Aalto-yliopisto
Aalto-universitetet
Aalto University

Bachelor's Programme in 2023

Analysis of the Hot Hand Phenomenon: Examining Its Influence on Decision-Making and Probabilistic Errors in Basketball

---

Otto Pakarinen

Bachelor's thesis
2023

Aalto-yliopisto
Aalto-universitetet
Aalto University

Author Otto Pakarinen

Title of thesis Analysis of the Hot Hand Phenomenon: Examining Its Influence on Decision Making and Probabilistic Errors in Basketball

Programme Bachelor of Science in Economics and Business Administration

Major Economics

Thesis supervisor Nelli Valmari

Thesis advisor(s) Daniel Hauser

Date 21.12.2023 **Number of pages** 25 **Language** English

Abstract

This thesis analyses the concepts of hot hand and hot hand bias. I observe these concepts in basketball context. The thesis is a literature review, in which I analyse these concepts based on previous research. In the past hot hand in basketball was thought of being a myth. In the thesis I present newer papers that have been able to find a hot hand effect in different basketball scenarios. Research in this field shows that the closer a situation resembles a controlled setting, the stronger hot hand effect is often found. Based on the found hot hand effect, and in some cases lack of one, I then analyse the possibility of judgement bias and irrational decision-making, which is caused by the hot hand bias. In run of play basketball there are situations in which the hot hand bias likely exists for both the defending and the attacking sides.

Keywords Hot Hand, Hot Hand Bias, Basketball

Table of contents

1 Introduction

This thesis observes the "*hot hand"* phenomenon. Generally, the phenomenon describes "a random process in which outcomes sometimes enter a "hot" state and have temporarily higher probability than normal" (Benjamin, 2018). The thesis is a literature review, in which I analyze the hot hand phenomenon and its implications. The main implication being a phenomenon called "*hot hand bias"* and the probabilistically irrational reasoning it could lead to. Essentially, in their decision-making process, people sometimes overvalue the effect of a hot hand, which then leads to suboptimal decisions. Consecutive coin flips can be used as an example for both the hot hand and the hot hand bias. If consecutive flips yielding heads increased the chances of more heads showing up in the following flips, this would indicate a hot hand effect. In this example if someone believes in this hot hand effect, they would be experiencing a hot hand bias, as with a fair coin, the probability for heads and tails is always 50 %.

This thesis explores irrational decision-making by first trying to evaluate the existence and magnitude of a true hot hand effect in different scenarios. After this, it can be analysed, whether people's actions align with the actual hot hand effect. If, however, the actions suggest that people are overvaluing the effect, it indicates hot hand bias. The bias is interesting to analyse from economics perspective, since one of the main principles in economics, is the assumption that agents' behavior is rational and optimizing (Aharoni and Sarig, 2012). The bias, if found, contradicts this assumption.

The thesis reviews the hot hand in a sports context. Most of the research in the hot hand is done on basketball, which is also the focus in this paper. Basketball is a global, financially significant business and in 2022 National the Basketball Association (NBA) alone generated just over 10 billion in revenue (Statista, 2022). This means that all results, and the decisions leading up to them, are worth a substantial amount of money. Uncovering and fixing probabilistically irrational behavior in the game could lead to teams making monetary victories. Also, if results are found in basketball, it could make possible the implementation of these results regarding human behavior into different fields of research.

Firstly, the thesis clarifies the concepts “hot hand” and “hot hand bias”. Then, I go through some of the history of the hot hand and explain why incorrect math by Gilovich et al. (1985) shaped the belief around hot hand in the wrong direction. I analyse the existence of the actual hot hand in various scenarios in a basketball context. Based on the findings in terms of the real hot hand, I also try to uncover the possible bias around it. In essence, to see, if people in basketball overvalue the effect of a hot hand based on how they react to it. Rational behavior in basketball can be defined as an action that either helps a team to score more points or makes it more difficult for the opposition to score more points (Csapo and Raab, 2014).

2 Concepts

Before getting into the thesis, it is important to define the concepts, around which, I write this paper. From the two main concepts, I first define hot hand and then hot hand bias, both in their own sub-sections. I also include relevant examples of these concepts from other sports and other real-life scenarios.

2.1 Hot hand

Hot hand has somewhat lacked a precise definition in literature (Green and Zwiebel, 2018). The term is the most popularly used in a basketball context. While watching the sport people can often hear commentators describing player “having a hot hand” or saying a player is a “streak shooter” (Gilovich et al., 1985). However, the term can describe any random process where positive outcomes enter a “hot” state and at least temporarily have a higher probability than usual (Benjamin, 2018). Moreover, this implies that in scenarios where hot hand is in effect, positive outcomes breed more positive outcomes.

In sports, people tend to believe that teams and players are in “good form” when they perform many successful plays in a row. This then leads to people believing that the in-form players are due to continue plays with positive outcome (Gilovich et al., 1985). However, it is debated if these patches of good form will lead to higher probability of positive outcome plays in the future (Lantis and Nesson, 2021a). For example, in

basketball there is empirical proof from Gilovich et al. (1985) and Brown and Sauer (1993) stating that many players, coaches and fans believe that the hot hand really exists. Still, there is mixed evidence on if this is the case (Lantis and Nesson, 2021a).

