The Cold Facts About the "Hot Hand" in Basketball

Do basketball players tend to shoot in streaks? Contrary to the belief of fans and commentators, analysis shows that the chances of hitting a shot are as good after a miss as after a hit.

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> *You're in a world all your own. It's hard to describe. But the basket seems to be so wide. No matter what you do, you know the ball is going to go in.*
> –Purvis Short, of the NBA's Golden State Warriors

This statement describes a phenomenon known to everyone who plays or watches the game of basketball, a phenomenon known as the "hot hand." The term refers to the putative tendency for success (and failure) in basketball to be self-promoting or self-sustaining. After making a couple of shots, players are thought to become relaxed, to feel confident, and to "get in a groove" such that subsequent success becomes more likely. The belief in the hot hand, then, is really one version of a wider conviction that "success breeds success" and "failure breeds failure" in many walks of life. In certain domains it surely does–particularly those in which a person's reputation can play a decisive role. However, there are other areas, such as most gambling games, in which the belief can be just as strongly held, but where the phenomenon clearly does not exist.

What about the game of basketball? Does success in this sport tend to be self-promoting? Do players occasionally get a "hot hand"?

Misconceptions of Chance Processes

One reason for questioning the widespread belief in the hot hand comes from research indicating that people's intuitive conceptions of randomness do not conform to the laws of chance. People commonly believe that the essential characteristics of a chance process are represented not only globally in a large sample, but also locally in each of its parts. For example, people expect even short sequences of heads and tails to reflect the fairness of a coin and to contain roughly 50% heads and 50% tails. Such a locally representative sequence, however, contains too many alternations and not enough long runs.

This misconception produces two systematic errors. First, it leads many people to believe that the probability of heads is greater after a long sequence of tails than after a long sequence of heads; this is the notorious gamblers' fallacy. Second, it leads people to question the randomness of sequences that contain the expected number of runs because even the occurrence of, say, four heads in a row– which is quite likely in even relatively small samples– makes the sequence appear non representative. Random sequences just do not look random.

Perhaps, then, the belief in the hot hand is merely one manifestation of this fundamental misconception of the laws of chance. Maybe the streaks of consecutive hits that lead players and fans to believe in the hot hand do not exceed, in length or frequency, those expected in any random sequence.

To examine this possibility, we first asked a group of 100 knowledgeable basketball fans to classify sequences of 21 hits and misses (supposedly taken from a basketball player's performance record) as *streak shooting*, *chance shooting*, or *alternating shooting*. Chance shooting was defined as runs of hits and misses that are just like those generated by coin tossing. Streak shooting and alternating shooting were defined as runs of hits and misses that are longer or shorter, respectively, than those observed in coin tossing. All sequences contained 11 hits and 10 misses, but differed in the probability of alternation, $p(a)$, or the probability that the outcome of a given shot would be different from the outcome of the previous shot. In a random (i.e., independent) sequence, $p(a) = .5$; streak shooting and alternating shooting arise when $p(a)$ is less than or greater than .5, respectively. Each respondent evaluated six sequences, with $p(a)$ ranging from .4 to .9. Two (mirror image) sequenceswere used for each level of $p(a)$ and presented to different respondents.

The percentage of respondents who classified each sequence as "streak shooting" or "chance shooting" is presented in Figure 1 as a function of $p(a)$. (The percentage of "alternating shooting" is the complement of these values.) As expected, people perceive streak shooting where it does not exist. The sequence of $p(a) = .5$, representing a perfectly random sequence, was classified as streak shooting by 65% of the respondents. Moreover, the perception of chance shooting was strongly biased against long runs: The sequences selected as the best examples of chance shooting were those with probabilities of alternation of .7 and .8 instead of .5.

It is clear, then, that a common misconception about the laws of chance can distort people's observations of the game of basketball: Basketball fans detect" evidence of the hot hand in perfectly random sequences. But is this the main determinant of the widespread conviction that basketball players shoot in streaks? The answer to this question requires an analysis of shooting statistics in real basketball games.

Cold Facts from the NBA

Although the precise meaning of terms like "the hot hand" and streak shooting" is unclear, their common use implies a shooting record that departs from coin tossing in two essential respects (see accompanying box). First, the frequency of streaks (i.e., moderate or long runs of successive hits) must exceed what is expected by a chance process with a constant hit rate. Second, the probability of a hit should be greater following a hit than following a miss, yielding a positive serial correlation between the outcomes of successive shots.

