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The Hot Hand in Basketball: On the Misperception of Random Sequences

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We investigate the origin and the validity of common beliefs regarding "the hot hand" and "streak shooting" in the game of basketball. Basketball players and fans alike tend to believe that a player's chance of hitting a shot are greater following a hit than following a miss on the previous shot. However, detailed analyses of the shooting records of the Philadelphia 76ers provided no evidence for a positive correlation between the outcomes of successive shots. The same conclusions emerged from free-throw records of the Boston Celtics, and from a controlled shooting experiment with the men and women of Cornell's varsity teams. The outcomes of previous shots influenced Cornell players' predictions but not their performance. The belief in the hot hand and the "detection" of streaks in random sequences is attributed to a general misconception of chance according to which even short random sequences are thought to be highly representative of their generating process.

In describing an outstanding performance by a basketball player, reporters and spectators commonly use expressions such as "Larry Bird has the hot hand" or "Andrew Toney is a streak shooter." These phrases express a belief that the performance of a player during a particular period

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is significantly better than expected on the basis of the player's overall record. The belief in "the hot hand" and in "streak shooting" is shared by basketball players, coaches, and fans, and it appears to affect the selection of plays and the choice of players. In this paper we investigate the origin and the validity of these beliefs.

People's intuitive conceptions of randomness depart systematically from the laws of chance.[1] It appears that people expect the essential characteristics of a chance process to be represented not only globally in the entire sequence, but also locally, in each of its parts. For instance, people expect even short seqeunces of heads and tails to reflect the fairness of a coin and contain roughly 50% heads and 50% tails. This conception of chance has been described as a "belief in the law of small numbers" according to which the law of large numbers applies to small samples as well (Tversky & Kahneman, 1971). A locally representative sequence, however, deviates systematically from chance expectation: It contains too many alternations and not enough long runs.

A conception of chance based on representativeness, therefore, produces two related biases. First, it induces a belief that the probability of heads is greater after a long sequence of tails than after a long sequence of heads—this is the notorious gambler's fallacy (see, e.g., Tversky & Kahneman, 1974). Second, it leads people to reject 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 a sequence of 20 tosses—makes the sequence appear nonrepresentative (Falk, 1981; Wagenaar, 1972).

Sequences of hits and misses in a basketball game offer an interesting context for investigating the perception of randomness outside the psychological laboratory. Consider a professional basketball player who makes 50% of his shots. This player will occasionally hit four or more shots in a row. Such runs can be properly called streak shooting, however, only if their length or frequency exceeds what is expected on the basis of chance alone. The player's performance, then, can be compared to a sequence of hits and misses generated by tossing a coin. A player who produces longer sequences of hits than those produced by tossing a coin can be said to have a "hot hand" or be described as a "streak shooter." Similarly, these terms can be applied to a player who has a better chance of hitting a basket after one or more successful shots than after one or more misses.

This analysis does not attempt to capture all that poeple might mean

[1] Feller (1968) describes some striking examples of the nonintuitive character of chance processes (e.g., matching birthdates or the change of sign in a random walk), which he attributes to "faulty intuitions" about chance and common misconceptions of "the law of averages."

by "the hot hand" or "streak shooting." Nevertheless, we argue that the common use of these notions—however vague or complex—implies that players' performance records should differ from sequences of heads and tails produced by coin tossing in two essential respects. First, these terms imply that the probability of a hit should be greater following a hit than following a miss (i.e., positive association). Second, they imply that the number of streaks of successive hits or misses should exceed the number produced by a chance process with a constant hit rate (i.e., non-stationarity).

It may seem unreasonable to compare basketball shooting to coin tossing because a player's chances of hitting a basket are not the same on every shot. Lay-ups are easier than 3-point field goals and slam dunks have a higher hit rate than turnaround jumpers. Nevertheless, the simple binomial model is equivalent to a more complicated process with the following characteristics: Each player has an ensemble of shots that vary in difficulty (depending, for example, on the distance from the basket and on defensive pressure), and each shot is randomly selected from this ensemble. This process provides a more compelling account of the performance of a basketball player, although it produces a shooting record that is indistinguishable from that produced by a simple binomial model in which the probability of a hit is the same on every trial.

We begin with a survey that explores the beliefs of basketball fans regarding streak shooting and related phenomena. We then turn to an analysis of field goal and free-throw data from the NBA. Finally, we report a controlled experiment performed by the men and women of Cornell's varsity teams that investigates players' ability to predict their performance.

STUDY 1: SURVEY OF BASKETBALL FANS

One hundred basketball fans were recruited from the student bodies of Cornell and Stanford University. All participants play basketball at least "occasionally" (65% play "regularly"). They all watch at least 5 games per year (73% watch over 15 games per year). The sample included 50 captains of intramural basketball teams.

The questionnaire examined basketball fans' beliefs regarding sequential dependence among shots. Their responses revealed considerable agreement: 91% of the fans believed that a player has "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"; 68% of the fans expressed essentially the same belief for free throws, claiming that a player has "a better chance of making his second shot after *making* his first shot than after *missing* his first shot"; 96% of the fans thought that "after having made a series of shots in a row . . . players tend to take more shots than they normally would''; 84% of the fans believed that ''it is important to pass the ball to someone who has just made several (two, three, or four) shots in a row.''

