a probit specification, while model 2 is a linear probability model. The second two columns predict passive errors with seat position using dummies for table size. By including table-size dummies, the point estimate on seat position is only identified by variation in seat position within tables of a certain size. Again, model 3 is a probit specification, while model 4 is a linear probability model. Table 5 contains no evidence that seat position predicts passive mistakes. The models reported in this table are robust to including dummies for seat position, including a dummy for whether the person making the mistake was seated just before the dealer.

6 The Evolution of Regret in Repeated Play

While data limitations prevent us from tracking the behavior of particular respondents over time, we can ask how the prevalence of a particular type of play in one round affects play in later rounds. We take up this issue in Table 6. This table reports Probit regressions in which the dependent variable is a dummy for making a mistake, making an aggressive mistake, or making a passive mistake.

The first two columns focus on mistakes overall. Basically, these two columns provide no evidence that mistakes cluster in time—there is no evidence that behavior in the previously recorded round of play affects the overall error rate in the current round. This holds whether or not we include dummies for the bet size categories noted in Table 3.

Columns (3) and (4) focus only on aggressive mistakes, and here we see a different picture. The left-hand side variable is a dummy for whether a player committed an aggressive mistake; in column (3) the right-hand side variables include dummies for whether anyone in the prior round received blackjack, as well as whether anyone played aggressively. Here, aggressive play is defined as any of the following: (i) a player made an aggressive error in the prior round, (ii) a player split or doubled down in the prior round. The loading in column (3) indicates that aggressive mistakes are about 1% less likely if aggressive play occurred in the prior round. In column (4) we introduce controls for the number of players in the current round, the running count, and bet-size dummies. The loading on aggressive play is effectively unchanged. To put this number in economic perspective, about ten percent of all hands involve errors, and about one in five errors is aggressive; therefore, a one percent reduction in the rate of aggressive errors cuts the error rate in half.

Columns (5) and (6) indicate that passive mistakes are largely unpredictable based on past play. Like overall mistakes, they are not explained by whether there was aggressive play in the prior, or whether there was a blackjack in the prior round. This is true regardless of whether we control for bet size and the number of players at the table.

Because we have a richer set of data for the hands involving mistakes, we turn to an analysis of aggressive versus passive play conditional on a mistake occurring. This is presented in Table 7, which reports Probit regressions in which the dependent variable is a dummy for whether a mistake was passive. By including a richer set of explanatory variables than what is available in Table 6, we can better explore reasons for the rebound effect that we see, whereby aggressive play is less likely in the wake of prior aggressive play.

The first three columns of Table 7 predict passive mistakes with a dummy for whether a natural was scored in the previous round, with various specifications accounting for bet size and seat position fixed effects. In general, the point estimates on Prior Round Blackjack in the first three columns support the idea that players make more passive mistakes when the table is perceived to be "hot" or favoring the players rather than the dealer. But these effects are not statistically significant. In the second three columns we add a dummy for Prior Round Aggressive Play. In column (4), the variable is added alone. In Column (5), we include bet size dummies, while in Column (6), we include seat order dummies. In all specifications, prior aggressive play raises the probability of a passive mistake by about 13%.

Columns (7), (8) and (9) include additional controls. These include the number of players in the current round, the running count, and a dummy for whether the player was dealt a soft-hand. (This is identifiable because we are focusing only on mistakes.) In general, these columns show that the Prior Round Aggressive Play continues to raise the probability of a passive error, even after we control for the fact that passive mistakes are more common at larger tables. There is no statistically reliable evidence that soft-totals or the running count of the deck has any effect on passive mistakes.

While Table 7 shows that prior aggressive play affects the probability of a passive error, it lumps together splits, doubling down, and aggressive errors. Of these, doubling down is the most aggressive form of play: it involves adding more money to the bet, taking a hit, and extinguishing the option to take any additional hits thereafter. Thus, if prior aggressive play causes a rebound effect, we would expect this to be strongest in situations where the prior aggression came from doubling down.

Table 8 explores this by breaking prior aggressive play into three sources: splits, doubling down, and aggressive mistakes that lead to losses. The first four columns model the probability of a passive error. Column (1) shows that prior doubling down alone has about a 12% increase on the probability of a passive mistake. Columns (2) and (3) show a large, but statistically insignificant, effect on prior aggressive losses and prior splits, respectively. When we put these together in Column (4), we see that the doubling down variable dominates.