To examine whether these patterns accurately describe the performance of players in the NBA, the field-goal records of individual players were obtained for 48 home games of the Philadelphia 76ers during the 1980-81 season. Table 1 presents, for the nine major players of the 76ers, the probability of a hit conditioned on 1, 2, and 3 hits and misses. The overall hit rate for each player, and the number of shots he took, are presented in column 5. A comparison of columns 4 and 6 indicates that for eight of the nine players the probability of a hit is actually higher following a miss (mean = .54) than following a hit (mean = .51), contrary to the stated beliefs of both players and fans. Column 9 presents the (serial) correlations between the outcomes of successive shots. These correlations are not significantly different than zero except for one player (Dawkins) whose correlation is negative. Comparisons of the other matching columns (7 vs. 3, and 8 vs. 2) provide further evidence against streak shooting. Additional analyses show that the probability of a hit (mean = .57) following a "cold" period (0 or 1 hits in the last 4 shots) is higher than the probability of a hit (mean = .50) following a "hot" period (3 or 4 hits in the last 4 shots). Finally, a series of Wald-Wolfowitz runs tests revealed that the observed number of runs in the players' shooting records does not depart from chance expectation except for one player (Dawkins) whose data, again, run counter to the streak-shooting hypothesis. Parallel analyses of data from two other teams, the New Jersey Nets and the New York Knicks, yielded similar results.

Although streak shooting entails a positive dependence between the outcomes of successive shots, it could be argued that both the runs test and the test for a positive correlation are not sufficiently powerful to detect occasional "hot" stretches embedded in longer stretches of normal performance. To obtain a more sensitive test of stationarity (suggested by David Freedman) we partitioned the entire record of each player into non-overlapping series of four consecutive shots. We then counted the number of series in which the player's performance was high (3 or 4 hits), moderate (2 hits) or low (0 or 1 hits). If a player is occasionally 'hot," his record must include more high-performance series than expected by chance. The numbers of high, moderate, and low series for each of the nine Philadelphia 76ers were compared to the expected values, assuming independent shots with a constant hit rate (taken from column 5 of Table 1). For example, the expected percentages of high-, moderate-, and low performance series for a player with a hit rate of .50 are 31.25%, 37.5%, and 31.25%, respectively. The results provided no evidence for non-stationarity or streak shooting as none of the nine chi-squares approached statistical significance. The analysis was repeated four times (starting the partition into quadruples at the first, second, third, and fourth shot of each player), but the results were the same. Combining the four analyses. the overall observed percentages of high, medium, and low series are 33.5%, 39.4%, and 27.1%, respectively, whereas the expected percentages are 34.4%, 36.8%, and 28.8%. The aggregate data yield slightly fewer high and low series than expected by independence, which is the exact opposite of the pattern implied by the presence of hot and cold streaks.

At this point, the lack of evidence for streak shooting could be attributed to the contaminating effects of shot selection and defensive strategy. Streak shooting may exist, the argument goes, but it may be masked by a hot player's tendency to take more difficult shots and to receive more attention from the defensive team. Indeed, the best shooters on the team (e.g., Andrew Toney) do not have the highest hit rate, presumably because they take more difficult shots. This argument however, does not explain why players and fans erroneously believe that the probability of a hit is greater following a hit than following a miss, nor can it account for the tendency of knowledgeable observers to classify random sequences as instances of streak shooting. Nevertheless, it is instructive to examine the performance of players when the difficulty of the shot and the defensive pressure are held constant. Free-throw records provide such data. Free throws are shot, usually in pairs, from the same location and without defensive pressure. If players shoot in streaks, their shooting percentage on the second free throws should be higher after having made their first shot than after having missed their first shot. Table 2 presents the probability of hitting the second free throw conditioned on the outcome of the first free throw for nine Boston Celtics players during the 1980-81 and the 1981-82 seasons.

These data provide no evidence that the outcome of the second shot depends on the outcome of the first. The correlation is negative for five players and positive for the remaining four, and in no case does it approach statistical significance.

The Cold Facts from Controlled Experiments

To test the hot hand hypothesis, under controlled conditions, we recruited 14 members of the men's varsity team and 12 members of the women's varsity team at Cornell University to participate in a shooting experiment. For each player, we determined a distance from which his or her shooting percentage was roughly 50%, and we drew two 15-foot arcs at this distance from which the player took 100 shots, 50 from each arc. When shooting baskets, the players were required to move along the arc so that consecutive shots were never taken from exactly the same spot.