The belief in a positive dependence between successive shots was reflected in numerical estimates as well. The fans were aked to consider a hypothetical player who shoots 50% from the field. Their average estimate of his field goal percentage was 61% ''after having just made a shot,'' and 42% ''after having just missed a shot.'' Moreover, the former estimate was greater than or equal to the latter for every respondent. When asked to consider a hypothetical player who shoots 70% from the free-throw line, the average estimate of his free-throw percentage was 74% ''for second free throws after having made the first,'' and 66% ''for second free throws after having missed the first.''

Thus, our survey revealed that basketball fans believe in ''streak shooting.'' It remains to be seen whether basketball players actually shoot in streaks.

STUDY 2: PROFESSIONAL BASKETBALL FIELD GOAL DATA

Field goal records of individual players were obtained for 48 home games of the Philadelphia 76ers and their opponents during the 1980–1981 season. These data were recorded by the team's statistician. Records of consecutive shots for individual players were not available for other teams in the NBA. Our analysis of these data divides into three parts. First we examine the probability of a hit conditioned on players' recent histories of hits and misses, second we investigate the frequency of different sequences of hits and misses in players' shooting records, and third we analyze the stability of players' performance records across games.

Analysis of Conditional Probabilities

Do players hit a higher percentage of their shots after having just *made* their last shot (or last several shots), than after having just *missed* their last shot (or last several shots)? Table 1 displays these conditional probabilities for the nine major players of the Philadelphia 76ers during the 1980–1981 season. Column 5 presents the overall shooting percentage for each player ranging from 46% for Hollins and Toney to 62% for Dawkins. Columns 6 through 8 present the players' shooting percentages conditioned on having *hit* their last shot, their last two shots, and their last three shots, respectively. Columns 2 through 4 present the players' shooting percentages conditioned on having *missed* their last shot, their last two shots, and their last three shots, respectively. Column 9 presents the (serial) correlation between the outcomes of successive shots.

A comparison of columns 4 and 6 indicates that for eight of the nine

TABLE 1

Probability of Making a Shot Conditioned on the Outcome of Previous Shots for Nine Members of the Philadelphia 76ers

Player	P(hit/3 misses)	P(hit/2 misses)	P(hit/1 miss)	P(hit)	P(hit/1 hit)	P(hit/2 hits)	P(hit/3 hits)	Serial correlation r
Clint Richardson	.50 (12)	.47 (32)	.56 (101)	.50 (248)	.49 (105)	.50 (46)	.48 (21)	−.020
Julius Erving	.52 (90)	.51 (191)	.51 (408)	.52 (884)	.53 (428)	.52 (211)	.48 (97)	.016
Lionel Hollins	.50 (40)	.49 (92)	.46 (200)	.46 (419)	.46 (171)	.46 (65)	.32 (25)	−.004
Maurice Cheeks	.77 (13)	.60 (38)	.60 (126)	.56 (339)	.55 (166)	.54 (76)	.59 (32)	−.038
Caldwell Jones	.50 (20)	.48 (48)	.47 (117)	.47 (272)	.45 (108)	.43 (37)	.27 (11)	−.016
Andrew Toney	.52 (33)	.53 (90)	.51 (216)	.46 (451)	.43 (190)	.40 (77)	.34 (29)	−.083
Bobby Jones	.61 (23)	.58 (66)	.58 (179)	.54 (433)	.53 (207)	.47 (96)	.53 (36)	−.049
Steve Mix	.70 (20)	.56 (54)	.52 (147)	.52 (351)	.51 (163)	.48 (77)	.36 (33)	−.015
Daryl Dawkins	.88 (8)	.73 (33)	.71 (136)	.62 (403)	.57 (222)	.58 (111)	.51 (55)	−.142**
Weighted means	.56	.53	.54	.52	.51	.50	.46	−.039

Note. Since the first shot of each game cannot be conditioned, the parenthetical values in columns 4 and 6 do not sum to the parenthetical value in column 5. The number of shots upon which each probability is based is given in parentheses.

* $p < .05$.

** $p < .01$.

players the probability of a hit is actually lower following a hit (weighted mean: 51%) than following a miss (weighted mean: 54%), contrary to the hot-hand hypothesis. Consequently, the serial correlations in column 9 are negative for eight of the nine players, but the coefficients are not significantly different from zero except for one player (Dawkins). Comparisons of column 7, P (hit/2 hits), with column 3, P (hit/2 misses), and of column 8, P (hit/3 hits), with column 2, P (hit/3 misses), provide additional evidence against streak-shooting; the only trend in these data runs counter to the hot-hand hypothesis (paired $t = -2.79$, $p < .05$ for columns 6 and 4, $t = -3.14$, $p < .05$ for columns 7 and 3, $t = -4.42$, $p < .01$ for columns 8 and 2). Additional analyses show that the probability of a hit following a "hot" period (three or four hits in the last four shots) was lower (weighted mean: 50%) than the probability of a hit (weighted mean: 57%) following a "cold" period (zero or one hit in the last four shots).

