Catching Card Counters

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ABSTRACT

The casino industry has been researched through a variety of disciplines including psychological gambling habits, technological advances, business strategies, and mathematical simulations. In the vast number of studies that have been conducted, there are few scholarly articles that focus on the specific aspect of card counting. The majority of games in the casino are designed to favor the "house". This study focuses on the game of blackjack, in which players using a card counting strategy can tip the odds in their favor. A computer simulation was used to model the betting strategy of a card counter who would bet methodically. Conversely, the unpredictable betting strategy of a "normal" gambler was gathered through observations of over one thousands hands of blackjack. The comparison of the two led to deviations in behavior and betting habits. An understanding of these differences will provide a casino with additional information to catch card counters at the table.

INTRODUCTION

This study has been created with the intent of providing the casino industry with an outline for identifying and catching card counters. In the game of blackjack, the goal is to get a score as close as possible to 21 without going over. Each player is dealt two cards at the beginning of the hand and individually plays against the dealer or the "house". The value of each card two through ten is face value, the jack, queen and king have a value of ten and the ace can be played as a one or an eleven at the player's discretion. The player has the choice to ask for additional cards at his or her own discretion, however the dealer is required to deal himself another card if the total is below 17.

A card counter would choose whether or not to ask for another card using a method called basic strategy. The table in Appendix A explains when a person should "hit" meaning to ask for another card, or "stand" meaning not to ask for additional cards. Other options include to "split" which is when the player's cards are the same they choose to play them as two separate hands and to "double" which is to bet twice as much. This table shows which choice a player using basic strategy should make based on both what cards the player has been dealt and what the dealer's one face up card is.

Blackjack is played with a given number of decks, and therefore a defined number of cards. Mathematically speaking this is considered sampling without replacement which means that each card has a certain probability of appearing. As a card is played, this probability changes in relation to the remaining cards in the deck. To exploit this

advantage, card counting was invented to estimate when a given hand is more or less likely to win.

In a typical hand of blackjack, the house has between .5% and 3% advantage over the player. However by card counting a player can have a 1%, 2%, or even 3% advantage over the house (Ma, 2015). A card counter using the Hi-Lo strategy assigns a value of -1, 0, or 1 to each card dealt according to the following table:

Card:	Ace	2	3	4	5	6	7	8	9	10	Jack	Queen	King
Assigned Value	1	1	1	1	0	0	0	0	0	-1	-1	-1	-1

Table 1: Hi-Lo Strategy

The card counter will keep a mental tally of this count after every card is dealt. The dealer has the highest chance of going over 21 when there are the most 10s, jacks, queens and kings left in the deck. This means that as the count increases the player is more likely to win and should therefore bet more. The next step is to determine the betting strategy that the player will implement which will be discussed in the Methodology section below.

LITERATURE REVIEW

Introduction

This research thesis is relevant because it relates to a recent article that reported on events from the 1980's through the early 2000's. This case study tells the story of the most widely known incident of card counting; when a group of individuals at MIT used card counting to make millions (Casey, 2008). It explained the rigorous training process and

techniques they used to remain undetected. It followed these individuals from formation to disbandment, while providing insight into the casino industry. This event has social relevance because there was both a book written about this team and a corresponding movie made. The media sensation around card counting in the early 2000's provides social interest for this analysis.

Furthermore, Jeff Ma who was a member of this team, spoke at a SAS Global Forum in 2015 about card counting in relation to data (Ma, 2015). This brought card counting into the big data arena, and he utilized examples from his own card counting to explain the advantage of leveraging every piece of data available. Ma states that card counting is still utilized and easy enough to teach anyone. This suggests the need for card counting detection because many people may be counting without the casino's knowledge. This project is also relevant in regards to the use of big data, a popular subject now that analytics has come to the forefront of mathematics. Ma campaigns that every person should understand the importance of data and use all available information to make educated decisions. When this is applied to the casino industry, to best catch card counters casinos should not merely use one method or area of research analysis. This shows the impact that this research analysis could have on casinos.

Background

Professors and researchers in the fields of mathematics and science have previously conducted simulations for various casino games. One researcher considered the game of blackjack in continuous time, as a theoretical model (Andersson, 2012). The article was printed in England, as a part of the author's doctorate thesis for Stockholm University.

The purpose was to provide the optimal betting strategy in card games, such as blackjack, that are played with multiple rounds of the same deck prior to shuffling. Andersson was able to create a stochastic differential equation to estimate the best strategy in continuous time though it cannot be directly applied while a card counter is in a casino. This data was one of many studies that incorporated mathematical equations in predicting outcomes of casino games.

Another analyzed the game of blackjack through computer simulations to determine changes in various player advantages. This study analyzed the use of multiple decks, a method casinos implemented to deter card counters (Golden, 2011). It was a study conducted for the Applied Probability Trust School of Mathematics and Statistics, produced by Professor Golden at the University of Illinois Chicago. It ran Monte Carlo simulations to model the potential hands in a game of blackjack with the use of one deck up to eight decks at a time. It used normal approximations to create each situation and created graphical presentations of the findings. This article was beneficial to the card counting equations to provide information to calculate the "true count". The true count is an aspect of card counting that accounts for the number of decks left to be played. When multiple decks are in effect a high count early in the decks has more variability and is less predictive of success than a high count later in the game. This study was used to determine the effect of multiple decks on the success of a card counter.