The analysis of the Cornell data parallels that of the 76ers. The overall probability of a hit following a hit was .47, and the probability of a hit following a miss was .48. The serial correlation was positive for 12 players and negative for 14 (mean r = .02). With the exception of one player (r = .37) who produced a significant positive correlation (and we might expect one significant result out of 26 just by chance). both the serial correlations and the distribution of runs indicated that the outcomes of successive shots are statistically independent.

We also asked the Cornell players to predict their hits and misses by betting on the outcome of the upcoming shot. Before every throw, each player chose whether to bet high, in which case he or she would win 5 cents for a hit and lose 4 cents for a miss, or to bet low, in which case he or she would win 2 cents for a hit and lose 1 cent for a miss. The players were advised to bet high when they felt confident in their shooting ability and to bet low when they did not. We also obtained betting data from another player who observed the shooter and decided, independently, whether to bet high or low on each trial. The players' payoffs included the amount of money won or lost on the bets made as shooters and as observers.

The players were generally unsuccessful in predicting their performance. The average correlation between the shooters' bets and their performance was .02, and the highest positive correlation was .22. The observers were also unsuccessful in predicting the shooter's performance (mean r = .04). However, the bets made by both shooters and observers were correlated with the outcome of the shooters' previous shot (mean r = .40 for the shooters and .42 for the observers). Evidently, both shooters and observers relied on the outcome of the previous shot in making their predictions, in accord with the hot-hand hypothesis. Because the correlation between successive shots was negligible (again, mean r = .02), this betting strategy was not superior to chance, although it did produce moderate agreement between the bets of the shooters and the observers (mean r = .22).

The Hot Hand as Cognitive Illusion

To summarize what we have found, we think it may be helpful to clarify what we have not found. Most importantly, our research does not indicate that basketball shooting is a purely chance process, like coin tossing. Obviously, it requires a great deal of talent and skill. What we have found is that, contrary to common belief, a player's chances of hitting are largely independent of the outcome of his or her previous shots. Naturally, every now and then. a player may make, say, nine of ten shots, and one may wish to claim–after the fact–that he was hot. Such use, however, is misleading if the length and frequency of such streaks do not exceed chance expectation.

Our research likewise does not imply that the number of points that a player scores in different games or in different periods within a game is roughly the same. The data merely indicate that the probability of making a given shot (i.e., a player's shooting percentage) is unaffected by the player's prior performance. However, players' willingness to shoot may well beaffected by the outcomes of previous shots. As a result, a player may score more points in one period than in another not because he shoots better, but simply because he shoots more often. The absence of streak shooting does not rule out the possibility that other aspects of a player's performance, such as defense, rebounding, shots attempted, or points scored, could be subject to hot and cold periods. Furthermore, the present analysis of basketball data does not say whether baseball or tennis players, for example, go through hot and cold periods.

Our research does not tell us anything general about sports, but it does suggest a generalization about people, namely that they tend to 'detect" patterns even where none exist, and to overestimate the degree of clustering in sports events, as in other sequential data. We attribute the discrepancy between the observed basketball statistics and the intuitions of highly interested informed observers to a general misconception of the laws of chance that induces the expectation that random sequences will be far more balanced than they generally are, and creates the illusion that there are patterns or streaks in independent sequences. This account explains both the formation and maintenance of the belief in the hot hand. If independent sequences are perceived as streak shooting. no amount of exposure to such sequences w ill convince the player, the coach, or the fan that the sequences are actually independent. In fact, the more basketball one watches, the more one encounters w hat appears to be streak shooting. This misconception of chance has direct consequences for the conduct of the game. Passing the ball to the hot player, who is guarded closely by the opposing team, may be a non-optimal strategy if other players who do not appear hot have a better chance of scoring. Like other cognitive illusions, the belief in the hot hand could be costly.