Analysis of Runs

Table 2 displays the results of the Wald–Wolfowitz run test for each player (Siegel, 1956). For this test, each sequence of consecutive hits or misses is counted as a "run." Thus, a series of hits and misses such as X000XX0 contains four runs. The more a player's hits (and misses) cluster together, the fewer runs there are in his record. Column 4 presents the observed number of runs in each player's record (across all 48 games), and column 5 presents the expected number of runs if the outcomes of all shots were independent of one another. A comparison of columns 4 and 5 indicates that for five of the nine players the observed number of runs is actually greater than the expected number of runs, contrary to the streak-shooting hypothesis. The z statistic reported in column 6 tests the significance of the difference between the observed and the expected number of runs. A significant difference between these values exists for only one player (Dawkins), whose record includes significantly *more* runs than expected under independence, again, contrary to streak shooting.

Run tests were also performed on each player's records within individual games. Considering both the 76ers and their opponents together, we obtained 727 individual player game records that included more than two runs. A comparison of the observed and expected number of runs did not provide any basis for rejecting the null hypothesis (t (726) < 1).

Test of Stationarity

The notions of "the hot hand" and "streak shooting" entail temporary elevations of performance—i.e., periods during which the player's hit rate is substantially higher than his overall average. Although such changes in performance would produce a positive dependence between

TABLE 2
Runs Test—Philadelphia 76ers

Players	Hits	Misses	Number of runs	Expected number of runs	Z
Clint Richardson	124	124	128	125.0	−0.38
Julius Erving	459	425	431	442.4	0.76
Lionel Hollins	194	225	203	209.4	0.62
Maurice Cheeks	189	150	172	168.3	−0.41
Caldwell Jones	129	143	134	136.6	0.32
Andrew Toney	208	243	245	225.1	−1.88
Bobby Jones	233	200	227	216.2	−1.04
Steve Mix	181	170	176	176.3	0.04
Daryl Dawkins	250	153	220	190.8	−3.09**
M =	218.6	203.7	215.1	210.0	−0.56

* $p < .05$.
** $p < .01$.

the outcomes of successive shots, it could be argued that neither the runs test nor the test of the serial correlation are sufficiently powerful to detect occasional "hot" stretches embedded in longer stretches of "normal" performance. To obtain a more sensitive test of stationarity, or a constant hit rate, we partitioned the entire record of each player into nonoverlapping sets of four consecutive shots. We then counted the number of sets in which the player's performance was high (three or four hits), moderate (two hits), or low (zero or one hit). If a player is occasionally hot, then his record must include more high-performance sets than expected by chance.

The number of high, moderate, and low sets for each of the nine players were compared to the values expected by chance, assuming independent shots with a constant hit rate (derived from column 5 of Table 1). For example, the expected proportions of high-, moderate-, and low-performance sets for a player with a hit rate of 0.5 are 5/16, 6/16, and 5/16, respectively. The results provided no evidence for nonstationarity, or streak shooting, as none of the nine χ^2 values approached statistical significance. This analysis was repeated four times, starting the partition into consecutive quadruples at the first, second, third, and fourth shot of each player's shooting record. All of these analyses failed to support the nonstationarity hypothesis.

Analysis of Stability across Games—Hot and Cold Nights

To determine whether players have more "hot" and "cold" nights than expected by chance, we compared the observed variability in their per game shooting percentages with the variability expected on the basis of their overall record. Specifically, we compared two estimates of the standard error of each players' per game shooting percentages: one based on the standard deviation of the player's shooting percentages for each game, and one derived from the player's overall shooting percentage across all games. If players' shooting percentages in individual games fluctuate more than would be expected under the hypothesis of independence, then the (Lexis) ratio of these standard errors (*SE* observed/*SE* expected) should be significantly greater than 1 (David, 1949). Seven 76ers played at least 10 games in which they took at least 10 shots per game, and thus could be included in this analysis (Richardson and C. Jones did not meet this criterion). The Lexis ratios for these seven players ranged from 0.56 (Dawkins) to 1.03 (Erving), with a mean of 0.84. No player's Lexis ratio was significantly greater than 1, indicating that variations in shooting percentages across games do not deviate from their overall shooting percentage enough to produce significantly more hot (or cold) nights than expected by chance.

Discussion

Before discussing these results, it is instructive to consider the beliefs of the Philadelphia 76ers themselves regarding streak shooting and the hot hand. Following a team practice session, we interviewed seven players and the coach who were asked questions similar to those asked of the basketball fans in Study 1.

Most of the players (six out of eight) reported that they have on occasion felt that after having made a few shots in a row they "know" they are going to make their next shot—that they "almost can't miss." Five players believed that a player "has 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." (Two players did not endorse this statement and one did not answer this question.) Seven of the eight players reported that after having made a series of shots in a row, they "tend to take more shots than they normally would." All of the players believed that it is important "for the players on a team to pass the ball to someone who has just made several (two, three, or four) shots in a row." Five players and the coach also made numerical estimates. Five of these six respondents estimated their field goal percentage for shots taken after a hit (mean: 62.5%) to be higher than their percentage for shots taken after a miss (mean: 49.5%).