A third study simulated games of blackjack with a specified number of chips to determine the average length of play (Yang, Li, Zhoa, Liu, & Han, 2011). It was produced by professors at the Beijing Normal University and has been published as an international

scientific study. The researchers ran upwards of a million rounds of simulations to ensure accuracy. In addition to the numerous trials, they also accounted for different rule changes and controlled some player decisions. This was a very specific study in which assumptions of minimum bets were necessary, so it cannot be considered entirely reflective of a person's true gambling behavior. This study was originally analyzed as a potential baseline for the behavior of a normal gambler, however in order to use this study it would require incorporating all of the controls.

Multiple sources analyzed the application of the central limit theorem to use normal approximation for certain casino games. One study utilized Monte Carlo simulation and applied the central limit theorem to replicate slot machine probabilities (Singh, Lucas, Dalpatadu, & Murphy, 2013). The simulation was conducted by four doctorate level professors at the University of Nevada Las Vegas. It was funded by the Caesars Foundation, a leader in the casino industry, but appears to be written objectively without bias. It explained the mathematical approach to calculating probabilities of success and provided table and graphical representation of the findings. The slot machine does not have the same property of sampling without replacement therefore it is not directly applicable. It was used by Caesars Foundations and therefore validates the use of simulation techniques in the casino industry today.

The business applications for this topic consist of the casino success and technology advances used to detect card counters. The profile of the casino and gambling industry provides a market definition and segmentation, as well as listings of industry leaders (Casinos & Gambling Industry Profile: North America, 2014). This was produced by the

company MarketLine, which is a Datamonitor business and as such collects and compiles data on various industries. It provided definitions of each market segment, which clarified the industry layout. It also provided information on one market leader, Caesar's. This data enhanced the information on the size and strength of the casino market and as the industry grows the opportunities for card counters increase.

There are also articles that include the technical specifications of the industry that already are and soon will be implemented (Wyld, 2007). One article analyzed the capabilities of Radio Frequency Identification (RFID) technology that has been and will be implemented in casinos. It was written by a Professor Wyld at Southeastern Louisiana University in 2007. It demonstrated the data that can be collected and the improvements that will lead to preventing counterfeit, cheating, and problem gambling. In recent years, some of this technology has been implemented and there are future opportunities for continued utilization of RFID technology. One future possibility includes the use of RFID chips in the cards for blackjack, this would provide casinos with insight into card counter strategies and possible card counting suspects. This business research provides insight into the casino market useful for understanding the measures already used to detect card counters.

Finally, extensive psychological research has been done analyzing the behavior and choices of gamblers. Some are specific and provide findings based on small populations or data (Chau, Phillips, & Von Baggo, Departures from sensible play in computer blackjack, 2000). A few researchers used a small sample of students, 16 undergraduates from the University of Hong Kong, to conduct an experiment. This research explored the

irrational choices that gamblers make when playing blackjack. It showed that players will often forgo advice from others in order to proceed with one's own strategy. The results of the experiment may not be reflective of society as a whole due to the lack of diversity of the participants and the small sample size. The article itself provided insight into what questions should be discussed from a psychological standpoint.

Other studies were performed on a larger scale and illustrate valuable information about the choices gamblers make. An extensive study on the psychology of blackjack which involved simulation, experimentation and interviews was conducted in the 1980's by two psychologists Dr. Keren and Dr. Wagenaar for the American Psychological Association. The goal was to determine the behavior of gamblers and whether rational thinking was employed. The study included observation of over one hundred players, and personal interviews with one hundred and fifty players (Keren & Wagenaar, 1985). It provides valuable insight into a players mind set when approaching a game of blackjack and explores the concept of "luck". These insights are vital to the understanding of normal player behavior, as compared to strategic card counter behavior.

Review

Many ideas related to the project have been debated from opposing sides, especially due to the various fields combined for this study. One of the issues that has been disputed is the validity of simulation, the key method used in this analysis. An article by Claus Beisbart and John D. Norton, published for international publication in 2012, specifically analyzed the process of utilizing Monte Carlo simulations for investigative purposes. It critiqued the pseudorandom generation and the mathematical basis for running such

simulations (Beisbart & Norton, 2012). This article claims that Monte Carlo simulations are inferential rather than experimental. It presents an argument from Michael R. Dietrich, a Professor at Dartmouth College, who believes that these simulations are the same as controlled experiments. Beisbart and Norton proceed to describe their main argument, which states that pseudorandom numbers are derived and no element of a true experiment can be derived.

In contrast, Professor Paul Humphreys describes the attributes of Monte Carlo simulation which he believes should be classified as a new type of analysis. In his paper, he says that it is neither empirical experimentation nor a numeric method, instead it is what he calls numerical experimentation (Humphreys, 1994). He utilizes the law of large numbers which explains that probabilities will converge to the statistical estimate as the number of trials increases. This suggests that the larger amount of simulations that can be run will lead to more accuracy in the results. He further explains the value of transparent computations, which suggests that the complexity of the equations will play a factor in the accuracy of results. Humphreys sees Monte Carlo simulation as a valid method of accurately running an experiment.

The discussion of simulation as a legitimate method of research is pivotal to this project. This is the primary method of modeling the card counter's behavior and therefore challenges the legitimacy of this entire study. Beisbart and Norton raise the argument that the derivation of the pseudorandom number generator proves that simulation is inferential not experimental. However, Humphrey counters that the law of large numbers illustrates the value behind this method. Furthermore, countless professors and

researchers have utilized this method of simulation in papers published in the mathematics field, rendering it a substantial method of analysis.