While doubling down may be the most aggressive play at the table—since it involves exercising the option to continue drawing cards—it also involves elements of risk aversion, since it requires the player to double the size of the bet. This opens the possibility that it is risk aversion, rather than regret, that is rebounding in the wake of prior aggressive play. To investigate this possibility, column (5) regresses the size of the initial bet on prior doubling down, prior aggressive losses, and prior splits. Aggressive losses have the predicted sign, lowering the size of the bet, but this is insignificant. (Again, we cannot rule out that players have departed or new players have joined.) Prior instances of doubling down, however, actually raise the initial bet. This does not support the hypothesis that that it is risk aversion, rather than regret, that is rebounding.

7 Discussion

This paper uses novel field data obtained from actual play at a Las Vegas Blackjack table to show that errors of omission are four times more likely than errors of commission. This profound omission bias occurs in spite of the fact that real economic agents are making real decisions with their own money, reaping the rewards of skill and good luck, suffering the costs of bad luck and mistakes. The bias we observe grows more common in the wake of past aggressive play, and is robust to controls for memory and skill.

Perhaps few decisions of economic consequence are made at a Blackjack table. Nevertheless, the underlying mechanism here—choosing between acting or not acting in an economic environment with uncertain payoffs—is present in many economic problems, such as planning for retirement, searching for a job, or starting a business. Indeed, the findings from our field study are striking when one considers that Blackjack players are not a random sample of economic agents: they have self-selected into the game of Blackjack based on their willingness—indeed, desire—to bear risk. The conservatism that we identify at a Blackjack table is all the more severe when we consider this self-selection issue. And of course, unlike Blackjack, everyday economic problems that involve the decision to act typically also involve risk, ambiguity and other behavioral factors. Exploring the broader economic implications of omission bias in more complicated settings where multiple biases interact remains an important question for future research.

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Table 1: The Basic Strategy

Your hand	Dealer's face-up card 2	3	4	5	6	7	8	9	10	A
Hard totals										
17-20	S	S	S	S	S	S	S	S	S	S
13-16	S	S	S	S	S	H	H	H	H	H
12	H	H	S	S	S	H	H	H	H	H
11	D	D	D	D	D	D	D	D	D	H
10	D	D	D	D	D	D	D	D	H	H
9	H	D	D	D	D	H	H	H	H	H
8	H	H	H	H	H	H	H	H	H	H
Soft totals										
	2	3	4	5	6	7	8	9	10	A
A,8 A,9	S	S	S	S	S	S	S	S	S	S
A,7	S	D	D	D	D	S	S	H	H	H
A,6	H	D	D	D	D	H	H	H	H	H
A,4 A,5	H	H	D	D	D	H	H	H	H	H
A,2 A,3	H	H	H	D	D	H	H	H	H	H
Pairs										
	2	3	4	5	6	7	8	9	10	A
A,A	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
10,10	S	S	S	S	S	S	S	S	S	S
9,9	SP	SP	SP	SP	SP	S	SP	SP	S	S
8,8	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP
7,7	SP	SP	SP	SP	SP	SP	H	H	H	H
6,6	SP	SP	SP	SP	SP	H	H	H	H	H
5,5	D	D	D	D	D	D	D	D	H	H
4,4	H	H	H	SP	SP	H	H	H	H	H
3,3	SP	SP	SP	SP	SP	SP	H	H	H	H
2,2	SP	SP	SP	SP	SP	SP	H	H	H	H

Basic strategy table for 3 or more decks, dealer stands on soft 17, double on any 2 cards, double after split allowed except on aces, and blackjack pays 3:2. Key: S = Stand, H = Hit, D = Double, SP = Split.

Table 2: Variables Used in the Analysis

Variable	Definition	Availability?
Players	The number of players seated at the table for each round of play. Varies from 1 to 6.	All
Blackjack	A dummy for whether a player in a particular round scored a natural.	All
Win, Loss, Push	An indicator for whether the player won, lost, or tied with the dealer. Available for any subhand that was played deriving from a split.	All
Initial Bet Size	The amount of dollars placed in the initial bet	All
Running Count	The number of cards 2-6 that have been played minus the number of cards 10, Jack, Queen, King, or Ace that have been played. A high running count indicates that the remaining deck is rich in high point cards. Likewise, a low running count indicates that the remaining deck is rich in low cards.	All
Prior Round Black Jack	A dummy for whether any player in the most recent round of play scored a natural.	All
Prior Round Aggressive Play	A dummy for whether any player in the most recent round of play doubled down, split, or committed an aggressive error.	All
Passive Error	A dummy for whether the player deviated from the basic strategy by standing when they should have asked for an additional card, or by otherwise failing to split or to double-down as required under the basic strategy.	Mistakes
Aggressive Error	A dummy for whether the player deviated from the basic strategy by taking a card when they should not have, or whether they split or doubled-down when they should not have.	Mistakes
Soft Hand	A dummy for whether an Ace was dealt	Mistakes
Seats Position	An indicator, ranging from 1 to 6, that indicates where the player sat in the order of play at the table.	Mistakes

This table describes the variables that are provided in the data as well as the ones that we are able to construct. The column “Availability” indicates whether a variable is available for all hands, or rather for errors only.

