**SEIS 631 Foundations of Data Analysis**

**Assignment 3**

Basketball players who make several baskets in succession are described as having a “hot hand”. Fans and players have long believed in the hot hand phenomenon, which refutes the assumption that each shot is independent of the next. However, a 1985 paper by Gilovich, Vallone, and Tversky collected evidence that contradicted this belief and showed that successive shots are independent events. This paper started a great controversy that continues to this day. In this assignment we’ll apply one approach to answering questions like this.

The goals for this assignment are to (1) think about the effects of independent and dependent events, (2) learn how to simulate shooting streaks in R, and (3) to compare a simulation to actual data in order to determine if the hot hand phenomenon appears to be real.

**Getting Started:** Our investigation will focus on the performance of one player: Kobe Bryant of the Los Angeles Lakers. His performance against the Orlando Magic in the 2009 NBA finals earned him the title “Most Valuable Player” and many spectators commented on how he appeared to show a hot hand. Let’s load some data from those games and look at the first several rows:

**load("kobe.RData")**

**head(kobe)**

In this data frame, every row records a shot taken by Kobe Bryant. If he hit the shot (made a basket), a hit, H, is recorded in the column named basket, otherwise a miss, M, is recorded.

Just looking at the string of hits and misses, it can be difficult to gauge whether or not it seems like Kobe was shooting with a hot hand. One way we can approach this is by considering the belief that hot hand shooters tend to go on shooting streaks. For this assignment, we define the length of a shooting streak to be the *number of consecutive baskets made until a miss occurs*.

For example, in Game 1 Kobe had the following sequence of hits and misses from his nine shot attempts in the first quarter:

H M *|* M *|* H H M *|* M *|* M *|* M

To verify this use the following command:

**kobe$basket[1: 9]**

Within the nine shot attempts, there are six streaks, which are separated by a “*|* ” above. Their lengths are one, zero, two, zero, zero, zero (in order of occurrence).

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| **Question 1** [MULTIPLE CHOICE] What does a streak length of 1 mean, i.e. how many hits and misses are in a streak of 1? (a) A miss followed by a hit. (b) A hit followed by a miss. (c) Two hits followed by a miss. |

The custom function **calc\_streak**, which was loaded in with the data, can be used to calculate the lengths of all shooting streaks and then look at the distribution.

**kobe\_streak <- calc\_streak(kobe$basket)  
barplot(table(kobe\_streak))**

Note that instead of making a histogram, we chose to make a bar plot from a table of the streak data. A bar plot is preferable here since our variable is discrete – counts – instead of continuous.

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| **Question 2** [MULTIPLE CHOICE] Which of the following is ***FALSE***about the distribution of Kobe’s streak lengths from the 2009 NBA finals. (note – only one of the answers is false). *Hint: You might want to also use other visualizations and summaries of kobe streak in order to answer* *this question.* (a) The distribution of Kobe’s streaks is unimodal and left skewed. (b) The typical length of a streak, as measured by the median, is 0. (c) The IQR of the distribution is 1. (d) Streak lengths of 3 and 4 are unusually high compared to the rest of the distribution. |

**Compared to What?:** We’ve shown that Kobe had some long shooting streaks, but are they long enough to support the belief that he had hot hands? What can we compare them to? To answer these questions, let’s return to the idea of *independence*. Two processes are independent if the outcome of one process doesn’t affect the outcome of the second. If each shot that a player takes is an independent process, having made or missed your first shot will not affect the probability that you will make or miss your second shot.

A shooter with a hot hand will have shots that are *not* independent of one another. Specifically, if the shooter makes his first shot, the hot hand model says he will have a *higher* probability of making his second shot.

Let’s suppose for a moment that the hot hand model is valid for Kobe. During his career, the percentage of time Kobe makes a basket (i.e. his shooting percentage) is about 45%, or in probability notation, *P* (shot 1 = H ) = 0.45.

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| **Question 3** [TRUE / FALSE] If Kobe has a hot hand (not independent shots), then the probability that he makes his second shot would go up given that he made the first shot: *P*(shot 2 = H *|* shot 1 = H ) *>* 0.45 *◦* TRUE *◦* FALSE |

As a result of these increased probabilities, you’d expect Kobe to have longer streaks. Compare this to the skeptical perspective where Kobe does *not* have a hot hand, where each shot is independent of the next. If he hit his first shot, the probability that he makes the second is still 0.45, i.e. *P* (shot 2 = H *|* shot 1 = H) = 0.45.

In other words, making the first shot did nothing to affect the probability that he’d make his second shot. If Kobe’s shots are independent, then he’d have the same probability of hitting every shot regardless of his past shots: 45%.