Professor Patrik Andersson of Stockholm University applied simulation for his analysis of card counting in a continuous manner, mentioned above. Similarly, Professor Leslie Golden, of the University of Illinois employed this in the analysis of the effects of multiple decks. In addition, the professors of Beijing Normal University published their article on simulation in an international journal. Lastly, the professors and statisticians that wrote the article for the University of Las Vegas Gaming Research & Review Journal, simulated slot machines patterns, therefore this method has also been proven in the casino industry. Overall, the dispute over Monte Carlo simulation raised concerns that have been disproven by the research and continued use of this method for research analysis.

The business articles that contributed to this research suggest that the best practice in the casino industry is to acquire data. The casino and gambling industry have a market value of over $119 billion dollars, 38.5% of that corresponds directly to casinos (Casinos & Gambling Industry Profile: North America, 2014). Moreover, by the year 2018 this industry is projected to see a 15.5% increase in market value from its 2013 numbers. This suggests that with a growing industry the demand for data and technology will continue to trend upward. Therefore, the articles relating to the business and technology aspect of casinos are constantly becoming outdated.

In 2002, a professor at the University of Nevada Las Vegas presented a study which provided analysis of all computer systems on the market that provide player tracking and slot accounting for casinos (Wang & Aquino, 2002). Its purpose was solely to present the list of attributes for each product on the market to help educate casino management of their options. The increase in technology in the recent years has decreased the value of this study because this software is no longer a complete list of the options. However, one beneficial element of the study is that it illustrates the desired qualities in casino technology. This article found that casinos will accept high initial cost if it would lead to a business practice that will increase savings in the long run.

Professor Wyld of Southeastern Louisiana University conducted a study in 2007 that would once again profile the technology offered. It explains the risks that casinos face in terms of both counterfeit and theft of casino chips. In response, new technology is being developed that will put microchips in each poker chip. This will allow casinos to track the players' movement through the casino as well as their betting behavior. It directly mentions the application for gathering analytics with these chips to detect card counting based on betting patterns. These chips are not currently in use but expected to be developed in the near future. If this new technology is implemented, this will enhance the data in the casino industry.

The movement for data has led to the infusion of mathematics into most important business decisions. Jeff Ma emphasizes the importance of gathering as much data as possible to make informed decisions. The profile of the casino industry estimates the future growth and has projected it to rise steadily through 2018. The article for the

Gaming Research and Review journal published in 2002 showed that technology is a large upfront cost that casinos are often willing to invest if it will lead to long term savings. In 2007, only the concept for smart chips utilizing RFID technology had been conceived but this will potentially be implemented in the future. Overall, casinos will continue to collect and analyze data to support their business decisions.

Another point of contention related to many analyses of gambling is based on the concept of "luck". This is an idea that has been psychologically reviewed with respect to effects of luck in group dynamics versus individual play. The concept of luck has also been referred to as irrational behavior. Each researcher and psychologist have a different method of analysis to interpret the patterns of winning and losing that some people term luck. The small sample size in many of these experiments makes it difficult to apply their proven findings. Each psychological study provides insight into the thoughts and behaviors of gamblers even though they may not all directly represent the population.

An experiment was conducted by psychology professors Gunnarsson, Whiting, and Dixon at the Southern Illinois University Carbondale in 2014, however the results may not be representative of the whole population. The experiment was conducted with sixteen people and it was based on refined rules of the game. This study was designed to compare the person's self-perception when played alone or among a group. Each player was asked to estimate his or her likelihood of winning a hand of blackjack when played in each environment. The players were also given modified rules to help control the variables in the experiment. The findings indicate that players' perception is based on their relative position to others. The results showed that when playing alone the players

in the experiment lost 45% of the time, however when playing in a group they lost 63.5% of the time (Gunnarsson, Whiting, & Dixon, 2014). They drew the conclusion based on these participants that betting behavior was influenced more by the other players' proximity to a score of 21 rather than the dealer's proximity to 21. They also concluded that this meant players were concerned with comparing their potential for winning to their peers. Therefore, the typical casino setting which has multiple players may reflect the group dynamics exhibited in this experiment. However, based on the small sample size and modified rules these results are less reflective of society.

Another study analyzed player behavior in a game of blackjack to determine whether gambling behavior is related to a player's perception of his or her own level of control (Chau & Phillips, Effects of perceived control upon wagering and attributions in computer blackjack, 1995). The study was limited to computer based blackjack which was then manipulated to determine players' responses to the winning and losing. It was conducted with only twelve participants from the University of Hong Kong in 1995. The manipulated hands make it difficult to determine whether a player would have made rational decisions in a truly random game of blackjack. Overall, this study showed insight into a small sample of players' opinions throughout the duration of game. The professors who conducted this study also ran an experiment on the gambling behavior.

The second study conducted by Professors Chau, Phillips, and Baggo looked into the rationality of decision making in gamblers. In this experiment the players were given advice on what moves rational play would suggest. However, in many cases the player would ignore the advice based on their own personal strategies or emotional feelings.

The professors concluded that it was not a lack of intelligence that caused the stray in player choices from the sensible decision, instead they believe that gambling leads to a lack of control (Chau, Phillips, & Von Baggo, Departures from sensible play in computer blackjack, 2000). This corresponds to the findings from the study by Professors Gunnarsson, Whiting, and Dixon who showed that group dynamics increase the loss ratios of players. The studies both suggest that group dynamics decrease a player's success when playing blackjack.

