

## Stat 100a: Introduction to Probability.

### Outline for the day:

1. Kohlberg/Murphy example.
2. A♠ vs 2♣ after first ace.
3. Negreanu and Elezra.
4. Conditional probability, independence, and multiplication rule.
5. Independence and dependence examples.
6. Odds ratios.
7. Random variables.
8. cdf, pmf, and density, or pdf.
9. Expected value.
10. Gus vs. Daniel.
11.  $P(\text{flop 3 of a kind})$ ,  $P(\text{eventually 4 of a kind})$ ,  $P(\text{flop full house})$ .
12. Heads up with AA or 55.

Read through chapter 4!

Note that the answers to many odd problems are in the back of the book.



1. Example: *Poker Royale: Comedians vs. Poker Pros*, Fri 9/23/05.

Linda Johnson	\$543,000	Kathy Kolberg	\$300,000
Phil Laak	\$475,000	Sue Murphy	\$155,000
Tammy Pescatelli	\$377,000	Mark Curry	\$0.

No small blind. Johnson in big blind for \$8000.

Murphy (8♥ 8♠). Calls \$8,000.

Kolberg. (9♣ 9♦). Raises to \$38,000.

Pescatelli (Kh 3♠) folds, Laak (9♥ 3♥) folds, Johnson (J♥ 6♦) folds.

Murphy calls.

TV Screen: Kolberg. (9♣ 9♦) 81% Murphy (8♥ 8♠) 19%

Flop: 8♣ 10♦ 10♠.

Murphy quickly goes all in. Kolberg thinks for 2 min, then calls.

Laak (to Murphy): “You’re 92% to take it down.”

TV Screen: Kolberg. (9♣ 9♦) 17% Murphy (8♥ 8♠) 83%

Who’s right?

(Turn 9♠ river A♦), so Murphy is eliminated. Laak went on to win.

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Cardplayer.com: 16.8% 83.2%

Laak (about Kolberg): “She has two outs twice.”

P(9 on the turn or river, given just their 2 hands and the flop)?

= P(9 on turn) + P(9 on river) - P(9 on both)

=  $2/45 + 2/45 - 1/\text{choose}(45,2)$  = 8.8%

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Given just their 2 hands and the flop, what is

P(9 or T on the turn or river, but not 98 or T8)?

$$\begin{aligned} &P(9 \text{ or } T \text{ on the turn}) + P(9 \text{ or } T \text{ on river}) - P(9T) - [P(98) + P(T8)] \\ &= 4/45 + 4/45 - [\text{choose}(4,2) + 2 + 2]/\text{choose}(45,2) = 16.77\% \end{aligned}$$

2. Deal til first ace appears. Let  $X$  = the *next* card after the ace.

$P(X = A\spadesuit)$ ?  $P(X = 2\clubsuit)$ ?

(a) How many permutations of the 52 cards are there?

52!

(b) How many of these perms. have  $A\spadesuit$  right after the 1st ace?

(i) How many perms of the *other* 51 cards are there?

51!

(ii) For *each* of these, imagine putting the  $A\spadesuit$  right after the 1st ace.

1:1 correspondence between permutations of the other 51 cards & permutations of 52 cards such that  $A\spadesuit$  is right after 1st ace.

So, the answer to question (b) is 51!.

Answer to the overall question is  $51! / 52! = 1/52$ .

Obviously, same goes for  $2\clubsuit$ .

3. Negreanu and Elezra.

#### 4. Conditional Probability, Independence, & Mult. Rule.

$P(A \& B)$  is often written “ $P(AB)$ ”.

“ $P(A \cup B)$ ” means  $P(A \text{ or } B \text{ [or both]})$ .

Conditional Probability:

$P(A \text{ given } B)$  [written “ $P(A|B)$ ”] =  $P(AB) / P(B)$ .

Independent: A and B are “independent” if  $P(A|B) = P(A)$ .

Fact (*multiplication rule for independent events*):

If A and B are independent, then  $P(AB) = P(A) \times P(B)$

Fact (*general multiplication rule*):

$$P(AB) = P(A) P(B|A)$$

$$P(ABC\dots) = P(A) \times P(B|A) \times P(C|A\&B) \dots$$

## 5. Independence and Dependence Examples

Independence:  $P(A \mid B) = P(A)$  [and  $P(B \mid A) = P(B)$ ].

So, when independent,  $P(A \& B) = P(A)P(B \mid A) = P(A)P(B)$ .

Reasonable to assume the following are independent:

- a) Outcomes on different rolls of a die.
- b) Outcomes on different flips of a coin.
- c) Outcomes on different spins of a spinner.
- d) Outcomes on different poker hands.
- e) Outcomes when sampling from a large population.

Ex:  $P(\text{you get AA on 1st hand and I get AA on 2nd hand})$

$$= P(\text{you get AA on 1st}) \times P(\text{I get AA on 2nd})$$

$$= 1/221 \times 1/221 = 1/48841.$$

$P(\text{you get AA on 1st hand and I get AA on 1st hand})$

$$= P(\text{you get AA}) \times P(\text{I get AA} \mid \text{you have AA})$$

$$= 1/221 \times 1/(50 \text{ choose } 2) = 1/221 \times 1/1225 = 1/270725.$$

Example: High Stakes Poker, 1/8/07, Negreanu vs. Elezra.