There is proof of a hot hand existing in other sports than basketball. One paper on baseball, made by Green and Zwiebel (2018), research hot hand in 5 categories for batters and pitchers each and finds evidence for a hot hand in all of them. One concrete example from their paper is that on average a 50th percentile hitter will hit as good as a 75th percentile hitter when they had previously performed consecutive successful hits. This suggests that consecutive successful plays can elevate player's performance during games, as if their ability to play baseball had improved. Most studies that have been able to find evidence for a hot hand in sports are from individual sports. This is because in individual sports the omitted variable bias is more limited compared to team sports (Smith, 2003). There is evidence on hot hand also existing for example in darts (Jin, 2018) and bowling (Yaari and David, 2012). This thesis, however, will focus on analysing hot hand in basketball.

2.2 Hot hand bias

After giving a meaning to the term hot hand, in this section I next explain a phenomenon called hot hand bias. As briefly mentioned in the introduction, hot hand bias describes a situation where people believe the hot hand effect is stronger than it is regardless, if it exists or not (Benjamin, 2018). This can then lead to them making probabilistically irrational decisions because of this false belief.

Hot hand bias is easier to analyse in situations where the outcomes are independent and identically distributed (i.i.d.) random variables (Benjamin, 2018). In situations where outcomes are i.i.d., the probabilities of every outcome stay constant over time, regardless of the previous outcomes or people's actions. Roulette and coinflips are classic examples in this. It has been discovered that people playing lottery have tendency to choose numbers that have previously come up in the recent past, even though the probability for each number to come up is exactly same (Benjamin, 2018). Another example of this is the paper by Guryan and Kearney (2008) in which they

report the so called “lucky store effect”. The effect describes a phenomenon where in Texas people buying lottery tickets preferred the stores that had sold the previous winning tickets for up to 40 weeks.

The odds of a lottery win stay constant over time. To win, one must always choose same number of correct numbers from the same batch of available numbers. If the probability of an outcome is always the same, as it is in lottery and other i.i.d. outcome situations, there cannot be a real hot hand in effect (Benjamin, 2018). This means that when people pick previous winning lottery numbers or stores, their actions are probabilistically always irrational. In this case the existence of hot hand bias is relatively clear. Irrational decision-making caused by hot hand bias is interesting, since as mentioned in the introduction, one of the main principles in economics is the assumption that people’s behavior is rational and optimizing (Aharoni and Sarig, 2012).

The bias then becomes harder to analyse when human performance comes into the equation, as it does in sports. In these scenarios the outcome probabilities do not usually stay constant between rounds (Benjamin, 2018). This means that in terms of the actions people choose to make, the distinction between the real hot hand effect and the hot hand bias can be harder to make. However, as stated by Gilovich et al. (1985) if there exists a false belief in a hot hand it likely leads to sub-optimal decision-making. For example, in a basketball game a coach organizes his team’s defense. If that coach overvalues opposition player’s hot hand, he might set up his team to defend this opposition player more closely. Thus, leaving other players open. In this scenario the coach would be overestimating the threat of a player and consequently allocate his defense resources in a sub-optimal way. On the other hand, players might overanalyse their teammate’s hot hand and allocate the ball too much to that player (Raab and MacMahon, 2015). A player might even overvalue his own hot hand and get too confident with his throws (Lantis and Nesson, 2021a). These are all cases where too strong belief in the hot hand effect leads to probabilistically irrational decision-making and can be called hot hand bias.

Also, the paper by Jin (2018), which finds evidence for a hot hand in darts, also reports something that could be described as hot hand bias. In the paper it is unveiled that when a darts player enters a hot hand state, the player also attempts more difficult shots, than the magnitude of the actual hot hand probabilistically would allow them. Consequently, their decision-making becomes sub-optimal. Similar case is found in basketball as well which I get into in the later sections. These are examples where the hot hand bias is directly caused by the actual hot hand, leading people to act in a probabilistically irrational way.

3 History of the hot hand in basketball

Previously hot hand in basketball was thought of being "a massive and widespread cognitive illusion" (Arvai, 2013) that people overvalue in their decision-making. This is mostly the result of the paper made by Gilovich et al. (1985) in which they argue that hot hand does not exist in basketball. Along with controlled shooting experiment, they analyse data from field goal and free throw shooting and conclude that attempted shots in basketball are independent events. This conclusion would imply that every decision during a game made to counter the hot hand of a player, for example guarding a "hot" player more closely, would be irrational. To elaborate, it would not decrease the opposition team's expected points. However, the results by Gilovich et. al (1985) have since been proven faulty. There is a paper done by Sanjurjo and Miller (2018) that point out the mistake in the prior research (The paper proving the mistake was published originally in 2014 but the current version is from 2018).

