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# Randomness and inductions from streaks: "Gambler's fallacy" versus "hot hand"

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Sometimes people believe that a run of similar independent events will be broken (belief in the *gambler's fallacy*) but, other times, that such a run will continue (belief in the *hot hand*). Both of these opposite inductions have been explained as being due to belief in a law of small numbers. We argue that one factor that distinguishes these phenomena is people's beliefs about the randomness of the underlying process generating the events. We gave participants information about a streak of events but varied the scenarios in such a way that the mechanism generating the events should vary in how random the participants would judge it to be. A manipulation check confirmed our assumptions about the scenarios. We found that with less random scenarios, the participants were more likely to continue a streak.

Faced with a streak of events and the necessity to make a choice, people may make one of three possible inductions: (1) that the streak is irrelevant, (2) that the streak will continue, or (3) that the streak will stop. If people generally accepted the first of these inductions, then when faced with a forced choice, they should predict the next event with a probability equal to its base rate (e.g., 50% for a fair coin flip). However, what is often observed is a bias toward one of the other two inductions, even when the events are independent. The induction that the streak should continue was observed by Gilovich, Vallone, and Tversky (1985) in their study of the basketball phenomenon known as the *hot hand.* They found that basketball fans believed that a streak should be more likely to continue if a basketball player experiences a streak of hits than if that player had experienced a streak of misses. Yet Gilovich et al. also showed that streaks of hits are no more likely than chance. The third induction is often known as the *gambler's fallacy*, a tendency to believe that a streak of events is likely to end. Laplace (1814/1951) first wrote about this phenomenon, and its existence has been well documented (Tune, 1964).

Tversky and Kahneman's (1971) explanation for belief in the gambler's fallacy was that it is due to the representativeness heuristic, leading to a belief in a *law of small numbers*. In order for a sequence of events to be considered representative, people think that every segment of a random sequence should reflect the true proportion. Thus, a streak of one type of event must quickly end and be evened out by other events. Gilovich et al. (1985) argued that belief in the hot hand is also due to belief in the law of small numbers. A belief that things should even out will be challenged by a long streak; therefore, basketball players may reconcile the apparently unusual streak and their belief in the law of small numbers by assuming that the events are dependent.

Falk and Konold (1997) have pointed out that, in general, representativeness offers a convincing account of what participants do when judging random sequences but that its predictive power is weak. Similarly, Gigerenzer (2000, pp. 290–291) has pointed out that explaining the opposite phenomena with the same principle raises problems, yet this is what has been done with the gambler's fallacy (i.e., the streak should stop) and the hot hand (i.e., the streak should continue). A step toward understanding how people use streak information would be to understand what distinguishes situations in which people tend to think a streak will continue from those in which they tend to think it will stop. The law of small numbers cannot explain this.

## Randomness and Streaks

Defining randomness has raised problems (Nickerson, 2002), but definitions often focus on three features of a sequence considered random (see Wagenaar, 1991): (1) a fixed set of alternatives, (2) a selection procedure that does not utilize previous outcomes (i.e., independence of events), and (3) a selection procedure with no preference for any of the outcomes (i.e., equiprobability of events). There would be no advantage in favoring one event over another when someone is faced with a sequence of events with these characteristics. However, if people think of the process as *nonrandom*, this would imply a violation of at least one of these conditions, and it would be possible that following streaks is advantageous.

If independence (Condition 2) is violated so that there is a positive dependency between events, it is obviously better to continue streaks; however, a negative depen-

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dency would suggest that going against streaks would be better. In the absence of any other information, the possibility that independence alone is violated does not predict which induction should be favored. However, equiprobability (Condition 3) may be the most widely accepted assumption about random events (Nickerson, 2002), so that when people evaluate events as nonrandom, it is implied that they may think that this assumption is being violated. In contrast to violation of independence, any violation of equiprobability leads to an advantage when streaks are followed, everything else being equal. This is the implication from Burns's (in press) analysis of the hot hand in basketball, which shows that it is beneficial to a team to have a bias to give shots to players experiencing streaks. This analysis applies to any situation in which there must be a choice made between multiple events and in which the outcomes of events are independent but the events vary in terms or their probabilities. The full Markov modeling supporting this claim (Burns, in press) is presented elsewhere, but the key idea is that a streak is a valid predictive cue for the probability of an event (mathematically, the number of streaks generated within a stream of stable independent events is a function of their probabilities). Also implying that following a streak is advantageous is Kareev's (1995, especially Table 5) analysis, which shows that if two options are not equiprobable, having a bias toward assuming a positive covariance between consecutive events leads to better outcomes when those events are uncorrelated and even when they are slightly negatively correlated. Although Kareev does not discuss streaks, functionally his definition of positive covariance is a bias toward repeating the response that was successful on the previous trial, and his analysis applies equally to longer streaks. (Kareev's analysis is less general than Burns's, but both apply to the type of events used in our experiment: a choice between two options with dichotomous, mutually exclusive outcomes.)