Greenstein folds, Todd Brunson folds, Harman folds. Elezra calls \$600, Farha (K♠ J♥) raises to \$2600, Sheikhan folds. Negreanu calls, Elezra calls. Pot is \$8,800.

Flop: 6♠ 10♠ 8♥.

Negreanu bets \$5000. Elezra raises to \$15000. Farha folds.

Negreanu thinks for 2 minutes..... then goes all-in for another \$96,000.

Elezra: 8♣ 6♣. (Elezra calls. Pot is \$214,800.)

Negreanu: A♦ 10♥.

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At this point, the odds on tv show 73% for Elezra and 25% for Negreanu.

They “run it twice”. First: 2♠ 4♥. Second time? A♥ 8♦!

P(Negreanu hits an A or 10 on turn & still loses)?



Given both their hands, and the flop, and the first “run”, what is  $P(\text{Negreanu hits an A or 10 on the turn \& loses})$ ?

Since he can't lose if he hits a 10 on the turn, it's:

$P(\text{A on turn \& Negreanu loses})$

$$= P(\text{A on turn}) \times P(\text{Negreanu loses} \mid \text{A on the turn})$$

$$= \frac{3}{43} \times \frac{4}{42}$$

$$= 0.66\% \text{ (1 in 150.5)}$$

Note: this is very different from:

$P(\text{A or 10 on turn}) \times P(\text{Negreanu loses}),$

which would be about  $\frac{5}{43} \times 73\% = 8.49\% \text{ (1 in 12)}$

## 6. Odds ratios.

Odds ratio of A =  $P(A)/P(A^c)$

Odds *against* A = Odds ratio of  $A^c = P(A^c)/P(A)$ .

Ex: (from Phil Gordon's *Little Blue Book*, p189)

Day 3 of the 2001 WSOP, \$10,000 No-limit holdem championship.

613 players entered. Now 13 players left, at 2 tables.

Phil Gordon's table has 5 other players. Blinds are 3,000/6,000 + 1,000 antes.

Matusow has 400,000; Helmuth has 600,000; Gordon 620,000.

(the 3 other players have 100,000; 305,000; 193,000).

Matusow raises to 20,000. Next player folds.

Gordon's next, in the *cutoff seat* with  $K\clubsuit K\spadesuit$  and re-raises to 100,000.

Next player folds. Helmuth goes all-in. Big blind folds. Matusow folds.

Gordon's decision.... Fold!

Odds against Gordon winning, if he called and Helmuth had AA?

What were the odds against Gordon winning, if he called and Helmut had AA?

$P(\text{exactly one K, and no aces}) = 2 \times C(44,4) / C(48,5) \sim 15.9\%$ .

$P(\text{two Kings on the board}) = C(46,3) / C(48,5) \sim 0.9\%$ .

[also some chance of a straight, or a flush...]

Using [www.cardplayer.com/poker\\_odds/texas\\_holdem](http://www.cardplayer.com/poker_odds/texas_holdem),

$P(\text{Gordon wins})$  is about 18%, so the odds against this are:

$P(A^c)/P(A) = 82\% / 18\% = 4.6$  (or “4.6 to 1” or “4.6:1”).

## 7. Random variables.

A *variable* is something that can take different numeric values.

A *random variable* (X) can take different numeric values with different probabilities.

X is *discrete* if all its possible values can be listed. If X can take any value in an interval like say  $[0,1]$ , then X is *continuous*.

Ex. Two cards are dealt to you. Let X be 1 if you get a pair, and X is 0 otherwise.

$$P(X \text{ is } 1) = 3/51 \sim 5.9\%.$$

$$P(X \text{ is } 0) \sim 94.1\%.$$

Ex. A coin is flipped, and  $X=20$  if heads,  $X=10$  if tails.

The *distribution* of X means all the information about all the possible values X can take, along with their probabilities.

## 8. cdf, pmf, and density (pdf).

Any random variable has a *cumulative distribution function* (cdf):

$$F(b) = P(X \leq b).$$

If  $X$  is discrete, then it has a *probability mass function* (pmf):

$$f(b) = P(X = b).$$

Continuous random variables are often characterized by their *probability density functions* (pdf, or *density*):

a function  $f(x)$  such that  $P(X \text{ is in } B) = \int_B f(x) \, dx$ .

## 19. Expected Value.

For a discrete random variable  $X$  with pmf  $f(b)$ , the *expected value* of  $X = \sum b f(b)$ .

The sum is over all possible values of  $b$ . (continuous random variables later...)

The expected value is also called the *mean* and denoted  $E(X)$  or  $\mu$ .

Ex: 2 cards are dealt to you.  $X = 1$  if pair, 0 otherwise.

$P(X \text{ is } 1) \sim 5.9\%$ ,  $P(X \text{ is } 0) \sim 94.1\%$ .