It is evident from our interview that the Philadelphia 76ers—like our sample of basketball fans, and probably like most players, spectators, and students of the game—believe in the hot hand, although our statistical analyses provide no evidence to support this belief.

It could be argued that streak shooting exists but it is not common and we failed to include a "real" streak shooter in our sample of players. However, there is a general consensus among basketball fans that Andrew Toney is a streak shooter. In an informal poll of 18 recreational basketball players who were asked to name five streak shooters in the NBA, only two respondents failed to include Andrew Toney, and he was the first player mentioned by half the respondents. Despite this widespread belief that Toney runs hot and cold, his runs of hits and misses did not depart from chance expectations.[2] We have also analyzed the field goal records of two other NBA teams: the New Jersey Nets (13 games) and the New York Knicks (22 games). These data were recorded from live television broadcasts. A parallel analysis of these records provides evidence consistent with the findings reported above. Of seven New York Knicks and seven New Jersey Nets, only one player exhibited a significant positive correlation between successive shots (Bill Cartwright of the Knicks). Thus, only two of the 23 major players on three NBA teams produced significant serial correlations, one of which was positive, and the other negative.

The failure to detect evidence of streak shooting might also be attributed to the selection of shots by individual players and the defensive strategy of opposing teams. After making one or two shots, a player may become more confident and attempt more difficult shots; after missing a shot, a player may get conservative and take only high-percentage shots. This would obscure any evidence of streak shooting in players' performance records. The same effect may be produced by the opposing team's defense. Once a player has made one or two shots, the opposing team may intensify their defensive pressure on that player and "take away" his good shots. Both of these factors may operate in the game and they are probably responsible for the (small) negative correlation between successive shots. However, it remains to be seen whether the elimination of these factors would yield data that are more compatible with people's expectations. The next two studies examine two different types of

[2] Why do people share the belief that Toney, for example, is a streak shooter if his record does not support this claim? We conjecture that the players who are perceived as "streak shooters" are the good shooters who often take long (and difficult) shots. Making a few such shots in a row is indeed a memorable event, the availability of which may bias one's recollection of such players' performance records (Tversky & Kahneman, 1973). The finding that 77% of the players identified as "streak shooters" in our survey play the guard position provides some support for our conjecture because long shots are usually taken by guards more frequently than by other players.

shooting data that are uncontaminated by shot selection or defensive pressure.

STUDY 3: PROFESSIONAL BASKETBALL FREE-THROW DATA

Free-throw data permit a test of the dependence between successive shots that is free from the contaminating effects of shot selection and opposing defense. Free throws, or foul shots, are commonly shot in pairs, and they are always shot from the same location without defensive pressure. If there is a positive correlation between successive shots, we would expect players to hit a higher percentage of their second free throws after having made their first free throw than after having missed their first free throw. Recall that our survey of basketball fans found that most fans believe there is positive dependency between successive free throws, though this belief was not as strong as the corresponding belief about field goals. The average estimate of the chances that a 70% free-throw shooter would make his second free throw was 74% after making the first shot and 66% after missing the first shot.

Do players actually hit a higher percentage of their second free throws after having just *made* their first free throw than after having just *missed* their first free throw? Table 3 presents these data for all pairs of free throws by Boston Celtics players during the 1980–1981 and the 1981–1982 seasons. These data were obtained from the Celtics' statistician. Column 2 presents the probability of a hit on the second free throw given a *miss* on the first free throw, and column 3 presents the probability of a hit on the second free throw given a *hit* on the first free throw. The correlations between the first and the second shot are presented in column 4. These data provide no evidence that the outcome of the second free throw is influenced by the outcome of the first free throw. The correlations are positive for four players, negative for the other five, and none of them are significantly different from zero.[3]

STUDY 4: CONTROLLED SHOOTING EXPERIMENT

As an alternative method for eliminating the effects of shot selection and defensive pressure, we recruited members of Cornell's intercollegiate basketball teams to participate in a controlled shooting study. This experiment also allowed us to investigate the ability of players to predict their performance.

The players were 14 members of the men's varsity and junior varsity basketball teams at Cornell and 12 members of the women's varsity team.

[3] Aggregating data across players is inappropriate in this case because good shooters are more likely to make their first shot than poor shooters. Consequently, the good shooters contribute more observations to P (hit/hit) than to P (hit/miss) while the poor shooters do the opposite, thereby biasing the pooled estimates.

TABLE 3
Probability of Making a Second Free Throw Conditioned on the Outcome of the First Free Throw for Nine Members of the Boston Celtics during the 1980–1981 and 1981–1982 Seasons

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 upon which each probability is based is given in parentheses.