To explain the mistake Gilovich et. al (1985), along with replications, make in their research, I will next showcase some of the reasoning that led to incorrect results. This is highlighted in the controlled shooting experiment, in which the authors have 12 players from women's and 14 players from men's university Basketball teams. The subjects threw a basketball 100 times each changing location after every shot. The distance and locations of the shots were picked to resemble a 50 percent Bernoulli i.i.d. shooter, meaning that each shot would constantly have around 50 percent chance of

going in. The main issue in their calculating process is mistakenly employing a bias selection procedure (Miller and Sanjurjo, 2018). To illustrate, I will next use the simplification of the bias that Miller and Sanjurjo (2018) have in their paper. In the simplification, they use a normal coin flip done three times in a row and observing only the flips that follow heads. Moreover, the interest is in heads following heads. The selection bias Gilovich et al. (1985) made, resembles the assumption that the average proportion of heads in this scenario would be one-half. However, when following sequences in which coin is flipped three times in a row, considering all eight possible sequences, the actual average proportion of heads after heads is in fact strictly less than one-half, as shown in Table 1.

Table 1:

Three flip sequence	Proportion of Hs on recorded flips
TTT	-
TTH	-
TH<u>T</u>	0
H<u>T</u>T	0
TH<u>H</u>	1
H<u>T</u>H	0
H<u>HT</u>	$\frac{1}{2}$
H<u>HH</u>	1
Expectation:	$\frac{5}{12}$

(Sanjurjo and Miller, 2018)

As I continue to go through the simplification made by Sanjurjo and Miller (2018) from the Table 1 simplification, it can be observed, that the average proportion of heads after heads in this scenario is $\frac{5}{12}$. In longer sequences than three, the magnitude of the selection bias gets smaller, but it always stays strictly below one half. The bias in the research from Gilovich et al. (1985) comes in to the calculations when, as Sanjurjo and

Miller (2018) explain, "Just as it is (surprisingly) incorrect to expect a fair coin flipped 100 times to yield heads half of the time on those flips that immediately follow three consecutive heads, it is incorrect to expect a consistent 50 percent (Bernoulli i.i.d.) shooter who has taken 100 shots to make half of the shots that immediately follow a streak of three hits".

Next, I will showcase the original results by Gilovich et al. (1985) and then the results Miller and Sanjurjo (2018) got when they remove the selection bias from the calculations. The null hypothesis in the paper by Gilovich et al. (1985) is the following.

$$E[P^i(hit|k\ hits) - P^i(hit|k\ misses)] = 0$$

Put into words, expected value of the difference between a successful shot after k successful shots and a successful shot after k misses is zero, indicating that hot hand does not exist. Analysing successful shots after streaks of k = 3, for both successful shots and misses, led to results that on average when a player is on a scoring streak, their probability to score the next shot is 49 % and while on a missing streak 45 %, difference being +4 percentage points. When Miller and Sanjurjo (2018) then performed unbiased research with the same premise that probability of a shot going in is 50 % they find that the difference of +4 percentage points in fact grows to +12 percentage points. Furthermore, they replicate the calculations changing the 50 percent Bernoulli i.i.d. assumption to player's personal observed shooting success. Along with keeping the assumption of consistent shooting, by doing this the average difference in percentage points goes from +3 to +13. It is easy to understand why these results vastly changed the perception regarding the hot hand. To underline the magnitude of +13 percentage points difference in three-point shooting, during the 2015-16 NBA season the difference between the league's best three-point shooter and the median three-point shooter was +12 percentage points (Miller and Sanjurjo, 2018).

As mentioned before, the paper made by Gilovich et. al (1985) shaped the belief on hot hand in basketball for a long time (Miller and Sanjurjo, 2019). For example, the papers from Koehler and Conley (2003) and Avugos et. al (2013) along with many others replicate the same selection bias (Miller and Sanjurjo, 2018). This is an interesting case in point on how in all research, if not thoroughly examined or even totally left

unquestioned, previous papers can send the whole field of research in the wrong direction, where new papers build on the incorrect information.

4 Hot hand research post-selection bias discovery

Next, I showcase some of the relevant research and results regarding the hot hand in basketball. I mainly focus on the research done after the year 2014 when Miller and Sanjurjo (2018) proved the mistake in Gilovich et. al (1985) research methodology. The reason being, as mentioned in the previous section, that in the time between these two papers, notable portion of the made research is replicating the same selection bias (Miller and Sanjurjo, 2018).

The research regarding hot hand in basketball is made from in-game scenarios and controlled setting. In-game section consists of results from free throws and run of play scenarios. In the controlled setting section, I include shooting experiments from a laboratory setting as well as data from the NBA three-point contests through the years. Even though, the three-point contest is not strictly a controlled setting, I made the decision to include it to that section, since most of the characteristics of it are much closer to a controlled setting than an in-game scenario (Lantis and Nesson, 2021).