From the above analysis can be derived a clear prediction about when people should be more likely to follow streaks: People should be more likely to follow streaks when the mechanism generating events is nonrandom (or is believed to be nonrandom) than when the generating mechanism is random. We tested this proposition empirically by presenting participants with scenarios that varied in terms of how likely people were to view them as random (validated by asking them whether they saw the process as random or nonrandom) and then presenting the participants with information about a streak and asking them to predict the next event.

### Manipulating Randomness

Our experiment presented the participants with three different scenarios, a *random* scenario and two nonrandom ones: *noncompetition* and *competition.* In each scenario, the participants read that there had been a sequence of 100 dichotomous events, with each occurring exactly 50 times, but that there had been a particular streak of 4 in a row of one of those events. They were then asked to predict the next event after that streak and to estimate the probability of success if they predicted that the event would continue.

In the random scenario, the events involved red or black on a roulette wheel. A roulette wheel was chosen because it is often regarded as a prototypically random process. Two different nonrandom scenarios were presented, to test whether a scenario's degree of nonrandomness would affect the likelihood of the participants' continuing a streak. The events in the noncompetition scenario were a person hitting or missing a basketball free throw. Gilovich et al. (1985) had demonstrated a belief in the hot hand in basketball, so we expected such a scenario to be judged as less random than spins of a roulette wheel. In the competition scenario the events involved one of two salespeople coming out ahead for a given week's sales. We used a competitive situation to try to amplify how nonrandom a scenario would be judged to be, because there is evidence that competition is often seen as causal and, thus, nonrandom. It has been shown empirically that people see the results of their own sporting competitions in terms of causality (e.g., McAuley & Gross, 1983). Also arguing that competition is seen as nonrandom is the fact that the extensive sports betting industry usually does not assign two competitors an equal probability of winning a contest. We used a nonsporting contest because the noncompetition scenario was already about a sport and we assumed that other forms of competition would also be viewed as nonrandom.

To validate our assumptions about these scenarios' judged randomness, we asked the participants to rate the outcomes in each scenario on a scale of 1–6, with 1 labeled *completely random* and 6 labeled *completely nonrandom.* We expected the participants to rate the competition scenario higher on this scale than the noncompetition scenario, which should itself be rated higher than the random scenario.

In the experiment, we also manipulated the factor of *time*—that is, whether the event had already occurred or was about to occur. We did this primarily because, when designing the experiment, there did not seem to be a good reason to place the event in the past or the present; thus, we used both forms, rather than make an arbitrary decision to use one or the other. For each scenario, *future* and *past* versions were created. The two versions differed in when the streak occurred. In the future versions, the streak was the last 4 of 100 events, and the participant had to predict the 101st event. In the past versions, the streak had occurred at some unstated time during the 100 events, so the next event (which the participant had to predict) had already occurred. In the past versions, the participants read that someone had been reviewing a history of the events by watching videotapes (random and noncompetition scenarios) or by reviewing sales records (competition scenario). The participants did not themselves observe the sequence of events.

### Predictions

Our predictions were based on the assumption that our randomness scale would empirically validate that the

**Table 1**
**Means and Standard Deviations for How Nonrandom Participants Thought the Events Were**

| | Competition | | Noncompetition | | Random | |
|---|---|---|---|---|---|---|
| Time | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Future | 3.6 | 1.3 | 3.2 | 1.4 | 2.2 | 1.4 |
| Past | 3.1 | 1.5 | 2.9 | 1.2 | 2.3 | 1.4 |

Note—1, *completely random*; 6, *completely nonrandom*.

random (roulette) scenarios would be rated as more random than the noncompetition scenarios, which in turn would be rated as less random than the competition scenarios. We predicted that the participants would be most likely to follow the streak in the competition scenarios and least likely in the random scenarios, with the likelihood in the noncompetition scenarios falling in between these two. We had no prediction regarding the direction of any time effect, but including it allowed us to try to generalize any randomness effect across this other factor.

