Golden Arm: A Probabilistic Study of Dice Control in Craps

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Abstract

This paper calculates how much control a craps shooter must possess on dice outcomes to eliminate the house advantage. A golden arm is someone who has dice control (or a rhythm roller or dice influencer). There are various strategies for dice control in craps. We discuss several possibilities of dice control that would result in several different mathematical models of control. We do not assert whether dice control is possible or not (there is a lack of published evidence). However, after studying casino-legal methods described by dice-control advocates, we can see only one realistic mathematical model that describes the resulting possible dice control, that in which the four faces on a rotating (horizontal) axis are favored. This is the model that we analyze in this paper.

Keywords: craps; dice; dice control; probability

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Wine loved I deeply, dice dearly
(William Shakespeare, King Lear, Act 3, Scene 4)

Introduction

Craps is a unique casino game because the shooter directly affects (i.e., picks up and throws) the gambling instruments (dice). Craps players, more than other casino gamblers, may be the most susceptible to Langer's (1975) illusion of control where they think they can control the outcome of a random game. In James Henslin's article "Craps and Magic" (1967) subjects were asked to roll a die. He found that when they wanted high numbers they threw hard and when the wanted low numbers they threw softly.

"If one were going to try to exert control over a chance event, one would exert influence before the outcome of the event was determined. […] Subjects were involved in a dice-throwing game in which they selected from a number of alternative wagers either before the dice were tossed or just after the toss but before the outcome was disclosed. They found that subjects took greater risks, that is, placed larger bets, when betting before rather than after the toss (Langer, 1975, pp. 312-313).

This paper studies how much influence a craps player must possess to beat the house advantage. We outline the most common dice control methods to measure the exact change in outcomes needed to overcome the house's advantage in a pass line bet in craps. We discuss several possibilities of dice control that would result in several different mathematical models of control. We do not assert whether dice control is possible or not (there is a lack of published evidence). However, after studying casino-legal methods described by dice-control advocates, we can see only one realistic mathematical model that describes the resulting possible dice control, that in which the four faces on a rotating (horizontal) axis are favored. This is the model that we analyze in this paper. We develop a deterministic model that yields solutions with static conditions. This information can be used in two ways: First, it gives dice controllers a specific minimum goal required to beat the traditional house advantage. Second, it provides estimates for how likely these outcomes are in random play.

A Brief History of Dice and Craps

Dice are prehistory. The earliest discovered six-sided dice date around 3,000 B.C. (Schwartz, 2006). Modern dice have the same number pattern where the sum of opposing sides always equal 7 (e.g., 1/6, 2/5 and 3/4 are always opposite each other). Casino dice (or precision dice) are regular hexahedrons (i.e., cubes) made from cellulose acetate—typically each side measures 0.75 inches. The spots (or pips) are drilled and then filled with an epoxy that is equal to the weight and density of the material removed.

Hazard is perhaps the earliest version of craps—where a player rolls a number then must roll that number again before her opponent. The name hazard was derived from the Arabic term for dice, az-zahr (Schwartz, 2006). Hazard was popular in England until the nineteenth century. Craps, as played today, started in New Orleans by French settlers, which they called crabs (rolling a 2, 3 or 12)—it is believed that a Gallic mispronunciation of crabs (or krabs) led to the name craps. "In 1804 the wealthy planter Bernard de Marigny lost so much of his money to [craps] he was forced to sell his land. He wistfully named a street carved from his property the Rue de Craps, perhaps the earliest mention of the game in America" (Schwartz, 2006, p. 250).

Casino Craps

The game of craps is played by a shooter rolling (shooting or throwing) two casino dice on a craps table, which vary in length from ten feet to fourteen feet. The inside lining of a craps table consists of a wall of rubber pyramids to introduce randomness—thus the dice must hit the opposing (short) wall to produce a fair throw. A shooter must place at least the table's minimum bet (spectators can bet or not); but only bettors are eligible to become shooters—the dice are passed to players clockwise. Bets are placed and the stickman uses a hooked stick to deliver the dice to a shooter. A shooter picks up the dice and throws to the far end of the table (a shooter can only handle the dice with one hand).