For each player we determined a distance from which his or her shooting percentage was roughly 50%. At this distance we then drew two 15-ft arcs on the floor from which each player took all of his or her shots. The centers of the arcs were located 60° out from the left and right sides of the basket. When shooting baskets, the players were required to move along the arc between shots so that consecutive shots were never taken from exactly the same spot. Each player was to take 100 shots, 50 from each arc.[4] The players were paid for their participation. The amount of money they received was determined by how accurately they shot and how accurately they predicted their hits and misses. This payoff procedure is described below. The initial analyses of the Cornell data parallel those of the 76ers.

Analysis of Conditional Probabilities

Do Cornell players hit a higher percentage of their shots after having just *made* their last shot (or last several shots), than after having just *missed* their last shot (or last several shots)? Table 4 displays these conditional probabilities for all players in the study. Column 5 presents the overall shooting percentage for each player ranging from 25 to 61% (mean: 47%). Columns 6 through 8 present the players' shooting percentages conditioned on having *hit* their last shot, their last two shots, and their last three shots, respectively. Columns 2 through 4 present the players' shooting percentages conditioned on having *missed* their last

[4] Three of the players were not able to complete all 100 shots.

shot, their last two shots, and their last three shots, respectively. Column 9 presents the serial correlation for each player.

A comparison of players' shooting percentages after hitting the previous shot (column 6, mean: 48%) with their shooting percentages after missing the previous shot (column 4, mean: 47%) indicates that for most players P (Hit/Hit) is less than P (Hit/Miss), contrary to the hot hand hypothesis. Indeed the serial correlations were negative for 14 out of the 26 players and only one player (9) exhibited a significant positive correlation. Comparisons of column 7, P (hit/2 hits), with column 3, P (hit/2 misses), and column 8, P (hit/3 hits), with column 2, P (hit/3 misses), lead to the same conclusion (paired t's < 1 for all three comparisons). Additional analyses show that the probability of a hit following a "hot" period (three or four hits in the last four shots) was not higher (mean: 46%) than the probability of a hit (mean: 47%) following a "cold" period (zero or one hit in the last four shots).

Analysis of Runs

Table 5 displays the results of the Wald–Wolfowitz run test for each player (Siegel, 1956). Recall that for this test, each streak of consecutive hits or misses is counted as a run. Column 4 presents the observed number of runs in each player's performance record, and column 5 presents the number of runs expected by chance. A comparison of these two columns reveals 14 players with slightly more runs than expected and 12 players with slightly fewer than expected. The z statistic reported in column 6 shows that only the record of player 9 contained significantly more clustering (fewer runs) of hits and misses than expected by chance.

Test of Stationarity

As in Study 2, we divided the 100 shots taken by each player into nonoverlapping sets of four consecutive shots and counted the number of sets in which the player's performance was high (three or four hits), moderate (two hits), or low (zero or one hit). If a player is sometimes hot, the number of sets of high performance must exceed the number expected by chance, assuming a constant hit rate and independent shots. A χ^2 test for goodness of fit was used to compare the observed and the expected number of high, moderate, and low sets for each player. As before, we repeated this analysis four times for each player, starting at the first, second, third, and fourth shots in each player's record. The results provided no evidence for departures from stationarity for any player but 9.

TABLE 4

Probability of Making a Shot Conditioned on the Outcome of Previous Shots for All Cornell Players