## METHOD

### Participants

A total of 195 students from the Michigan State University participant pool participated for partial course credit.

### Procedure

Each participant received written descriptions of either the future or the past versions of all three scenarios: random, noncompetition, and competition. The full text of each scenario is presented in the Appendix. Each scenario was solved in one of three separate episodes, with unrelated short problem-solving tasks in between each episode. There were six possible orders in which the three scenarios could be responded to, so the participants randomly received one of these orders.

For each scenario, the participants were asked three questions: to choose which of the two events would occur next, to estimate the percentage chance of the next event's being a continuation of the streak, and to indicate on a scale of 1 (*completely random*) to 6 (*completely nonrandom*) how random they thought the outcomes were.

In each scenario, the participants read that over the course of 100 events, the frequencies of the two outcomes had been equal. Thus, they had no explicit information indicating that, at least so far, the probabilities of the events were unequal. It was important to equalize base rate information across scenarios, because the participants might assume equal base rates for the two events in the roulette scenario, due to prior knowledge, but they lacked prior knowledge from which to derive base rates in the competition or noncompetition scenarios. If we had presented the participants only with a streak, they might have been more likely to continue the streak in the later two conditions, because in the absence of any base rate information they might have regarded the streak itself as an indicator of a higher base rate.

## RESULTS

### Randomness Ratings

We first checked the effectiveness of our randomness manipulation. Table 1 presents the mean randomness rating for each version of each condition. To analyze these data, a $3 \times 2 \times 6$ analysis of variance (ANOVA) was used, with between-subjects factors of time (past vs. future) and order (six possible), and a within-subjects factor of scenario (random, noncompetition, or competition). The preplanned comparisons showed that the competition scenario was rated as being more nonrandom than the noncompetition scenario [$F(1,183) = 9.51$, $p = .002$] and the noncompetition scenario was rated as being more nonrandom than the random scenario [$F(1,183) = 41.40$, $p < .001$]. There was also a significant interaction between time and scenario [$F(2,366) = 3.97$, $p = .020$]. There were no significant interactions with order, except for one between order and time [$F(5,183) = 3.65$, $p = .004$]. (Without a significant three-way interaction of time, order, and scenario, this interaction means only that the sum of the three randomness ratings was not a constant, which is hard to interpret.) Correlations between the participants' randomness ratings and whether they went with or against the streak were statistically significant, but not particularly high [for the first episode, $r(195) = .29$; for the second episode, $r(195) = .30$; for the third episode, $r(195) = .28$]. That the correlations were not higher is not surprising, since judgments of randomness should not be the only factor influencing people's choices and a single 6-point scale is inherently a noisy measure. Note that these correlations were calculated across scenario because we expected the randomness scale to be sensitive enough to detect differences between scenarios (which was its purpose), but not necessarily within scenarios, in which the range of randomness judgments was more restricted. Overall, the randomness scale results supported our assumptions about how the scenarios differed in terms of being judged random and, thus, justified our testing the predictions based on those assumptions.

### Predictions for the Next Event

Table 2 presents the proportion of participants who indicated that they would continue the streak in each scenario. A $3 \times 2 \times 6$ ANOVA was used for this data even though it was dichotomous, since Lunney's (1970) simulations suggest that an ANOVA can be validly used for analyzing dichotomous data. The streak was continued more often by the participants who were presented with the competition scenario than by those who were presented with the noncompetition scenario [$F(1,183) = 11.81$, $p = .001$], and the noncompetition scenario was more likely to lead to an expectation of the streak's being continued than was the random [$F(1,183) = 71.88$, $p < .001$]. Table 2 also shows that the future versions of the

**Table 2**
**Proportions of Participants Who Continued the Streak in Each Scenario**

| | Competition | | Noncompetition | | Random | |
|---|---|---|---|---|---|---|
| Time | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Future ($n = 109$) | .66 | .50 | .56 | .50 | .12 | .33 |
| Past ($n = 86$) | .52 | .48 | .34 | 48 | .14 | .35 |

competition and noncompetition scenarios were more likely to lead the participants to continue the streak, but this was not the case for the random scenario. This pattern led to a significant interaction between time and scenario [$F(2,366) = 4.74, p = .009$].

For the prediction measure, the only factor with a significant interaction with order was scenario [$F(10,366) = 1.88$, $p = .047$]. An examination of this interaction found that it appeared to be due to the streak's being less likely to be continued in the noncompetition scenario when it was the first scenario presented, although still much more likely than when the random scenario was presented in any order.