Table 3: Blackjack Outcomes

Panel A: Single-Hand Deals

Outcome	Hands	Followed BS	Committed Error	Percent Error	Percent: Aggressive	Passive
Player Wins	1856	1717[†]	139[†]	0.07	0.20	0.80
Player Loses	2091	1850	241	0.12	0.20	0.80
Player Pushes	340	324	16	0.05	0.19	0.81

Panel B: All Hands

Wins	Basic Strategy	Followed Error	Committed Error	Percent Aggressive	Percent: Passive	
0	2524	2258	266	0.11	0.20	0.80
1	1834	1701	133	0.07	0.20	0.80
2	31	25	6	0.19	0.00	1.00
3	5	1	4	0.80	0.50	0.50
4	1	0	1	1.00	1.00	0.00

Panel C: Total Amount of Money Won and Lost

	Hands	Followed BS	Committed Error	Percent Error	Cash from: Aggressive	Passive
Player Won	1,871	$62,035	$3,021	7.69%	$705	$2,316
Player Lost	2,524	$56,402	$6,387	11.59%	$1,142	$5,245

Panel D: Bet Size and Blackjack Outcomes

Bet Size	Basic Strategy	Followed Error	Committed Error	Percent Aggressive	Percent: Passive	
$10 or less	2284	2070	214	0.09	0.21	0.79
$11-$20	1037	956	81	0.08	0.14	0.86
$21-$50	827	733	94	0.11	0.23	0.77
$55-$100	132	120	12	0.09	0.33	0.67
$105-$500	81	73	8	0.10	0.00	1.00
$1000-$1100	31	30	1	0.03	0.00	1.00

† Note: Players that follow the basic strategy in our data win 48.1% of the time, and deviators win 36.6% of the time. The win rate among basic strategy followers in our data is very close to that observed widely in Blackjack manuals, for example Baldwin et al (1956).

Table 4: Do Passive Mistakes Reflect Anticipation?: Seat Position Evidence

		Players at Table						Total
Seat Position	Error	1	2	3	4	5	6	Percent
Seat 1	Passive	12	22	25	19	21	8	0.77
	Aggressive	4	11	5	6	6	0	0.23
Seat 2	Passive		23	16	13	23	1	0.77
	Aggressive		4	7	7	3	1	0.23
Seat 3	Passive			19	30	22	2	0.84
	Aggressive			4	8	2	0	0.16
Seat 4	Passive				19	16	4	0.87
	Aggressive				4	1	1	0.13
Seat 5	Passive					14	7	0.81
	Aggressive					2	3	0.19
Seat 6	Passive						4	1.00
	Aggressive						0	0.00
Total	Passive	0.75	0.75	0.79	0.76	0.87	0.84	0.80
Percent	Aggressive	0.25	0.25	0.21	0.24	0.13	0.16	0.20

Notes: The top number is the sum total of passive errors that occurred in Seat Position X at a table with Y players at the table. The bottom number is the sum of aggressive errors.

Table 5: Predicting Passive Mistakes with Seat Position

	(1)	(2)	(3)	(4)
Seat Position	0.027	0.026	0.021	0.019
	(0.0922)	(0.0947)	(0.266)	(0.296)
2-player table			-0.009	-0.008
			(0.935)	(0.940)
3-player table			0.017	0.023
			(0.870)	(0.839)
4-player table			-0.019	-0.015
			(0.857)	(0.893)
5-player table			0.088	0.091
			(0.375)	(0.414)
6-player table			0.031	0.040
			(0.801)	(0.761)
Observations	399	399	399	399
R^2	0.01	0.007	0.02	0.018

Notes: Observations are included only if they are deviations from the basic strategy. The dependent variable in each regression is a dummy for whether the mistake was passive. Seat position is a variable that takes on values 1 through 6 depending on where the person sat at the table, with seat 1 being the furthest seat from the dealer in a n-hand round. Variables labelled 'x-player table' are fixed effects for table size, which in turn identify the seat position variable by variation within tables of the same size, rather than across tables of different sizes. Columns (1) and (3) are probit specifications in which coefficients are reported as marginal probabilities. Columns (2) and (4) are linear probability model specifications. The constant terms estimated in Columns (2) and (4) are not statistically distinguishable from 0.80.