Player	*P*(hit/3 misses)	*P*(hit/2 misses)	*P*(hit/1 miss)	*P*(hit)	*P*(hit/1 hit)	*P*(hit/2 hits)	*P*(hit/3 hits)	Serial correlation *r*
Males								
1	.44 (9)	.50 (18)	.61 (46)	.54 (100)	.49 (53)	.48 (25)	.50 (12)	−.118
2	.43 (28)	.33 (42)	.35 (65)	.35 (100)	.35 (34)	.25 (12)	.00 (3)	−.001
3	.67 (6)	.68 (19)	.49 (39)	.60 (100)	.67 (60)	.62 (40)	.60 (25)	.179
4	.47 (15)	.45 (29)	.43 (53)	.40 (90)	.36 (36)	.23 (13)	.33 (3)	−.073
5	.75 (12)	.60 (30)	.47 (57)	.42 (100)	.36 (42)	.40 (15)	.33 (6)	−.117
6	.25 (12)	.38 (21)	.48 (42)	.57 (100)	.65 (57)	.62 (37)	.65 (23)	.173
7	.29 (7)	.50 (16)	.47 (32)	.56 (75)	.64 (42)	.63 (27)	.65 (17)	.174
8	.50 (6)	.50 (12)	.52 (25)	.50 (50)	.46 (24)	.64 (11)	.57 (7)	−.062
9	.35 (20)	.33 (30)	.35 (46)	.54 (100)	.72 (53)	.79 (38)	.83 (30)	.370**
10	.57 (7)	.50 (14)	.64 (39)	.59 (100)	.79 (38)	.60 (35)	.57 (21)	−.058
11	.57 (7)	.61 (18)	.56 (41)	.58 (100)	.59 (58)	.62 (34)	.62 (21)	.025
12	.41 (17)	.43 (30)	.46 (56)	.44 (100)	.42 (43)	.39 (18)	.43 (7)	−.046
13	.40 (5)	.62 (13)	.67 (39)	.61 (100)	.58 (60)	.56 (34)	.50 (18)	−.084
14	.50 (6)	.62 (16)	.60 (40)	.59 (100)	.58 (59)	.59 (34)	.60 (20)	−.031
Females								
1	.67 (9)	.61 (23)	.55 (51)	.48 (100)	.42 (48)	.45 (20)	.33 (9)	−.132
2	.43 (28)	.36 (44)	.31 (65)	.34 (100)	.41 (34)	.36 (14)	.40 (5)	.104
3	.36 (25)	.38 (40)	.33 (60)	.39 (100)	.49 (39)	.42 (19)	.50 (8)	.154
4	.27 (30)	.33 (45)	.34 (68)	.33 (100)	.29 (31)	.33 (9)	.33 (3)	−.048
5	.22 (27)	.36 (42)	.34 (64)	.35 (100)	.37 (35)	.50 (12)	.20 (5)	.028
6	.54 (11)	.58 (26)	.52 (54)	.46 (100)	.38 (45)	.41 (17)	.29 (7)	−.141
7	.32 (25)	.28 (36)	.36 (58)	.41 (100)	.49 (41)	.65 (20)	.62 (13)	.126
8	.67 (9)	.55 (20)	.57 (47)	.53 (100)	.50 (52)	.58 (26)	.73 (15)	−.075
9	.46 (13)	.55 (29)	.47 (55)	.45 (100)	.41 (44)	.47 (17)	.50 (8)	−.064
10	.32 (19)	.34 (29)	.46 (54)	.47 (100)	.47 (45)	.67 (21)	.71 (14)	.004
11	.50 (10)	.56 (23)	.51 (47)	.53 (100)	.56 (52)	.50 (28)	.39 (13)	.047
12	.32 (37)	.32 (54)	.27 (74)	.25 (100)	.20 (25)	.00 (5)	— (0)	.036
M =	.45	.47	.47	.47	.48	.49	.49	.015

Note. Since the first shot cannot be conditioned, the parenthetical values in columns 4 and 6 sum to one less than the parenthetical value in column 5. The number of shots upon which each probability is based is given in parentheses.

* $p < .05$.

** $p < .01$.

TABLE 5
Runs Test—Cornell Players

Player	Hits	Misses	Number of runs	Expected number of runs	Z
Males					
1	54	46	56	50.7	−1.08
2	35	65	46	46.5	0.11
3	60	40	40	49.0	1.89
4	36	54	47	44.2	−0.62
5	42	58	55	49.7	−1.09
6	57	43	41	50.0	1.85
7	42	33	31	38.0	1.64
8	25	25	27	26.0	−0.29
9	54	46	32	50.7	3.78**
10	60	40	51	49.0	−0.42
11	58	42	48	49.7	0.35
12	44	56	52	50.3	−0.35
13	61	39	52	48.6	−0.72
14	59	41	50	49.4	−0.13
Females					
1	48	52	57	50.9	−1.22
2	34	66	41	45.9	1.09
3	39	61	41	48.6	1.60
4	32	68	46	44.5	−0.34
5	36	64	45	47.1	0.45
6	46	54	57	50.7	−1.28
7	41	59	43	49.4	1.33
8	53	47	54	50.8	−0.64
9	45	55	53	50.5	−0.51
10	46	54	50	50.7	0.14
11	53	47	48	50.8	0.57
12	25	75	41	38.5	−0.67
M =	45.6	51.2	46.3	47.3	.21

* $p < .05$.
** $p < .01$.

Test of Predictability

There is another cluster of intuitions about "being hot" that involves predictability rather than sequential dependency. If, on certain occasions, a player can predict a "hit" before taking a shot, he or she may have a justified sense of being "hot" even when the pattern of hits and misses does not stray from chance expectation. We tested players' ability to predict hits and misses by having them bet on the outcome of each upcoming shot. Before every shot, each player chose whether to bet *high* in which case he or she would win 5¢ for a hit and lose 4¢ for a miss; or bet *low,* in which case he or she would win 2¢ for a hit and lose 1¢ 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. The players were run in pairs, alternating between the roles of "shooter" and "observer." On each trial, the observer also bet high or low on the outcome of the upcoming shot. The shooter and observer did not know each other's bets. Each player was paid $2, plus or minus the amount of money won or lost on the bets made as a shooter and observer.

If players can predict their hits and misses, their bets should correlate with their performance. The correlations between the shooters' performance and the bets made by the shooters and observers are presented in Table 6. These data reveal that the players were generally unsuccessful in predicting hits and misses. The average correlation between the shooters' bets and their performance, presented in column 2, was .02. Only 5 of the 26 individual correlations were statistically significant, of which 4 were quite low (.20 to .22), and the 5th was negative (−.51). The four small but significant positive correlations may reflect either a limited ability to predict the outcome of an upcoming shot, or a tendency to try harder following a high bet.