Craps is a two-state Markov chain. The first state is the come out roll and the odds are in favor of the shooter. If the dice add to 7 or 11 (known as a natural) then the pass line bets win.[1] If the shooter rolls a 2, 3 or 12 then this is known as craps and the pass line bets lose (don't pass line bets win with 2 and 3 and the game ends—a 12 (Bar 12) is a tie (or push) and the bet stays on the table until the game ends). During the come out roll any other number rolled is the point (4, 5, 6, 8, 9, 10). The second state of craps is the point cycle, and the odds shift demonstrably to the house's favor. If during the come out roll a point is established, then the shooter rolls until she gets a 7 (in which case the shooter's roll is over) or the dice equal the point number (e.g., pass line bets win) and the shooter starts again at the first stage (only the first roll in a game is technically known as the come out roll). Craps rolls follow a binomial distribution (see Table 1).

Table 1

Combinations and Probabilities of Craps Rolls

Number	Combinations	Odds	Probability
2	(1,1)	1 out of 36	2.78%
3	(1,2)(2,1)	2 out of 36	5.56%
4	(1,3)(2,2)(3,1)	3 out of 36	8.33%
5	(1,4)(2,3)(3,2)(4,1)	4 out of 36	11.11%
6	(1,5)(2,4)(3,3)(4,2)(5,1)	5 out of 36	13.89%
7	(1,6)(2,5)(3,4)(4,3)(5,2)(6,1)	6 out of 36	16.67%
8	(2,6)(3,5)(4,4)(5,3)(6,2)	5 out of 36	13.89%
9	(3,6)(4,5)(5,4)(6,3)	4 out of 36	11.11%
10	(4,6)(5,5)(6,4)	3 out of 36	8.33%
11	(5,6)(6,5)	2 out of 36	5.56%
12	(6,6)	1 out of 36	2.78%

The probability of winning (Pr (winning)) a pass line bet in craps is a combination of the come out roll and all subsequent rolls. The solution (using infinite series) follows:

$$\text{Pr (winning on the } n\text{th throw)} \begin{cases} 2\left(\frac{27}{36}\right)^{n-2}\left(\frac{3}{36}\right)^2 + 2\left(\frac{26}{36}\right)^{n-2}\left(\frac{4}{36}\right)^2 + 2\left(\frac{25}{36}\right)^{n-2}\left(\frac{5}{36}\right)^2 \; for \; n \geq 2 \\ \\ \frac{8}{36} \; for \; n = 1 \end{cases}$$

$$\text{The Pr (winning the game)} = \frac{8}{36} + 2\left(\frac{3}{36}\right)^2 \sum_{n=2}^{\infty}\left(\frac{27}{36}\right)^{n-2} + 2\left(\frac{4}{36}\right)^2 \sum_{n=2}^{\infty}\left(\frac{26}{36}\right)^{n-2} + 2\left(\frac{5}{36}\right)^2 \sum_{n=2}^{\infty}\left(\frac{25}{36}\right)^{n-2}$$

The first part of the equation calculates the odds of winning the come out roll—rolling a 7 or 11 (i.e., 6/36 + 2/36 = 8/36). The second part of the equation factors the odds of winning the come out roll (8/36) plus the odds of making your point. For example, if the point is 4 then there is a 3/36 (or 8.33%) probability of rolling a 4 and a 27/36 probability the roll is neither a 4 nor a 7. The probability for winning given with a point of 4 is the same as that for 10 (see Table 1 above), and 5 is the same probability as 9 and 6 is the same probability as 8, three functions are explicitly stated and multiplied by two (for more details see Mileti, 2008). Thus, summing all terms using a geometric progression leads to Pr(winning a game of craps) of 0.4929, or a house advantage of 1.414% on pass line bets.

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[1] It is beyond the scope of this paper to discuss all the betting possibilities in craps (there are many) and their subsequent payouts, so only common betting strategies are discussed (e.g., pass line and don't pass line).

Dice Control

Dice control is largely considered a myth. The idea that dice can be controlled in a modern casino on a typical craps table with the walls lined with pyramidal rubber (and some tables have "speed bumps" installed under the table's felt) appears doubtful. A sizable industry exists (e.g., books, videos and seminars) that teach people dice control. The History Channel produced an episode of their series Breaking Vegas (aired in 2004) called "Dice Dominator" that portrays the life of dice controller, Dominic "The Dominator" LoRiggio. Even the best dice controllers state that many hours of practice are required to get an advantage at craps—and a certain amount of natural skill (Wong, 2005). Great putters in golf can guide a golf ball into a hole under a variety of environmental factors; so, the idea is that throwing dice in craps can also be guided (to some degree).