4.1 In-game research

4.1.1 Run of play basketball

From all the different ways to analyse hot hand in basketball, although perhaps the most interesting perspective, the run of play research is in many ways the most difficult for finding conclusive results (Lantis and Nesson, 2021). Run of play basketball means open play field goal attempts without free throws. In run of play, the attempted shots are almost never similar. Firstly, the successive shots can be minutes apart and are almost never from the same position which already make them not optimal for

comparison (Lantis and Nesson, 2021) and on top of that there are countless other factors affecting the attempt such as fatigue, pressure and focus (Benjamin, 2018). Furthermore, if a player scores successive attempts the opposition might organize its defense to guard that player more closely adding another variable that makes the next shot even more different from the previous. This is supported by previous research which states that both offenses and defenses respond to made shots (Lantis and Nesson, 2021a; Csapo and Raab, 2014).

One research made by Daks et al. (2018) observes three of the best shooters in the NBA that year: Klay Thompson, Stephen Curry and Kevin Durant. The goal was to find, if these three players show hot hand effect in their shooting. The authors analyse all the games quarter by quarter from these three players during the 2016-2017 NBA season, observing field shots as well as free throws. Daks et al. (2018) find that not one of these players show signs of a hot hand. They also admit that when they followed these players closely there appeared to be instances, where the players displayed a hot hand while performing well during games. Even though, the math behind results from Gilovich et al. (1985) is proven faulty, the results from Daks et al. (2018) are somewhat similar in the way people think the hot hand exists when it in fact does not. Daks et al. (2018) use a small sample size in terms of players, but it is still interesting to see, that even the best basketball shooters fail to show signs of a hot hand at least in run of play.

While the sample size for players in the paper by Daks et al. (2018) is small, there is also research in which the data set is much larger. In the paper by Lantis and Nesson (2021a) they analyse shooting statistics from twelve NBA regular seasons from 2004-2005 to 2015-2016. Excluding the first shot attempted by players in a game, from prementioned seasons, they have over two million attempted field goals into their analysis. They report that, even though both defense and offense respond as if the hot hand did exist, there was again, no evidence for the actual hot hand in run of play basketball. In their research Lantis and Nesson (2021a) add controls step by step to reduce the magnitude of different variables that effect probability of a single shot. These controls include for example the month, day of the week, team, opponent, home games, away games, seconds on the clock and quadratic functions of player's height, weight and age. Even when adding these controls, they fail to find any sign of increased probability in field goals, after streaks of successive shots. Interestingly, in majority of

the controls, they even find negative statistically significant relationship between previously made field goal and the next attempted field goal. According to these results, a made field goal decreases the probability of the next attempt going in. This again supports the opinion that hot hand does indeed not exist in run of play basketball.

As mentioned, both defenses and offenses respond to made shots (Lantis and Nesson, 2021a; Csapo and Raab, 2014). This could also explain why the hot hand is not found in run of play basketball. There is evidence by Lantis and Nesson (2021a) that after a made shot the defending team is more likely to take a timeout or defend the scorer more closely. On the other hand, the authors also point out that after a player makes a shot, that player is more likely to shoot the next shot quicker and from a further distance. Lantis and Nesson (2021a) argue that the same physiological mechanisms that produce signs of hot hand in controlled settings, also exist in run of play basketball. These effects however are countered by the responses from the teams. The authors state that the response from attacking sides can also be the consequence of the responses from the defense. The attacking player might be forced to take shots quicker from longer distances. There is also the possibility that they take these more difficult shots because of a hot hand bias. Similarly, to the darts example used before, it is possible that after a made shot, players get too confident and start taking more difficult shots because of this. Lantis and Nesson (2021a) also argue that the overconfidence players experience after a made shot, is a large, or even the dominant factor on expective points dropping in future offenses. This indicates the existence of an attacking side hot hand bias. This example, along with the section 2.2 proof from darts (Jin, 2018), suggest that in many sports, overconfidence plays its part in decreasing probabilities for future successful plays.

It is difficult to remove the effects all the changing variables in run of play basketball have on the shooting probabilities (Lantis and Nesson, 2021a). However, people in their widespread belief of hot hand existing also acknowledge that these variables do exist and yet they still believe in the hot hand (Gilovich et al., 1985). People around basketball such as fans, coaches and players know that players can be fatigued, stressed, guarded by different players with different intensities etc. When somebody says for example that “Stephen Curry is a streak shooter” they most likely do not mean

he is a streak shooter in a controlled setting where every shot has the exact same characteristics. This, along with results presented earlier, suggest that even if there is an actual hot hand effect suppressed by the responses from both teams, the way many people believe in it is not rational.

4.1.2 Free throws

Another approach to in-game research in basketball is free throws. Free throws are closer to a controlled setting, since at least the shots are always from the same distance with no defenders being able to stop the free throw shooter from scoring (Yaari and Eisenmann, 2011). However, many of the run of play endogenous factors are still in play, such as fatigue, stress, home game advantage etc. (Sanjurjo and Miller, 2018). The paper by Lantis and Nesson (2021a), which was used in section 4.1.1, also research free throws. In their data they have over 500 000 free throws from the same twelve NBA seasons. They find a small hot hand in free throws which also grows in magnitude when the streaks of made shots got longer. After one successful free throw the probability of next free throw gross by 2 percentage points and after four successive free throws this grows to 4.5 percentage points. This partly supports the conclusion that the more a situation resembles controlled setting the more likely it is to find a true hot hand.