The study by Professors Keren and Wagenaar examined the patterns in which people believe they experience both good and bad luck. In fact, the survey responses reflected that 68.2% of people believed the game was determined by luck. Other players believed that the results of the games were predetermined rather than probabilistic. This relates to the study by Professors Chau, Phillips, and Baggo which suggests the irrational choices gamblers make. The concept of luck may lead gamblers to the notion that their own personal strategies will return better results than the calculated probabilistic choices. Ma remarks that a card counter should always bet the way the count tells him (Ma, 2015). The psychological research illustrates personal choices that deviate from the logical choices a card counter would make.

Conclusion

There are a number of concepts discussed around card counting which include mathematical, technological, and psychological ideas. One of the key components of this capstone is simulation, therefore it is necessary to consider the arguments around this subject. The psychological argument states that simulation should be considered

inferential rather than experimental. However, the professors of mathematics proved that in their field this is considered an adequate form of research. Another area discussed is that businesses want the most current technology and data. This concept requires mathematics in conjunction with analytics to interpret data that can inform casino business decisions. In respect to the psychological research that has been conducted, a gambler generally exhibits behavior that would deviate from sensible play. This may be the result of luck, or strategy but psychologically speaking the average gambler will not bet systematically as logic dictates.

This capstone is an addition to the field of mathematics and the casino and gambling industry. This project will include aspects of previous mathematical studies to be as accurate as possible, such as considering the multiple deck effects and applying the central limit theorem to find a baseline for card counter betting style. A thorough understanding of the business field will provide the best recommendation to casinos based on technological advances and preventative measures. The psychological examination of the player's choice will allow for the maximum accuracy of the baseline normal behavior, especially when used in combination with the observations. Overall, this project is focused on mathematical principles with the inclusion of studies from all relevant fields to increase the probability of catching card counters.

METHODOLOGY

Introduction

The method of research for this project consisted of a literature review, blackjack simulation, and player observations. The idea behind this capstone was to determine

what differences exist between a normal person playing blackjack and a person card counting at blackjack. The hypothesis was that if a casino monitors betting habits then the casino will be able to determine whether a player is card counting. In order to prove this hypothesis, data was gathered from current studies that pertained to casinos and card counting. This review included literature from mathematics, business and psychology fields to provide a complete analysis of the casino industry. Next, a simulation was created to model the dealer in a game of blackjack. Then, the player observations were collected to compare against a card counter. Afterward, an analysis was conducted comparing a variety of betting strategies for each. Finally, the simulated data was evaluated in contrast with the player observations to reach these findings.

Simulation

The simulation is an excel file that was originally developed by a student at Bryant University, Jean-Paul Saggal, who volunteered it for this project. At this stage of the program, the user would enter the desired number of hands to be played using a single deck and that many hands of blackjack would be dealt. It was able to calculate the total number of wins and losses for a player using basic blackjack strategy over the entire interval. The rules for basic strategy can be found in Appendix A. Next, Professor Jim Bishop modified the program to incorporate the fact that casinos use eight decks and reshuffle after every six decks (Golden, 2011). This was information gathered in the literature review that provided a more accurate simulation. Professor Bishop also adapted the program to display the card count after each hand and illustrate the respective wins and losses for each count.

Observations

The player observations were conducted on December 12th, 2015 at the Foxwoods Casino in Mashantucket, Connecticut. There were seven individuals that participated in observing player behavior during the hours of 4:00pm to 10:30pm. Each person observed a table of blackjack players for ten consecutive hands of play before moving on to another table. The observer noted the table minimum as well as the maximum bet for each player in ten hands. A total of 1,260 hands of blackjack were observed in this experiment. The gamblers were observed in different areas of the casino, at different tables, and playing at different table minimums. These observations were used to create a baseline for normal gambler maximum bet in 10 hands.

Betting Strategies

There are a number of betting strategies that can be employed by card counters, however all of the methods used involve betting based on the count (Tamburin, n.d.). This study focused on four main ways to bet based on count which include a five unit spread, a ten unit spread, betting as a function of the minimum bet and betting as a function of the maximum count.

Betting by Card Count

- **Five Unit Spread**: When using the Hi-Lo card counting strategy, as outlined in Table 1 on page 4, the method of betting should correlate to the true count. The true count is calculate by taking the observed count and dividing by the number of decks remaining to be played. This method begins with a minimum bet and increases based on the count up to five times that minimum (Golden, 2011). It

does not exceed five times the minimum bet to help the card counter avoid detection. The table below illustrates the pattern to follow for a minimum bet of 15 and can be adapted for any minimum bet.

Betting Amount	
Count	**Bet Unit**
Below 0	Don't Play
0-3	15
4-7	30
8-11	45
12-15	60
16+	75

Table 2: Five Unit Spread

This method does have a long term advantage over the house but may lead to short term losses in the process.

- **Ten Unit Spread**: Similar to the five unit spread, this method begins with a minimum bet and increases based on the count up to ten times that minimum (Betting Spread, 2016). The table below illustrates the pattern to follow for a minimum bet of 15 and can be adapted for any minimum bet.

Betting Amount	
Count	**Bet Unit**
Below 0	Don't Play
0-2	15
3-4	30
5-6	45
7-8	60
9-10	75
11-12	90
13-14	105
15-16	120
17-18	135
19+	150

Table 3: Ten Unit Spread

This method also will have long term advantage over the house, with the wider spread it is less likely to lead to short term losses but still possible.

- **Function of the Minimum**: Unlike the other methods, this method follows a formula which changes the bet based on each individual true count.