Table 6: What Causes Mistakes in Blackjack?

	Mistakes		Aggressive		Passive	
	(1)	(2)	(3)	(4)	(5)	(6)
Prior Round Blackjack	-0.010	-0.010	-0.011	-0.010	0.000	-0.001
	(0.388)	(0.371)	(0.0772)	(0.102)	(0.982)	(0.925)
Prior Round Aggressive Play	0.004	0.003	-0.013**	-0.013**	0.018*	0.017
	(0.673)	(0.745)	(0.00234)	(0.00242)	(0.0408)	(0.0571)
Players in Current Round		0.002		-0.002		0.004
		(0.565)		(0.134)		(0.170)
Running Count		0.000		-0.000		0.000
		(0.919)		(0.450)		(0.662)
Bet Size effects	No	Yes	No	Yes	No	Yes
Observations	4394	4391	4394	4279	4394	4391
Pseudo R^2	0.00	0.00	0.02	0.03	0.00	0.00

Notes: The sample includes all hands played, including hands that followed the basic strategy. Prior blackjack is a dummy equaling one if any player in the most recently recorded round of play had a blackjack. Prior aggressive play is a dummy for whether any player in the most recent round of play doubled down or split, regardless of whether this was dictated by the basic strategy. Controls include effects for bet sizes (as reported in Panel C of Table 2), the number of players at the table, and the running count.

Table 7: The Anatomy of Passive Mistakes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Prior Round Blackjack	0.103	0.112	0.105	0.091	0.105	0.100	0.085	0.102	0
	(0.0902)	(0.0706)	(0.0974)	(0.119)	(0.0785)	(0.100)	(0.143)	(0.0852)	(0.
Seat Position effects	No	No	Yes	No	No	Yes	No	No	
Bet Size effects	No	Yes	Yes	No	Yes	Yes	No	Yes	
Prior Round Aggressive Play				0.151**	0.154**	0.155**	0.145**	0.147**	0.1
				(0.000371)	(0.000348)	(0.000459)	(0.000759)	(0.000722)	(0.0
Players in Current Round							0.022	0.036*	0.
							(0.144)	(0.0419)	(0.
Running Count							0.005	0.006	0
							(0.423)	(0.347)	(0
Soft Hand							-0.064	-0.065	-0
							(0.334)	(0.333)	(0
Observations	410	405	396	410	405	396	410	405	
Pseudo R^2	0.01	0.01	0.02	0.04	0.05	0.06	0.05	0.06	0

Notes: The sample includes only those hands that deviated from the basic strategy. Prior blackjack is a dummy equaling one if any player in the most recently recorded round of play had a blackjack. Prior aggressive play is a dummy for whether any player in the most recent round of play doubled down or split, regardless of whether this was dictated by the basic strategy. Soft hand is a dummy for whether the hand included an Ace. This proxies for difficulty. Bet size effects are as reported in Panel C of Table 2. Seat Position effects are as reported in Table 4.

Table 8: Another Look at Passive Mistakes

Variable	DV = Pr(Passive Error) (1)	(2)	(3)	(4)	Bet size (5)
Prior Round Double-down	0.133*			0.123*	4.074
	(0.0103)			(0.0171)	(0.563)
Prior Round Aggressive Loss		0.144		0.127	-9.264
		(0.0606)		(0.108)	(0.380)
Prior Round Split			0.080	0.073	1.646
			(0.299)	(0.333)	(0.877)
Players	0.044*	0.042*	0.044*	0.041*	-0.077
	(0.0186)	(0.0250)	(0.0209)	(0.0293)	(0.975)
Running Count	0.005	0.005	0.005	0.005	-0.662
	(0.377)	(0.407)	(0.416)	(0.382)	(0.390)
Bet Size effects	Yes	Yes	No	Yes	No
Seat Position effects	Yes	Yes	Yes	Yes	Yes
Observations	396	396	396	396	410
Pseudo R^2	0.05	0.04	0.03	0.06	-

Notes: The sample includes only those hands that deviated from the basic strategy. Prior aggressive loss is a dummy for whether any player in the most recent round of play doubled down or split or made an aggressive error which subsequently resulted in a loss. Prior Double-down is a dummy equaling one if any player in the prior round doubled down. Prior Split is a dummy if any player split in the prior round. Bet size effects are as reported in Panel C of Table 2. Seat Position effects are as reported in Table 4.