4.2 Controlled setting research

Although maybe not the most relevant way for finding hot hand regards to game of basketball, most of the research that finds a hot hand effect is done in a controlled setting (Miller and Sanjurjo, 2018). This is because in a controlled setting the circumstances can be set in a way, that every attempted shot has near exact same characteristics with each other. Thus, minimizing the magnitude of omitted variable bias. As mentioned in the beginning of the section 4, I include the paper analysing NBA three-point contest by Lantis and Nesson (2021b) in controlled setting section. Even though, not strictly a controlled setting, it is much closer to one compared to an in-game scenario. Three-point contests can also be defined as “semi-controlled setting” (Lantis and Nesson 2021b).

In the aforementioned paper by Lantis and Nesson (2021b), the authors analyse data from NBA three-point contests from the years 1986-2019. In the contest some of the best shooters in the NBA compete with one another, taking five shots from five different locations. As the authors mention, in three-point contest the analysis is possible both within and across the shooting locations. What they find is that within location the hot hand effect occurs when the previous shot has gone in. The previous shot going in within a location increases the chance of next shot going in by five percentage points.

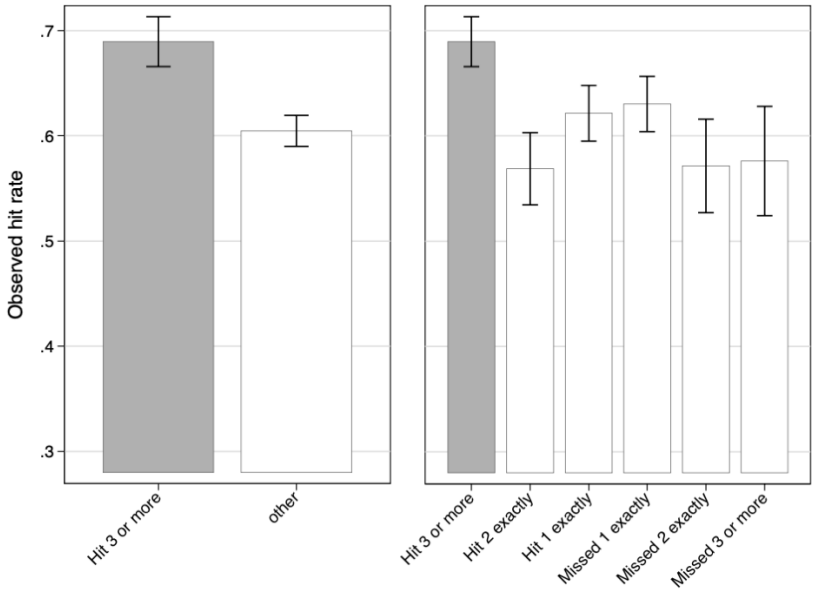
The paper also states that in terms of the hot hand, streaks are relevant only when the previous shot is included in it. For example, if a player scores first three shots but misses the fourth, the chances of the fifth shot going in is almost identical to a situation where the player misses all first four shots. This indicates that the hot hand, even in a semi-controlled setting, is fragile and its effect breaks easily. This fragility can also be found when the shooters change locations. As Lantis and Nesson (2021b) also report, changing locations has very similar effect to missing a shot within location. To clarify, the first shot after changing locations have virtually the same probability of going in regardless, if the last shot in the previous location went in. The conclusion that could be made from this is that in a semi-controlled setting hot hand in basketball exists only after a made shot within location. This could also partly explain the hot hand in free throws that is found also by Lantis and Nesson (2021a). The persistent hot hand the authors find in free throws, even though small in magnitude, puts notable importance particularly on the location. Free throws during a game are vulnerable to many different types of omitted variable bias (Lantis and Nesson, 2021b) compared to three-point contest, where only the change of location breaks an existing hot hand.

The hot hand in run of play can be difficult to analyse (Lantis and Nesson, 2021a). However, the hot hand effect breaks in three-point competition when a player moves only few meters after a made shot. This makes it difficult to put forward an argument that it would then exist in a basketball run of play, where circumstances change drastically more all the time. However, this conclusion is challenged by the unbiased research Miller and Sanjurjo (2018) perform with the original data by Gilovich et al. (1985). As explained in section 3, Miller and Sanjurjo (2018) find proof for hot hand in the controlled shooting experiment, in which the participants have to change

locations after each shot. These results suggest that hot hand effect is stronger within locations but changing locations do not entirely rule out a possible hot hand. Therefore, changing locations is more likely another case of omitted variable bias. Moreover, it is not the only reason why hot hand is not found in run of play basketball.