  (True Count-1)*(Minimum Bet)

  The formula is to subtract one from the true count and multiply that by the minimum bet (Bloch, 2016). This method further spreads the bet range and exploits the high counts.

- **Function of the Maximum:** This method requires knowledge of the maximum true count of the deck, and the maximum amount that the card counter is willing to bet. The equation is as follows (Blackjack Betting Spread Explained, 2015):

  $$\left(\frac{Maximum\ Bet}{Maximum\ True\ Count}\right) * \text{True Count}$$

  This method creates a range that allows the card counter to choose the maximum amount he or she will bet and therefore the largest possible amount he or she can win.

Analysis

The analysis consisted of a side by side comparison of each betting strategy run over 125,000 times in the simulation. In a separate excel worksheet the card count and win/loss for each hand were recorded. Next, the formula for each betting strategy was run to calculate the bet made each hand for each of the four methods. Finally, these games were broken into sections of ten hands each and compared to the maximum bets

found in the observations. This combination of data led us to the determining when a card counter could be detected.

Conclusion

This project focuses on methods that will increase the probability of catching card counters within a casino. It analyzed current studies that relate simulation data to the game of blackjack. These provided insight to the research that has previously been conducted to ensure that this study enhances the field, rather than repeating previous works. It utilized simulation to run multiple hands of blackjack and determine the likelihood of catching a card counter by focusing on the betting strategies of each type of player. Finally, it compared this data to the player observations to determine key differences in behavior.

FINDINGS

Simulations and Observations

In order for the observation data to be compared to the four card counting methods, the simulation data had to be in the same format. The observation data was recorded based on the maximum bet of ten consecutive hands. Therefore, the over 125,000 simulations that were run with each of the four methods had to be broken down into groups of ten as well. Once the simulation data was grouped into ten hands the maximum of those ten hands was recorded. The maximum bets for the observation data and each of the four methods were graphed and can be found in Appendices B-F.

Statistical Tests

To determine whether the card counter methods were significantly different from the observations of normal gamblers, statistical tests were run. In order to compare the data

further grouping was required and the maximum bets were broken into 5 groups as follows: bets from 15-20, bets of 25-35, bets of 40-55, bets of 60-70 and bets of 75 or more. The first test was a chi-square test to determine the significance of each group appearing. The table below shows the percentage of bets from each method that belong in each category compared to the percentage of bets in each category from the observed data.

	Method 1: 5 Unit Spread		Method 2: 10 Unit Spread		Method 3: Function of Minimum		Method 4: Functions of Max Count	
Bet Range	**Observed Bets**	**Card Counting Bets**	**Observed Bets**	**Card Counting Bets**	**Observed Bets**	**Card Counting Bets**	**Observed Bets**	**Card Counting Bets**
15-20	41%	44%	41%	33%	41%	18%	41%	18%
25-35	26%	29%	26%	21%	26%	14%	26%	0%
40-55	17%	17%	17%	14%	17%	12%	17%	15%
60-70	7%	8%	7%	10%	7%	9%	7%	11%
75+	9%	2%	9%	23%	9%	47%	9%	56%
P-Value:	0.9999		0.9929		0.7774		0.5939	
Significance:	Not Significant		Not Significant		Not Significant		Not Significant	

Table 4: Chi-Square Results

In order to prove significant the P-value would have to be <.1 and at the bottom of the table it is clear that none of the methods here are considered significantly different. At the point it was determined that if the casino monitored the maximum of all of the bets and compared each player it would be difficult to determine a difference between the card counter and the average gambler.

The next test focused only on the bets in the highest group, which is the bets of 75 or more. This test was a normal approximation to the binomial formula and it was run comparing the card counter methods to the observation data to produce the table below.

	Method 1: 5 Unit Spread		Method 2: 10 Unit Spread		Method 3: Function of Minimum		Method 4: Functions of Max Count	
	Observed Bets	Card Counting Bets	Observed Bets	Card Counting Bets	Observed Bets	Card Counting Bets	Observed Bets	Card Counting Bets
Bet: 75+	9%	2%	9%	23%	9%	47%	9%	56%
P-Value	.009%		<.001%		<.001%		<.001%	
Significance:	Significant		Significant		Significant		Significant	

Table 5: Normal Approximation Results

The results of this test were significant for each of the four methods. This proves that if the casino focused on only the maximum bets that are 75 and higher than the casino can determine whether the person is card counting. In the first method, the five unit spread, the card counter would bet over 75 dollars significantly less than the average player and in the other three methods the card counter would bet over 75 dollars significantly more than the average player.

The final element that was examined, was the frequency in which a high count comes up during the game of blackjack. In order to determine this the 125,000 simulations were used as the baseline. The graph in Appendix G shows how often each count appeared in the simulations. For this test a high count was determined as a true count of 14 or higher because this count would yield a bet of more than half of the maximum bet in every method. The results showed that a high count would come up in an 8 deck game about every 200 hands dealt. Therefore when playing at a table with 5 players and a dealer, the typical casino table layout, a player would see a high count approximately every 33 hands. This was also compared to the player observation data to determine how many high bets would be seen in a normal game. In the 1,260 hands observed a card counter would have been high 38 times, whereas the observed data only yielded 22 high bets.