As one might expect, the observers were also unsuccessful in predicting the shooters' performance. The average correlation between the observers' bets and the shooters' performance, presented in column 3, was .04. On the other hand, the bets of both shooters and observers *were* correlated with the outcome of the shooter's *previous* shot as shown in columns 4 and 5 (mean r = .40 for the shooters and .42 for the observers). It appears that both the shooter and observer anticipated a hit if the shooter had made the last shot. This betting strategy, which reflects a belief in the hot hand, produced chance performance because of the absence of a positive serial correlation. It also produced agreement between shooters' and observers' bets (column 6, mean r = .22) that vanishes when the effect of the previous shot is partialed out (column 7, mean r = .05).

DISCUSSION

This article investigated beliefs and facts concerning the sequential characteristics of hits and misses in basketball. Our survey shows that basketball fans believe that a player's chances of hitting a basket are greater following a hit than following a miss. Similar beliefs were expressed by professional basketball players. However, the outcomes of both field goal and free throw attempts were largely independent of the outcome of the previous attempt. Moreover, the frequency of streaks in players' records did not exceed the frequency predicted by a binomial model that assumes a constant hit rate. A controlled experiment, with

TABLE 6
Correlations between Bets and Performance for All Cornell Players

	Shooter's bets with shooter's hits	Observer's bets with shooter's hits	Shooter's bets with previous shot	Observer's bets with previous shot	Observer's bets with shooter's bets	Observer's bets with shooter's bets, partialing out previous shot
Males						
1	.06	−.06	.44**	.76**	.25*	−.14
2	−.01	−.06	.94**	.35**	.32**	−.03
3	−.07	.01	.35**	.38**	.37**	.27**
4	−.16	−.20*	.20	.75**	.24*	.14
5	−.03	.01	.38**	−.13	−.12	−.08
6	.22*	.24*	.36**	.72**	.27**	.02
7	.18	.24*	.17	.66**	−.03	−.19
8	.04	.21	.33**	.13	.21	.18
9	.05	.21*	.47**	.55**	.12	−.19
10	.00	−.19	.31**	.09	.27**	.26*
11	−.51*	.03	.15	.12	.07	.05
12	.20*	.00	.37**	.36**	.31**	.20*
13	.00	−.11	.23*	.42**	.19	.11
14	.20*	−.05	.21*	.59**	.27**	.19
Females						
1	−.04	−.09	.52**	.37**	.24*	.06
2	.17	.05	.39**	.72**	.40**	.19
3	.05	.16	.40**	.72**	.24*	−.08
4	−.05	−.03	.49**	.12	.18	.14
5	.03	.14	.43**	.42**	.43**	.30**
6	.03	.05	.31**	.53**	.02	−.18
7	.22*	.20*	.65**	.71**	.53**	.13
8	.07	.13	.50**	−.05	.35**	.43**
9	.11	−.01	.49**	.39**	.23*	.05
10	−.01	.11	.62**	.63**	.10	−.48**
11	.11	.18	.33**	.18	.22*	.17
12	.02	−.07	.35**	.42**	−.03	−.21*
$M =$	.02	.04	.40	.42	.22	.05

* $p < .05$
** $p < .01$

the varsity players of Cornell University, led to the same conclusions. With the exception of one player, no significant correlation between shots was found. Players' predictions of their own performance, expressed in the form of a betting game, revealed a consistent belief in the hot hand, although their actual performance did not support this belief. Evidently, the sense of being "hot" does not predict hits or misses.

How can we account for the prevalent belief in streak shooting despite the absence of sequential dependencies? This phenomenon could be due to a memory bias. If long sequences of hits (or misses) are more memorable than alternating sequences, the observer is likely to overestimate the correlation between successive shots. Alternatively, the belief in the hot hand may be caused by a misperception of chance that operates even when the data are in front of the subject rather than retrieved from memory.

The misperception hypothesis received support from our study of 100 basketball fans (Experiment 1). Following the survey, we presented each fan with six different sequences of hits (indicated by X's) and misses (indicated by O's). Subjects were asked to classify each sequence as "chance shooting," "streak shooting," or "alternate shooting." Chance shooting was defined as sequences of hits and misses that are just like the sequences of heads and tails usually found when flipping coins. Streak shooting and alternate shooting were defined as clusters of hits and misses that are longer or shorter, respectively, than the clusters of heads and tails usually found in coin tossing.

All six sequences included 11 hits and 10 misses. They differed in the number of runs (9, 11, . . ., 19), and thus the probability of alternation (0.4, 0.5, . . ., 0.9, respectively), or the probability that the outcome of a given shot will be different from the outcome of the previous shot. In coin tossing, the probability of alternation is 0.5—the outcome of a given trial is independent of the outcome of the previous trial. Streaks are produced when the probability of alternation is less than 0.5, and alternating sequences are produced when the probability of alternation is greater than 0.5. For example, the sequence X0X0X000XX0X0X00-XXX0X, and its mirror image, which consist of 15 runs, were used for the probability of alternation of 0.7.