Furthermore, Miller and Sanjurjo (2019) perform their own controlled setting study and again hot hand effect is found. In this study the authors have players from a semi-professional Spanish basketball team. The research is conducted in two phases six months apart for the purpose of using the first phase as a predictor for the second phase. In this experiment the players shot hundreds of times, changing locations after each shot and from distances where from they were expected to make around half of the shots. Along with finding proof for hot hand, this study helps to explain how the hot hand can be individual quality that is not the same for all and which would then make the term "streak shooter" plausible. The authors illustrate this by making the players choose the best "streak shooter" among themselves and then putting more focus on this player in the research. The authors denoted this player as "RC".

Table 2:



(Miller and Sanjurjo, 2019)

The Table 2 depicts results from RC's shooting. As can be seen form the grey bars, RC display significantly higher hit rate after 3 or more consecutive hits than after any other sequence of previous shots. This is the case even when looking at the thinner vertical bars which depict error margins. As Miller and Sanjurjo (2019) state, this +9 percentage points difference is again close to previously mentioned +12 percentage points, which was the difference between the best and the median three-point shooter in the 2015-16 NBA season. The authors find that even though other players displayed hot hand as well, the magnitudes of those hot hands are moderate compared to RC's hot hand. This suggests that there is some truth behind the belief that some players can be better "streak shooters" than others. Still, as seen from run of play results, the hot hand effect is not found in run of play basketball. Consequently, this indicates that, similarly to the hot hand effect, this belief is closer to the truth in controlled setting rather than in-game.

5 Hot hand bias in basketball

Now that the thesis has established the research around the existence of hot hand in basketball, I will next analyse scenarios where the hot hand, or the absence of one, can lead to bias. Moreover, if people do act irrationally because of the bias. As mentioned, most of the research around hot hand in basketball focuses either on controlled or semi-controlled setting, because these situations have the possibility of removing most of the omitted variable bias typical for basketball (Lantis and Nesson, 2021). In this model Lantis and Nesson (2021) had numerous control variables for the purpose of removing the bias and even then, there is always a chance that the authors leave out variables that affect probabilities of a single field shot attempt in basketball.

Even though, the omitted variable bias can be decreased in a controlled setting, the question in the canonical paper by Gilovich et al. (1985) was about the perceived shooting success specifically for in-game basketball. Therefore, making results from controlled setting not optimal for answering this question (Lantis and Nesson, 2021a). In the results section I conclude, supported by evidence from Lantis and Nesson (2021b), that the effect of a hot hand decreases significantly when players move

locations. Thus, it seems very unlikely that it would then exist in run of play basketball where, along with endless omitted variable bias, almost no shots are taken from the same exact location. Moreover, even if it did exist, the responses from defenses and offenses counter its effect.

There is previous literature stating that coaches, players and fans widely believe in the existence of in-game hot hand (Gilovich et al., 1985; Brown and Sauer, 1993). The results in run of play basketball suggest that this belief, at least from fans, is a case of hot hand bias, as Gilovich et al. (1985) originally argue (Lantis and Nesson, 2021b). In run of play basketball, there is no current evidence supporting that making a shot increases chances of the next going in, even if this was the result of offense and defense responses. If a fan believes a player is a streak shooter and has a hot hand in run of play basketball, this conclusion based on current research, is hot hand bias.

According to the field goal hot hand results by Lantis and Nesson (2021a), even the smallest belief in a hot hand would indicate existence of a bias. The authors report that the relationship between a successful shot and the shot following it is negative. This means that making a shot decreases the probability of next shot going in. This conclusion is further supported by the paper from Daks et al. (2018) in which the authors do not find evidence for an in-game hot hand observing some of the best shooters in the NBA, since the top players are often the ones people refer to when saying someone is a streak shooter (Gilovich et al., 1985).

The beliefs of fans, however, is not the main interest when evaluating irrational behavior in a game of basketball. The responses from the offense and defense offer perhaps the best opportunity for analysing hot hand bias. From the responses, the hot hand bias can emerge mainly in the following two ways. Either defense overvalue opposition hot hand and guard a player who made the shot too closely or offensive player overvalue his own hot hand and starts taking too difficult shots. The evidence from semi-controlled setting, that changing locations breaks the hot hand effect, suggests that the defensive responses are irrational. On the other hand, Lantis and Nesson (2021a) argue that offense too overvalue hot hand effect and starts to take too difficult shots which is also probabilistically irrational.

There is not enough research to say which one of these responses is the predominant factor, on why in the run of play results, the relationship between made shot and player's next shot is negative. To clarify, the negative effect for offense after a made shot is not optimal even for the defensive side, because it evidently leads other offensive players to have more space. Lantis and Nesson (2021a) find that after a player makes a shot, his teammates are more likely to score their next shot, suggesting easier shots due to less defensive pressure on them. Therefore, the negative effect made shots have on player's next shot, indicates hot hand bias from both the offense and the defense at the same time.