Conclusion

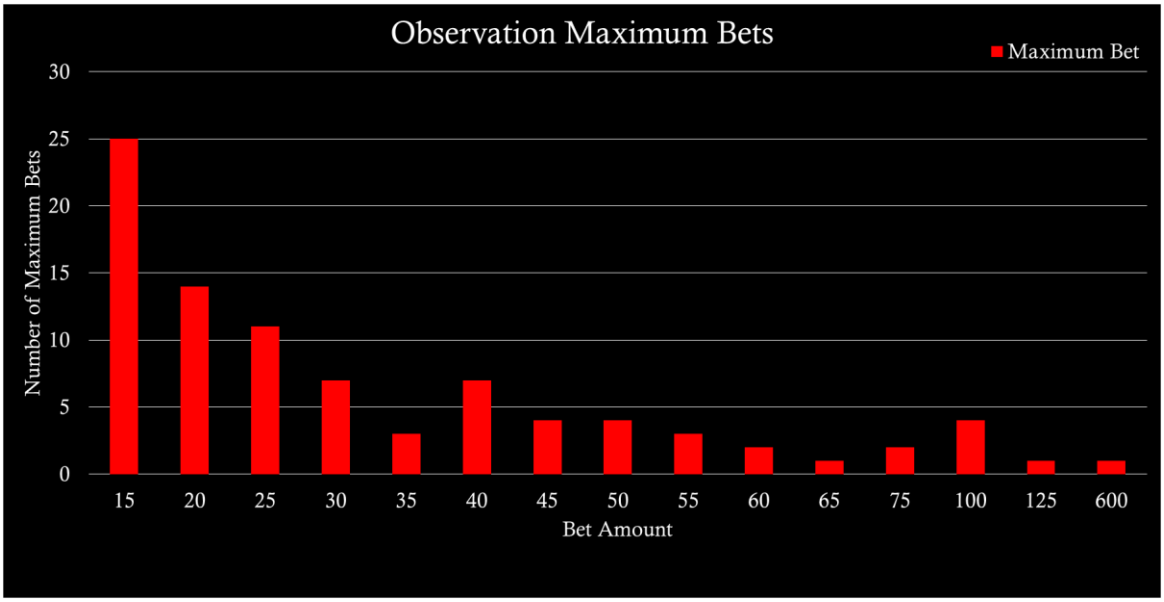
Overall, this study examined the game of blackjack to determine how a casino could catch a card counter. After reviewing the techniques in the field, the current practice is that the floor manager or dealer to watch any players exhibiting suspicious behavior or winning abnormally often. This study illustrates a new method that would require additional effort on the part of the casino but is statically proven to determine which players are card counters. In this method the casino would monitor how often high bets of five times the minimum or more were placed in the overall hands played. If a software was developed or the dealers were trained to observe this behavior card counters would be much easier to catch.

APPENDIX A: BLACKJACK BASIC STRATEGY

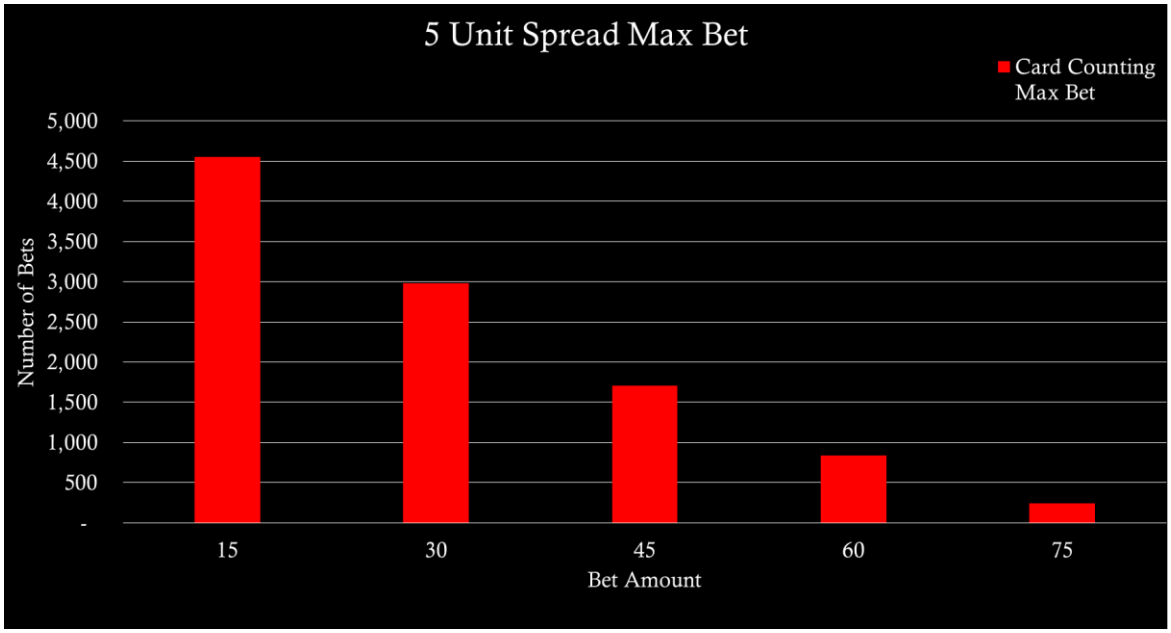
	My Hand	UpCard 2 – 6		UpCard 7 - A
HARD	4 – 8	HIT		
	9	DOUBLE except 2		HIT
	10 – 11	DOUBLE if more points than dealer		
	12 - 16	STAND Hit 12 vs 2, 3		HIT Surr 15 vs 9, 16 vs 9-A
	17+	STAND		
SOFT	13 – 14	HIT, but double vs 5,6		
	15 – 17	HIT, but double vs 4,5,6		
	18	STAND vs 2,7,8	DOUBLE vs 3-6	HIT vs 9-A
	19+	STAND		
SPLITS	2, 3, 7	SPLIT vs 2-7		
	4	SPLIT vs 5-6		
	6	SPLIT vs 2-6		
	8, A	SPLIT always		
	9	SPLIT vs 2-6 and 8-9		