Additional Reading

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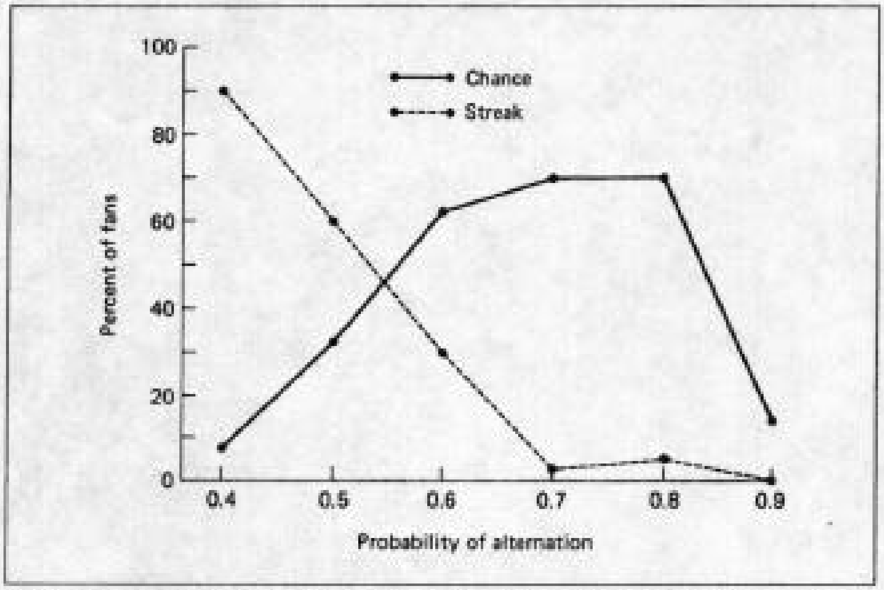

Figure 1. Percentage of basketball fans classifying sequences of hits and misses as examples of streak shooting or chance shooting, as a function of the probability of alternation within the sequences.

Table 1. Probability of making a shot conditioned on the outcome of previous shots for nine members of the Philadelphia 76ers; hits are denoted H, misses are M.

	PROBABILITY of...							Serial Correlation r
Player	H|3M	H|2M	H|1M	H	H|1H	H|2H	H|3H	
Clint Richardson	.50	.47	.56	.50(248)	.49	.50	.48	-.020
Julius Erving	.52	.51	.51	.52(884)	.53	.52	.48	+.016
Lionel Hollins	.50	.49	.46	.46(419)	.46	.46	.32	-.004
Maurice Cheeks	.77	.60	.60	.56(339)	.55	.54	.59	-.038
Caldwell Jones	.50	.48	.47	.47(272)	.45	.43	.27	-.016
Andrew Toney	.52	.53	.51	.46(451)	.43	.40	.34	-.083
Bobby Jones	.61	.58	.58	.54(433)	.53	.47	.53	-.049
Steve Mix	.70	.56	.52	.52(351)	.51	.48	.36	-.015
Darryl Dawkins	.88	.73	.71	.62(403)	.57	.58	.51	-.142*
Weighted Mean	.56	.53	.54	.52	.51	.50	.46	-.039

NOTE: The number of shots taken by each player is given in parentheses in Column 5.

*p<.01

Table 2. Probability of hitting a second free throw (H_2) conditioned on the outcome of the first free throw (H_1 or M_1) for nine members of the Boston Celtics.

Player	P (H_2 | M_1)	P (H_2 | H_1)	Serial Correlation (r)
Larry Bird	.91 (53)	.88 (285)	-.032
Cedric Maxwell	.76 (128)	.81 (302)	.061
Robert Parish	.72 (105)	.77 (213)	.056
Nate Archibald	.82 (76)	.83 (245)	.014
Chris Ford	.77 (22)	.71 (51)	-.069
Kevin McHale	.59 (49)	.73 (128)	.130
M.L. Carr	.81 (26)	.68 (57)	-.128
Rick Robey	.61 (80)	.59 (91)	-.019
Gerald Henderson	.78 (37)	.76 (101)	-.022

NOTE: The number of shots on which each probability is based is given in parentheses.

What People Mean by the "Hot Hand" and "Streak Shooting"

Although all that people mean by streak shooting and the hot hand can be rather complex, there is a strong consensus among those close to the game about the core features of non-stationarity and serial dependence. To document this consensus, we interviewed a sample of 100 avid basketball fans from Comell and Stanford. A summary of their responses are given below. We asked similar questions of the players whose data we analyzed as members of the Philadelphia 76ers and their responses matched those we report here.

• Does a player have a better chance of making a shot after having just made his last two or three shots than he does after having just missed his last two or three shots?

Yes 91 %
No 9%

• When shooting free throws, does a player have a better chance of making his second shot after making his first shot than after missing his first shot?

Yes 68%
No 32%

• Is it important to pass the ball to someone who has just made several (2, 3, or 4) shots in a row?

Yes 84%
No 16%

• Consider a hypothetical player who shoots 50% from the field.

What is your estimate of his field goal percentage for those shots that he takes after having just made a shot?

Mean = 61%

What is your estimate of his field goal percentage for those shots that he takes after having just missed a shot?

Mean = 42%