Now that we’ve phrased the situation in terms of independent shots, let’s return to the question: how do we tell if Kobe’s shooting streaks are long enough to indicate that he has hot hands? We can compare his streak lengths to someone without hot hands: an independent shooter.

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| **Question 4** [MULTIPLE CHOICE] If Kobe’s shooting streaks diverge significantly from an independent shooter’s streaks, (a) we can conclude that Kobe likely has a hot hand. (b) we can conclude that his shots are likely independent. (c) we cannot conclude anything |

**Simulations in R:** While we don’t have any data from a shooter we know to have independent shots, that is very easy to simulate in R. In a simulation, you set the ground rules of a random process and then the computer uses random numbers to generate an outcome that adheres to those rules. As a simple example, you can simulate flipping a fair coin with the following,

**outcomes <- c("heads", "tails")  
sample(outcomes, size = 1, replace = TRUE)**

The vector outcomes can be thought of as a hat with two slips of paper in it: one slip says “heads” and the other says “tails”. The function sample draws one slip from the hat and tells us if it was a head or a tail.

Run the second command listed above several times. Just like when flipping a coin, sometimes you’ll get a heads, sometimes you’ll get a tails, but in the long run, you’d expect to get roughly equal numbers of each.

If you wanted to simulate flipping a fair coin 100 times, you could either run the function 100 times or, more simply, adjust the size argument, which governs how many samples to draw (the replace = TRUE argument indicates we put the slip of paper back in the hat before drawing again). Save the resulting vector of heads and tails in a new object called sim\_fair\_coin.

**sim\_fair\_coin <- sample(outcomes, size = 100, replace = TRUE)**

To view the results of this simulation, type the name of the object and then use table to count up the number of heads and tails,

**sim\_fair\_coin  
table(sim\_fair\_coin)**

Since there are only two elements in outcomes, the probability that we “flip” a coin and it lands heads is 0.5. Say we’re trying to simulate an unfair coin that we know only lands heads 20% of the time. We can adjust for this by adding an argument called prob, which provides a vector of two probability weights.

**sim\_unfair\_coin <- sample(outcomes, size = 100, replace = TRUE, prob = c(0.2, 0.8))**

prob=c(0.2,0.8) indicates that for the two elements in the outcomes vector, we want to select the first one, heads, with probability 0.2 and the second one, tails with probability 0.8.

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| **Question 5**: In your simulation of flipping the unfair coin 100 times, how many flips came up heads? |

In a sense, we shrunk the size of the slip of paper that says “heads”, making it less likely to be drawn and we’ve increased the size of the slip of paper saying “tails”, making it more likely to be drawn. When we simulated the fair coin, both slips of paper were the same size. This happens by default if you don’t provide a prob argument; all elements in the outcomes vector have an equal probability of being drawn. If you want to learn more about sample or any other function, recall that you can always check out its help file,

**?sample**

**Simulating the Independent Shooter:** Simulating a basketball player who has independent shots uses the same mechanism that we use to simulate a coin flip. To simulate a single shot from an independent shooter with a shooting percentage of 50% we type,

**outcomes <- c("H", "M")  
sim\_basket <- sample(outcomes, size = 1, replace = TRUE)**

To make a valid comparison between Kobe and our simulated independent shooter, we need to align both their shooting percentages and their numbers of attempted shots.

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| What change needs to be made to the sample function so that it reflects a shooting percentage of 45%? Make this adjustment, then run a simulation to sample 133 shots (the number of shots of Kobe in this dataset). Assign the output of this simulation to a new object called sim\_basket. |

Note that we’ve named the new vector sim\_basket, the same name that we gave to the previous vector reflecting a shooting percentage of 50%. In this situation, R overwrites the old object with the new one, so always make sure that you don’t need the information in an old vector before reassigning its name.

With the results of the simulation saved as sim\_basket, we have the data necessary to compare Kobe to our independent shooter. We can look at Kobe’s data alongside our simulated data.

**kobe$basket  
sim\_basket**

Both data sets represent the results of 133 shot attempts, each with the same shooting percentage of 45%. We know that our simulated data is from a shooter that has independent shots. That is, we know the simulated shooter does not have a hot hand.

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| **Question 6**: Using calc\_streak, compute the streak lengths of sim\_basket. Describe the distribution of streak lengths.  True or False: Since Kobe’s streak length distribution looks very similar to the independent shooter’s simulated streak length distribution, we can conclude that Kobe Bryant likely does not have a “hot hand”. *◦* TRUE *◦* FALSE |

Save your script as a .R file by moving your cursor into your script, then selecting File-Save, or ctl+S.

**Submission:**

Submit the following two files (no need to compress into a folder):

* **Pdf or word document** with answers to all the questions asked in the assignment.
* **.R file** with relevant code. It is useful to add comments within the code with a pound sign.