There are examples of seemingly random games producing predictable outcomes (within a reasonable margin of error). One comparison to craps is roulette. Michael Small and Chi Kong Tse's paper "Predicting the Outcome of Roulette" (2012) shows clearly the process for predicting numbers in roulette with reasonable accuracy. Similarly, the paper "The Three-Dimensional Dynamics of the Die Throw" (Kapitaniak et al., 2012) questions whether a die that is fair by symmetry is also fair by dynamics. "Our studies show that the throw of the die is both deterministic and predictable (when the initial conditions are set with a sufficient accuracy). This confirms that closed dissipative mechanical systems cannot show chaotic behavior" (p. 7). While their model cannot be applied to casino craps directly, it is conceivable that under ideal conditions, dice control (to some degree) may be possible.

It is beyond the scope of this paper to test whether the various dice control methods work or not. These methods have not been studied in any rigorous way (at least none have been published in peer-reviewed journals). Even with a winning edge, shooters can still lose more money than they win with poor betting strategies. A pamphlet published by K.C. Card Co. (1927) titled "How to Control Fair Dice" presents various methods to control dice. First, the Hudson Shot (also known as the spin, English, Navy twist or whip shot) is where a shooter spins the dice out of her hand in such a way that the dice slide and spin rather than turn over. This method is illegal in casinos. Second, the Pique (or Peekay) shot is similar to the Hudson, but the goal is to release the dice out of your hand in a forward, sliding motion to reduce turnover (this method is also illegal). Third is the Blanket Roll, which is most similar to modern dice control methods. This shot usually occurs on a soft blanket or bed (hence the name) and the dice are thrown to ensure the top, bottom, front and back numbers roll straight ahead (thus eliminating the side numbers). When the dice are set with the top four numbers on each die in a way that is favorable to the thrower then that person can reduce the likelihood of the side numbers appearing on top (more below). The standard approach among all dice controllers (regardless of other methods taught) is to set the dice in a way that the front face combinations are ideal, thus reducing each individual die's outcomes from 1/6 to 1/4. Throwing on a casino craps table requires more skill because of the table's characteristics and casino rules; thus, modern dice control includes two principal elements: First, dice setting; second, throwing technique.

Dice Setting

All dice control methods we studied use dice setting. Dice setting ensures the arrangement of the dice when thrown (and settle) on their horizontal axis have a greater likelihood of producing desired results—i.e., all 16 combinations of the four front-facing faces will add up to a favorable number. For example, if we want to reduce the chance of rolling a 7 during the point cycle then we could use a variety of dice sets where the top numbers are less likely to add up to 7.

Throwing Technique

There are two aspects to throwing technique. First, is the grip. Most dice controllers set the dice side-by-side and use an overhand three finger grip—placing the thumb on the back of the dice (in the middle of the back seam between the two dice) with the index, middle and ring fingers gripping the front (the middle finger rests on the middle of the front seam). Second, most use a swinging arm motion (back then forward from low to high) that imparts a degree of backspin on the dice. The idea is to release the dice at the same time and at the correct launch angle (e.g., ~45 degrees) with sufficient on-axis (i.e., horizontal axis) backspin.[2] Ideally, this throw sends the dice to the far end

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2 There is debate about which launch angle is best, but many dice controllers aim for 40-45 degrees.

of the table hitting the table felt first then hitting below the bottom row of pyramids in an attempt to reduce randomness (i.e., the side numbers will not appear), but ensures a fair throw.

Beating the Craps out of the House

In this section we explain the common properties of dice control; but we do not attempt to show whether dice control is possible or not. Our question here is: How much control over the dice does a shooter need to have to overcome the house's odds on a pass line bet? First, we assume a dice controller can throw the dice in such a way that they spin on a horizontal axis and each die settles on only one of four front-facing (i.e., rotating) faces, which reduces the possible dice outcomes from 36 (6^2) to 16 (4^2). Each die can take three positions: A (2, 3, 4, 5) on top and (1, 6) on the side; B (1, 3, 4, 6) on top and (2, 5) on the side; and C (1, 2, 5, 6) on top and (3, 4) on the side. With the dice side-by-side and eliminating duplicates there are 6 possible dice arrangements A-A: (1, 6) on sides; A-B: (2, 6) on sides; A-C: (3, 6) on sides; B-B: (2, 5) on sides; B-C: (3, 5) on sides; C-C: (3, 4) on sides. These dice sets create the outcomes in Table 2.