$E(X) = (1 \times 5.9\%) + (0 \times 94.1\%) = 5.9\%$ , or 0.059.

Ex. Coin,  $X=20$  if heads,  $X=10$  if tails.

$E(X) = (20 \times 50\%) + (10 \times 50\%) = 15$ .

Ex. Lotto ticket.  $f(\$10\text{million}) = 1/\text{choose}(52,6) = 1/20\text{million}$ ,  $f(\$0) = 1 - 1/20\text{mil}$ .

$E(X) = (\$10\text{mil} \times 1/20\text{million}) = \$0.50$ .

The expected value of  $X$  represents a *best guess* of  $X$ .

Compare with the *sample mean*,  $\bar{X} = (X_1 + X_1 + \dots + X_n) / n$ .

Some reasons why Expected Value applies to poker:

- Tournaments: some game theory results suggest that, in symmetric, winner-take-all games, the optimal strategy is the one which uses the *myopic rule*: that is, given any choice of options, always choose the one that maximizes your *expected value*.
- Laws of large numbers: Some statistical theory indicates that, if you repeat an experiment over and over repeatedly, your long-term average will ultimately converge to the *expected value*. So again, it makes sense to try to maximize expected value when playing poker (or making deals).
- Checking results: A great way to check whether you are a long-term winning or losing player, or to verify if a certain strategy works or not, is to check whether the sample mean is positive and to see if it has converged to the *expected value*.

10. High Stakes Poker: Daniel vs. Gus

11. Which is more likely, given no info about your cards:

- \* flopping 3 of a kind,

or

- \* eventually making 4 of a kind?



11. P(flop 3-of-a-kind)?

[including case where all 3 are on board, and *not including full houses*]

Key idea: forget order! Consider all combinations of your 2 cards and the flop.

Sets of 5 cards. Any such combo is equally likely!  $\text{choose}(52,5)$  different ones.

$$P(\text{flop 3 of a kind}) = \# \text{ of different 3 of a kinds} / \text{choose}(52,5)$$

How many different 3 of a kind combinations are possible?

$13 * \text{choose}(4,3)$  different choices for the triple.

For each such choice, there are  $\text{choose}(12,2)$  choices left for the numbers on the other 2 cards, and for each of these numbers, there are 4 possibilities for its suit.

$$\text{So, } P(\text{flop 3 of a kind}) = 13 * \text{choose}(4,3) * \text{choose}(12,2) * 4 * 4 / \text{choose}(52,5)$$

$$\sim 2.11\%, \text{ or } 1 \text{ in } 47.3.$$

$$P(\text{flop 3 of a kind or a full house}) = 13 * \text{choose}(4,3) * \text{choose}(48,2) / \text{choose}(52,5)$$

$$\sim 2.26\%, \text{ or } 1 \text{ in } 44.3.$$

P(eventually make 4-of-a-kind)? [including case where all 4 are on board]

Again, just forget card order, and consider all collections of 7 cards.

Out of  $\text{choose}(52,7)$  different combinations, each equally likely, how many of them involve 4-of-a-kind?

13 choices for the 4-of-a-kind.

For each such choice, there are  $\text{choose}(48,3)$  possibilities for the other 3 cards.

So,  $P(4\text{-of-a-kind}) = 13 * \text{choose}(48,3) / \text{choose}(52,7) \sim 0.168\%$ , or 1 in 595.

## 12. Heads up with AA.

Dan Harrington says that, “with a hand like AA, you really want to be one-on-one.” True or false?

\* Best possible pre-flop situation is to be all in with AA vs A8, where the 8 is the same suit as one of your aces, in which case you're about 94% to win. (the 8 could equivalently be a 6,7, or 9.) If you are all in for \$100, then your expected holdings afterwards are \$188.

a) In a more typical situation: you have AA against TT. You're 80% to win, so your expected value is \$160.

b) Suppose that, after the hand vs TT, you get QQ and get up against someone with A9 who has more chips than you do. The chance of you winning this hand is 72%, and the chance of you winning both this hand and the hand above is 58%, so your expected holdings after both hands are \$232: you have 58% chance of having \$400, and 42% chance to have \$0.

c) Now suppose instead that you have AA and are all in against 3 callers with A8, KJ suited, and 44. Now you're 58.4% to quadruple up. So your expected holdings after the hand are \$234, and the situation is just like (actually slightly better than) #1 and #2 combined: 58.4% chance to hold \$400, and 41.6% chance for \$0.

\* So, being all-in with AA against 3 players is much better than being all-in with AA against one player: in fact, it's about like having two of these lucky one-on-one situations.

### What about with a low pair?

a) You have \$100 and 55 and are up against A9. You are 56% to win, so your expected value is \$112.

b) You have \$100 and 55 and are up against A9, KJ, and QJs. Seems pretty terrible, doesn't it? But you have a probability of 27.3% to quadruple, so your expected value is

$0.273 \times \$400 = \$109$ . About the same as #1!

[ For these probabilities, see

[http://www.cardplayer.com/poker\\_odds/texas\\_holdem](http://www.cardplayer.com/poker_odds/texas_holdem) ]