Strategy by www.wizardofodds.com *Card by Jeff Pepper*

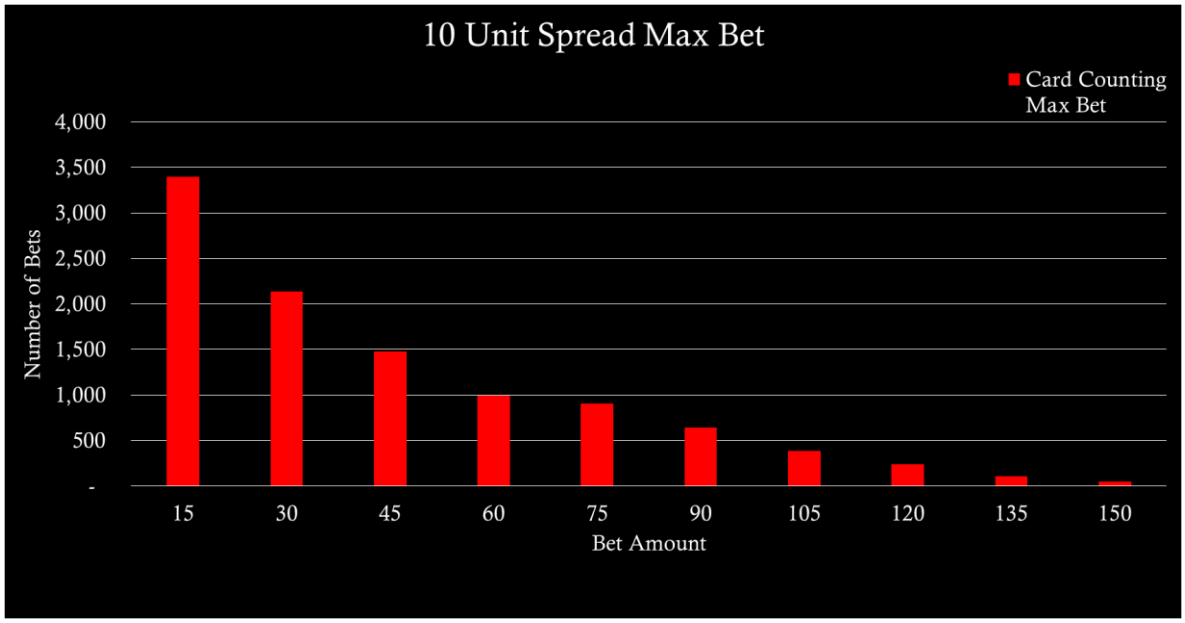
APPENDIX B: OBSERVATION MAXIMUM BETS



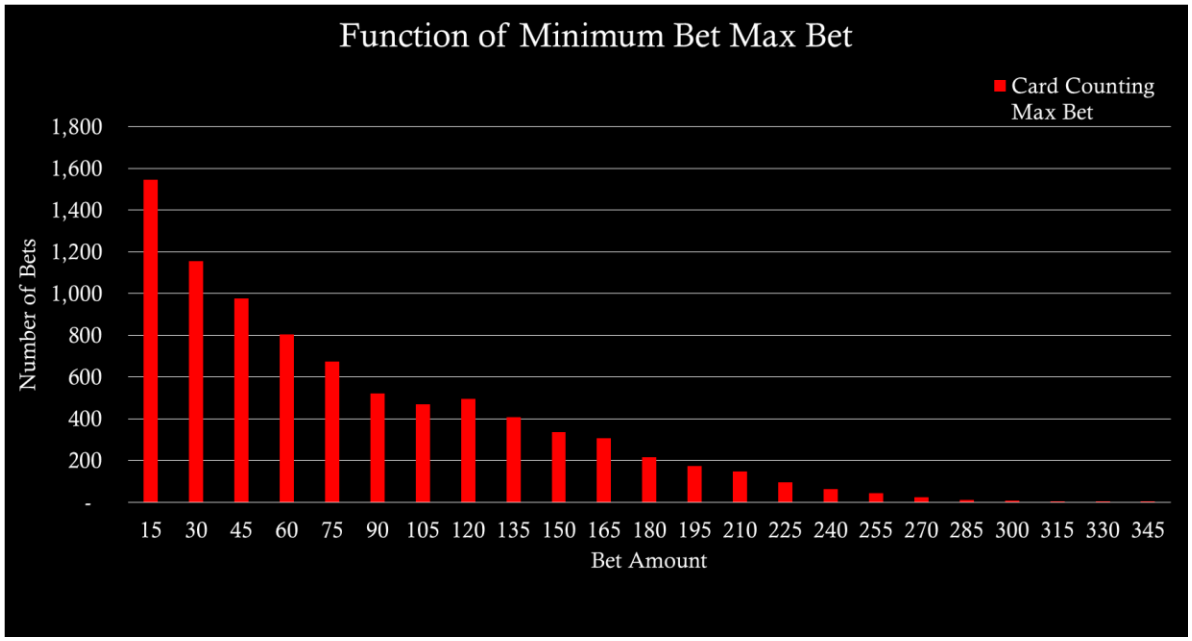
APPENDIX C: 5 UNIT SPREAD MAXIMUM BETS



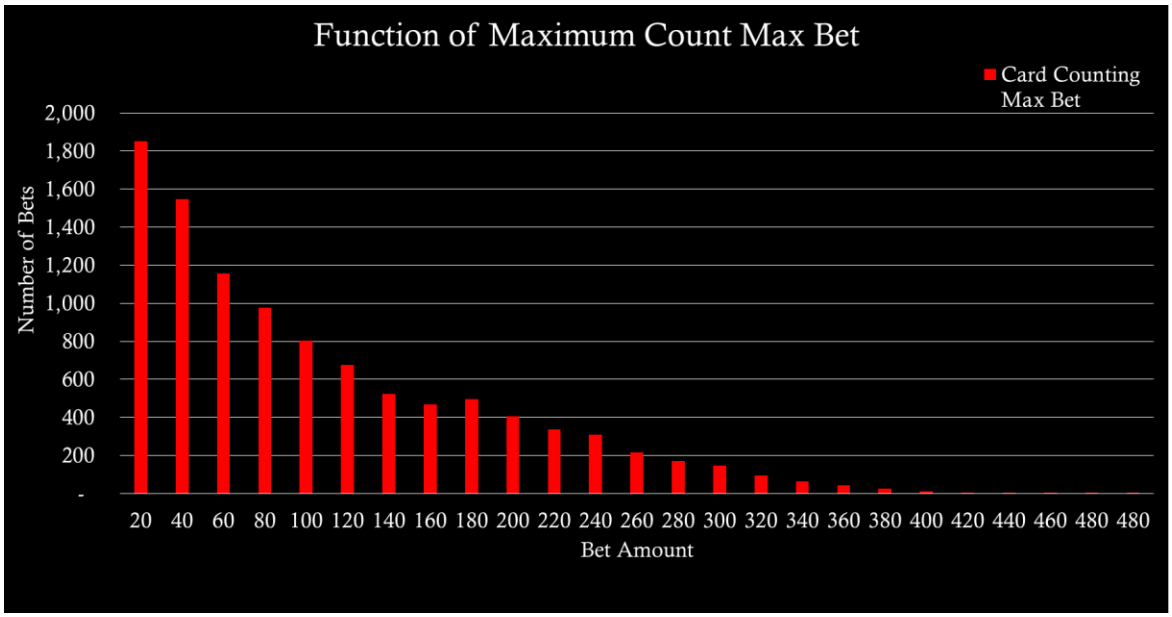