Table 2

Dice Outcomes for Different Dice Sets with Perfect Control Over Horizontal Axis

	Dice Outcomes (Totals)											
Frequencies	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**N**
A-A	0	0	1	2	3	4	3	2	1	0	0	16
A-B	0	1	1	2	3	2	3	2	1	1	0	16
A-C	0	1	2	2	2	2	2	2	2	1	0	16
B-B	1	0	2	2	1	4	1	2	2	0	1	16
B-C	1	1	1	2	2	2	2	2	1	1	1	16
C-C	1	2	1	0	2	4	2	0	1	2	1	16

Given the dice sets in Table 2, we see that if a shooter can throw the dice on a perfect horizontal axis and get them to settle that way, then the best dice set for the come out roll is A-A, which eliminates craps numbers (2, 3 and 12) and has 4 out of 16 possible 7s. If a 6 or 8 point is established then set A-B is optimal since it gives equal outcomes (3/16) for the point numbers (6 or 8) and also has the lowest possible 7s (2 out of 16). If a 5 or 9 point is established then sets A-B, A-C and B-C produce low 7s (2/16) and highest point number odds (2/16 each). If a 4 or 10 is the point then set A-C is optimal since it gives a low probability of 7 (2/16) and the maximum chance of rolling a point (2/16 each). Thus an optimal strategy for "winning" could be described as using the A-A set for the come out roll, followed by A-B set for points {6,8} each with 3/16, or an A-C set for points {4,5,9,10} gives the following overall probability of winning (by conditioning on the first number rolled, multiplied by the conditional probability for winning the point):

$$= (1/16)*(1/2) + (2/16)*(1/2) + (3/16)*(3/5) + (4/16)*(1) + (3/16)*(3/5) + (2/16)*(1/2) + (1/16)*(1/2)$$

$$= (6/16)*(1/2) + 6/16*(3/5) + 4/16 = 53/80 = 66.25\%$$ (or a 32.5% advantage over the house), almost a two-thirds chance of winning!

Clearly there is no known dice controller who can achieve this kind of control, and if such a person started playing in the casinos, either the rolling rules or the tables would be changed to correct the situation. However, it is conceivable that a dice controller might be able to control the dice more weakly in a probabilistic sense. Hence, we will introduce a parameter that indicates the percentage of horizontal axis control, with a c value of 100% corresponding to perfect horizontal axis control and a c value of

0% corresponding to total randomness. The probability of attaining a particular face is a probabilistic mixture of the two random variables.

We made an Excel spreadsheet that shows the probabilities of any dice total numbers with any level of control for all six dice-setting strategies. The spreadsheet also will calculate the probability of winning for any of the six dice-setting strategies for the first roll, followed by any of the six dice–setting strategies for all subsequent rolls. It will further calculate the overall probability of winning with any level of control for the optimal strategy of using A-A for the come out roll, followed by a dice-strategy for subsequent rolls that depends on the point number, i.e. A-B for points {6,8} and an A-C strategy for points {4,5,9,10}. On this calculation sheet (which also produced Figure 1 below), we used Solver with the "value of" selection to find the level of control using the optimal strategy that gives a 50% probability of winning (or the break-even point), which equals an 8.03% level of control (c).