Based on these results there seems to be an argument to be made for the existence of a hot hand bias. However, the original conclusion in the canonical paper by Gilovich et al. (1985) is that believing a hot hand exists in any basketball scenario, including controlled setting, would be a case of hot hand bias. As seen in the results section, this is evidently not the case. To elaborate, a true hot hand is found as already mentioned in the results section. Evidence for a hot hand in basketball is found in free throws (Lantis and Nesson, 2021a), semi-controlled setting (Lantis and Nesson, 2021b) and controlled setting (Miller and Sanjurjo, 2018). When the hot hand is found, the analysis for the hot hand bias becomes more complex, since it is not simple to quantify person's belief in something. However, the conclusion by Gilovich et al. (1985) that any belief in the hot hand in basketball context is a bias, cannot be correct either, because the hot hand is found in these more controlled scenarios.

6 Challenges

It is important to acknowledge that there are many changing variables that can make defining a hot hand or hot hand bias difficult (Benjamin, 2018). In this section I will go through some of these challenges. As concluded in section 4, the research of hot hand in basketball is done in either in-game situations or controlled settings. The in-game scenarios consist of run of play and free throws. Three-point contest is closer to controlled setting than in-game, but it also has similar characteristics to in-game situations (Lantis and Nesson, 2021).

Particularly from run of play situations conclusions are harder to make compared to free throws and three-point contests. Moreover, it is unclear if the results from the latter two translate to run of play scenarios, since the successive shooting situations are mostly from different locations and can be minutes apart. In other words, it can be hard to compare for example free throws to field shots. (Lantis and Nesson, 2021a)

Another aspect that makes analysing run of play scenarios difficult, is the reactions that teams have on made shots. As Lantis and Nesson (2021a) point out, both the defense and the offense react to made shots. One example of this is, that when a player makes a shot, the response will often be to guard this player more closely. This naturally makes it more difficult for that player to perform successful shots in succession. In a way, even if there was a true hot hand in play the response of the other team may counteract the positive autocorrelation in player's performance (Rao, 2009). These endogenous responses at least partly explain why there are only few papers that have researched hot hand in field shots and their results have been mixed (Lantis and Nesson, 2021a). Also, it is even argued that in-game situations cannot provide conclusive evidence for or against the hot hand and that controlled setting is necessary (Miller and Sanjurjo, 2018).

In sports, the probabilities can also be harder to analyse, because the outcomes are virtually never i.i.d. This is the consequence of natural human characteristics such as fatigue, anxiety and focus, that can have effect on the outcome probabilities between rounds (Benjamin, 2018). Consequently, if a player faces a game-winning free throw attempt, the nerves can get to him and the probability of the shot going in may go down compared to relatively insignificant shot in the middle of the game. There is evidence that college players who are in the public eye destined to go pro will have their free throw performance decrease 6 percentage points more than regular college players (Toma, 2017). This means that the outcome probabilities for a similar shot attempt change, regardless of the streak of successful or missed free throws. Also, adding challenge to hot hand bias analysis is that along with overvaluing a hot hand there is also evidence that sometimes hot hand effects are also undervalued (Stone and Arkes, 2018).

In addition to sports, the outcome probabilities in other repeated situations where human behavior and skill are relevant factors between rounds, are also virtually never

i.i.d. As presented, basketball is an example where hot hand bias can be found even though the probabilities and characteristics of successive rounds change all the time. This points to the possibility that hot hand bias could be found for example in economic settings such as consumer and investor behavior and corporate strategy etc. The current results seem to suggest that the hot hand bias does exist in basketball (Lantis and Nesson 2021a). However, the current research does not quantifie the bias in a way that it could be used to shift decision-making closer to the optimum. Consequently, there might be a need for additional research on the psychology behind hot hand bias, so that the decision-making process, in situations where hot hand bias is found, can be optimized.

7 Conclusion

The goal of this thesis was to analyse if a hot hand effect can be found in different scenarios in a basketball context. Moreover, if implications caused by the hot hand effect, mainly hot hand bias, lead to probabilistically irrational decision-making. The term hot hand is most often used in a basketball context. It describes a random process where a streak of positive outcomes at least momentarily increases the possibility of positive outcomes in future attempts. (Benjamin, 2018) Hot hand bias then describes is a phenomenon where people in their reasoning overplay an actual hot hand effect or wrongly believe in the existence of one. I also decided to include to the thesis some of the history behind hot hand research and how the paper by Gilovich et al. (1985) shaped the beliefs around this topic into a wrong direction.

As for evidence for the hot hand, the results are still somewhat mixed and highly dependent on the situation they are observed in. (Lantis and Nesson, 2021a) The results indicate that the closer a situation resembles a controlled setting, the more likely it is to find a true hot hand. The ends of this spectrum are controlled laboratory shooting experiments and run of play basketball analysis.