APPENDIX D: 10 UNIT SPREAD MAXIMUM BETS



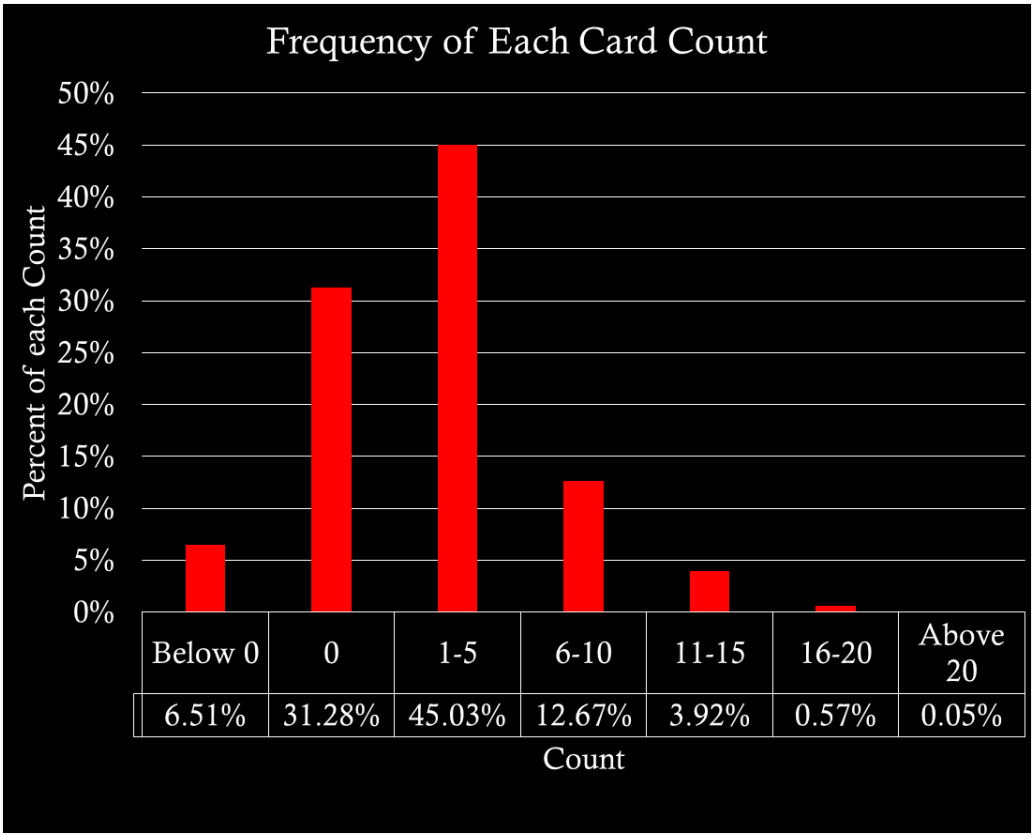
APPENDIX E: FUNCTION OF MINIMUM BET MAXIMUM BETS



APPENDIX F: FUNCTION OF MAXIMUM COUNT MAXIMUM BETS



APPENDIX G: FREQUENCY OF HIGH COUNTS



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