Figure 1 shows the probability of winning versus the level of control (c) for a pass line bet. To the right of the break-even point (the unshaded area) is a winning probability—the shaded area shows the level of dice control (c) for random (c = 0%) to the break-even point, where c = 8.03%.
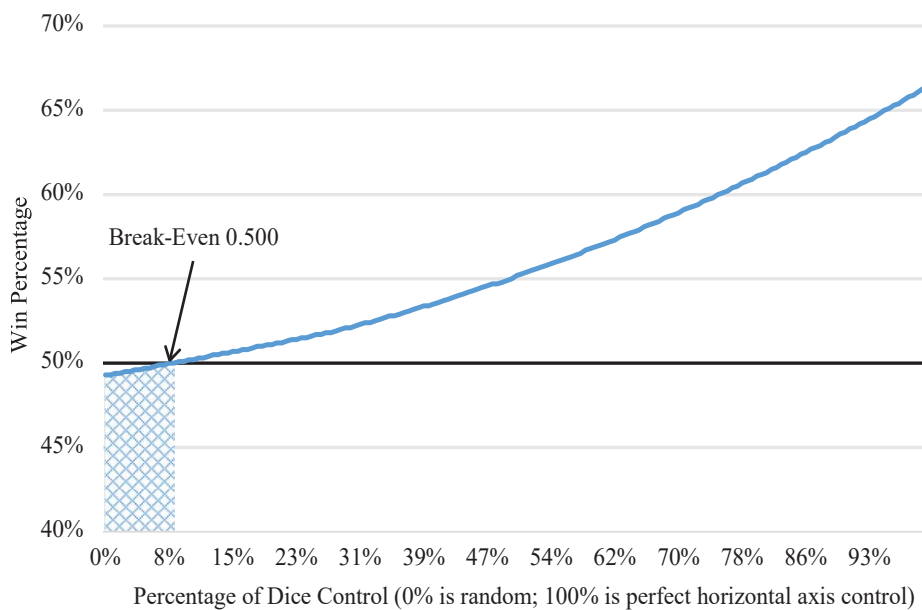

Figure 1. Win percentage in craps on a pass line bet given the level of dice control (0% is random and 100% is perfect horizontal axis control)

Sometimes a shooter is interested in controlling the dice, which might make it attractive to use sub-optimal dice sets on later rolls (depending on betting strategies). Clearly for a good dice controller in the point cycle, any of the strategies (A,B), (A,C) and (B,C) are tied with the lowest probabilities of rolling a seven.

Conclusion

Dice control is the idea that with the right throwing technique and dice set a craps shooter can throw the dice on their horizontal axis, thus reducing the chances of the side numbers landing up. We do not suppose whether dice control is possible or not. We showed above that there are six ways to set the dice. If the optimal dice set is chosen (both in the come out roll then in the point cycle) throwing the dice with perfect axis control (i.e., keeping the dice spinning on their horizontal axis and ending the same way) gives the shooter a 66.25% chance of winning the hand—or a 32.5% advantage over the house. This level of control is unrealistic, even among the best dice controllers. But using the same methods we found that to break-even at craps a shooter needs only an 8.03% level of control—where 0% is random and 100% is perfect horizontal axis control. While even this relatively small amount of control might seem implausible when shooters are required to hit the back wall (which is covered with random-inducing rubber pyramids) there are times when shooters can "short roll," i.e., get away with not hitting the back wall, which improves the chance of maintaining control. While this study does not

investigate the possibilities of dice control (and the illusion of control is no doubt present among many craps players), our deterministic models yield static results outlining the various probabilities associated with known dice control techniques.

References

Fleming, J., & Darley, J. (1989). Perceiving choice and constraint: the effects of contextual and behavioral cues on attitude attribution. *Journal of Personality and Social Psychology*, 56(1), 27–40.

Henslin, J. (1967). Craps and magic. *American Journal of Sociology*, 73, 316-330.

Kapitaniak, M., Strzalko, J., Grabski, J., & Kapitaniak, T. (2012) The three-dimensional dynamics of the die throw. *Chaos* 22, 1-8.

K. C. Card Co. (1927). *How to Control Fair Dice*, K. C. Card Co.

Langer, E. J. (1975). The illusion of control. *Journal of Personality and Social Psychology*, 32(2), 311-328.

Langer, E. J. (1977). The psychology of chance. *Journal for the Theory of Social Behaviour*, 7(2), 185–203.

Mileti, J. (2008). Infinite series and gambling. Retrieved from https://math.dartmouth.edu/archive/m60s08/public_html/craps.pdf

Schwartz, D. (2006). *Roll the Bones: The History of Gambling*. New York, NY: Gotham.

Small, M. & Tse, C. K. (2012) Predicting the outcome of roulette. Chaos, 22, 033150.

Wong, S. (2005). *Wong on Dice*. Las Vegas, NV: Pi Yee Press.