Most of the controlled setting research find at least some evidence for a hot hand but in run of play basketball this evidence is virtually non-existent (Lantis and Nesson,

2021a). The lack of evidence in run of play may be attributed to the omitted variable bias inherent in the game of basketball (Benjamin, 2018). Still, as of now, there is no evidence that supports the existence of hot hand in run of play basketball. Therefore, there is an argument to be made, supported by Lantis and Nesson (2021b), that hot hand bias is found in run of play basketball. The adjustments of defensive strategies by the defending team and more difficult shot attempts by the attacking team, triggered by player's streak of consecutive successful shots, can be considered as probabilistically irrational decisions caused by the hot hand bias. This is especially relevant in cases where these shifts in decision-making are big in their magnitude. If teams were able adjust their decision-making to the optimum, they could possibly score more points and at the same time stop their opposition of scoring more points. Thus, there is a chance they would then get better results and, in a league such as the NBA, concrete monetary gains because of it.

There is also an opportunity for future research to take the concepts hot hand and hot hand bias into another area of research. With these tools human behavior could be analysed for example in consumer and investment behavior context. However, there might be a need for additional understanding of the psychological mechanisms driving hot hand bias to enable better optimization of the behavioral shifts.

References

Aharoni, Gil, and Oded H. Sarig. "Hot hands and equilibrium." *Applied Economics* 44, no. 18 (2012): 2309-2320.

Arvai, Joseph. "Thinking, fast and slow, Daniel Kahneman, Farrar, Straus & Giroux." (2013): 1322-1324.

Benjamin, Daniel J. "Errors in probabilistic reasoning and judgment biases." *Handbook of Behavioral Economics: Applications and Foundations 1* 2 (2019): 69-186.

Brown, William O., and Raymond D. Sauer. "Does the basketball market believe in the hot hand? Comment." *The American Economic Review* 83, no. 5 (1993): 1377-1386.

Csapo, Peter, and Markus Raab. "“Hand down, man down.” analysis of defensive adjustments in response to the hot hand in basketball using novel defense metrics." *PloS one* 9, no. 12 (2014): e114184.

Daks, Alon, Nishant Desai, and Lisa R. Goldberg. "Do the golden state warriors have hot hands?." *The Mathematical Intelligencer* 40 (2018): 1-5.

Gilovich, Thomas, Robert Vallone, and Amos Tversky. "The hot hand in basketball: On the misperception of random sequences." *Cognitive psychology* 17, no. 3 (1985): 295-314.

Green, Brett, and Jeffrey Zwiebel. "The hot-hand fallacy: Cognitive mistakes or equilibrium adjustments? Evidence from major league baseball." *Management Science* 64, no. 11 (2018): 5315-5348.

Guryan, Jonathan, and Melissa S. Kearney. "Gambling at lucky stores: Empirical evidence from state lottery sales." *American Economic Review* 98, no. 1 (2008): 458-473.

Jin, Lawrence. "Evidence of Hot-Hand Behavior in Sports and Medicine." In *7th Annual Conference of the American Society of Health Economists*. ASHECON, 2018.

Lantis, Robert, and Erik Nesson. "Hot shots: An analysis of the “hot hand” in nba field goal and free throw shooting." *Journal of Sports Economics* 22, no. 6 (2021): 639-677.

Lantis, Robert M., and Erik T. Nesson. *The Hot Hand in the NBA 3-Point Contest: The Importance of Location, Location, Location*. No. w29468. National Bureau of Economic Research, 2021.

Miller, Joshua B., and Adam Sanjurjo. "Surprised by the hot hand fallacy? A truth in the law of small numbers." *Econometrica* 86, no. 6 (2018): 2019-2047.

Miller, Joshua B., and Adam Sanjurjo. "A cold shower for the hot hand fallacy: Robust evidence that belief in the hot hand is justified." (2019).

Raab, Markus, and Clare MacMahon. "Does framing the hot hand belief change decision-making behavior in volleyball?." *Research quarterly for exercise and sport* 86, no. 2 (2015): 152-162.

Rao, Justin M. "Experts' perceptions of autocorrelation: The hot hand fallacy among professional basketball players." *Unpublished technical manuscript. California. San Diego. Downloaded from http://www. justinmrao. com/playersbeliefs. pdf.(July 11th 2012)* (2009).

Smith, Gary. "Horseshoe pitchers' hot hands." *Psychonomic bulletin & review* 10 (2003): 753-758.

Statista (October, 2023). National Basketball Association total league revenue from 2001/02 to 2022/23. https://www.statista.com/statistics/193467/total-league-revenue-of-the-nba-since-2005/ [Last accessed on 2023-12-19]

Stone, Daniel F., and Jeremy Arkes. "March Madness? Underreaction to hot and cold hands in NCAA basketball." *Economic Inquiry* 56, no. 3 (2018): 1724-1747.

Toma, Mattie. "Missed shots at the free-throw line: Analyzing the determinants of choking under pressure." *Journal of Sports Economics* 18, no. 6 (2017): 539-559.

Yaari, Gur, and Shmuel Eisenmann. "The hot (invisible?) hand: can time sequence patterns of success/failure in sports be modeled as repeated random independent trials?." *PloS one*6, no. 10 (2011): e24532.

Yaari, Gur, and Gil David. "“Hot hand” on strike: Bowling data indicates correlation to recent past results, not causality." *PLoS One* 7, no. 1 (2012): e30112.