The percentage of "streak," and "chance" responses for each sequence is presented in Fig. 1. The percentage of "alternate" responses is the complement of these values. As expected, the tendency to perceive a sequence as streak shooting decreases with the probability of alternation. The most significant feature of Fig. 1, however, is the respondents' perception of chance shooting. The sequences selected as best examples of chance shooting had probabilities of alternation of 0.7 and 0.8 rather than 0.5. Furthermore, the sequence with the probability of alternation of 0.5 (the proper example of chance shooting) was classified as chance shooting only by 32% of subjects, whereas 62% identified it as an example of streak shooting.

Evidently, people tend to perceive chance shooting as streak shooting, and they expect sequences exemplifying chance shooting to contain many more alternations than would actually be produced by a random (chance) process. Thus, people "see" a positive serial correlation in independent sequences, and they fail to detect a negative serial correlation in alternating sequences. Hence, people not only perceive random sequences as positively correlated, they also perceive negatively correlated sequences as random. These phenomena are very much in evidence even when the sequences are displayed to the subject rather than retrieved from memory. Selective coding or biased retrieval, therefore, are not necessary for generating an erroneous belief in streak shooting, although they may enhance the effect. We attribute this phenomenon to a general miscon-

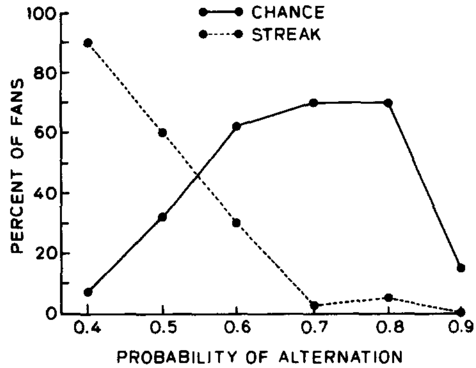

FIG. 1. Percentage of basketball fans classifying sequences of hits and misses as examples of streak shooting or chance shooting, as a function of the probability of alternation within the sequences.

ception of the laws of chance associated with the belief that small as well as large sequences are representative of their generating process (Tversky & Kahneman, 1974). This belief induces the expectation that random sequences should be far more balanced than they are, and the erroneous perception of a positive correlation between successive shots. These observations are highly consistent with earlier work on the perception of randomness in other contexts. Specifically, the "chance" curve in Fig. 1 closely resembles Falk's (1981) data on the judged randomness of sequences of 21 yellow and green cards.

This account explains both the formation and maintenance of the erroneous belief in the hot hand: If random sequences are perceived as streak shooting, then no amount of exposure to such sequences will convince the player, the coach, or the fan that the sequences are in fact random. The more basketball one watches and plays, the more opportunities one has to observe what appears to be streak shooting. In order to appreciate the sequential properties of basketball data, one has to realize that coin tossing produces just as many runs. If people's perceptions of coin tossing are biased, it should not be surprising that they perceive sequential dependencies in basketball when none exist.

The independence between successive shots, of course, does not mean that basketball is a game of chance rather than of skill, nor should it render the game less exciting to play, watch, or analyze. It merely indicates that the probability of a hit is largely independent of the outcome of previous shots, although it surely depends on other parameters such as skill, distance to the basket, and defensive pressure. This situation is analogous to coin tossing where the outcomes of successive tosses are independent but the probability of heads depends on measurable factors such as the initial position of the coin, and its angular and vertical momentum (see Keller, 1985). Neither coin tossing nor basketball are inherently random, once all the relevant parameters are specified. In the absence of this information, however, both processes may be adequately described by a simple binomial model. A major difference between the two processes is that it is hard to think of a credible mechanism that would create a correlation between successive coin tosses, but there are many factors (e.g., confidence, fatigue) that could produce positive dependence in basketball. The availability of plausible explanations may contribute to the erroneous belief that the probability of a hit is greater following a hit than following a miss.

The preceding discussion applies to the perception of randomness in general with no special reference to sports events or basketball. However, there are several specific factors linked to basketball that might enhance the effect. First, the intuition that a player is "hot" may stem from observations of his defense, hustling, and passing, which may be overgeneralized to shooting as well. Second, the coding of events may also help support the belief in sequential dependency. The common occurrence of a shot that pops out of the rim of the basket after having seemingly been made may be interpreted as continued evidence of being "hot" if the player had made the previous shot and as evidence of being "cold" if the player missed the previous shot (cf. Gilovich, 1983).

The present data demonstrate the operation of a powerful and widely shared cognitive illusion. Such illusions or biases have been observed in the judgments of both laypeople and experts in several fields (see, e.g., Fischhoff, Slovic, & Lichtenstein, 1981; Kahneman, Slovic, & Tversky, 1982; Nisbett & Ross, 1980; Tversky & Kahneman, 1983). If the present results are surprising, it is because of the robustness with which the erroneous belief in the "hot hand" is held by experienced and knowledgeable observers. This belief is particularly intriguing because it has consequences for the conduct of the game. Passing the ball to the player who is "hot" is a common strategy endorsed by basketball players. It is also anticipated by the opposing team who can concentrate on guarding the "hot" player. If another player, who is less "hot" on that particular day, is equally skilled, then the less guarded player would have a better chance of scoring. Thus the belief in the "hot hand" is not just erroneous, it could also be costly.

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