### Percentages

Table 3 presents the mean percentage estimated chance of the streak's continuing for each scenario, which was again analyzed with a $3 \times 2 \times 6$ ANOVA. These means were higher for the competition than for the noncompetition scenario [$F(1,183) = 5.86, p = .016$] and were higher for the noncompetition than for the random scenario [$F(1,183) = 12.43, p = .001$]. Although there was a main effect of time [$F(1,183) = 4.69, p = .032$], the interaction of time with scenario was not significant [$F(2,366) = 1.45, p = .236$]. The only interaction with order that was significant was that between order and time [$F(5,183) = 2.31, p = .046$], but this interaction again did not appear to indicate anything interpretable.

## DISCUSSION

The results of the experiment confirmed our hypotheses: The participants were more likely to continue a streak when the task implied that a nonrandom process was generating the events. Furthermore, the results showed that the degree to which different scenarios were rated as nonrandom predicted how likely the participants were to continue the streak when presented with each scenario. This supports our explanation for when people are biased toward either the induction represented by the hot hand or that represented by the gambler's fallacy: It appears to depend on how random/nonrandom the processes generating events are judged to be. This is consistent with the analysis we used to derive this prediction: When events are judged to be nonrandom, following streaks should yield better outcomes than does going against streaks.

The future condition appeared to amplify the effects of the noncompetition and competition scenarios, but perhaps not the random scenario. We had no hypotheses regarding the time factor, but it was more critical that we found the same pattern in the participants' ratings of nonrandomness. Thus, this supported our overall claim that how likely people are to continue a streak varies with differences in how nonrandom scenarios are judged to be. The finding that all four nonrandom conditions produced more continuations of the streak than did either of the two random conditions also shows that the nonrandomness effect generalizes across this factor. However, we can only speculate as to why future events were judged to be more nonrandom. Maybe a future event is seen as more controllable, or perhaps, because the 101st trial is outside the set of events with a 50% base rate, that base rate no longer applies to it. Further investigation of the time effect may increase our understanding of how people use streak information.

In the random scenarios, the participants had a strong bias toward behavior consistent with the gambler's fallacy. The focus of this experiment was on distinguishing when people may be more likely to continue a streak despite the consistent evidence that people have a belief in the gambler's fallacy; thus, it was not designed to investigate why belief in the gambler's fallacy is so strong. There have been a number of speculations about what accounts for the gambler's fallacy. As has been pointed out, Tversky and Kahneman (1971) saw it as being due to people's applying a law of small numbers, and our experiment does not refute this, even if appealing to the belief in such a law is inadequate for explaining when people will apply this belief. Fiorina (1971) and Nickerson (2002) have pointed out that a bias to go against streaks would be successful when events are generated randomly but without replacement. Thus, the gambler's fallacy may be an overgeneralization of this strategy, although Falk (1991) doubts that this could account for the magnitude of the gambler's fallacy. Kareev (1995) has suggested that subjectively random sequences actually have slightly negative sequential covariances, so that may lead to a general belief that it is beneficial in random sequences to go against a streak. Ayton, Hunt, and Wright (1989) put forward the possibility that even in situations people call "random," they may believe in a factor, such as "luck," that produces nonrandom outcomes. Our experiment cannot distinguish between these possible explanations, but it does provide evidence that the randomness of an event may play a role in people's use of the gambler's fallacy.

One limitation of our experiment was that the participants did not actually experience the 100 events that we told them had occurred. To do so would change the theoretical question we were addressing from *what affects which general bias people apply to information about a streak?* to *what do people learn from a specific sequence of events that inevitably contains streaks?* Clearly, the generalizability of our findings is limited to scenarios reporting the results of sequences, and we must be careful in drawing conclusions about how people react while experiencing sequences. However, situations in which people receive information about sequences of events, rather

**Table 3**
**Means and Standard Deviations of Participants' Estimates for the Percentage Chance of the Streak's Continuing**

| | Competition | | Noncompetition | | Random | |
|---|---|---|---|---|---|---|
| Time | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Future | 54.9 | 15.6 | 51.5 | 15.2 | 44.8 | 13.3 |
| Past | 51.8 | 15.3 | 46.7 | 12.6 | 44.8 | 11.1 |

than experiencing them directly are not uncommon—for example, when people are presented with base rates and short-run information when choosing between mutual funds. It is debatable whether such situations are less common than the type of situation often presented in experiments on sequence learning, in which people are faced with hundreds of rapidly presented identical choices over a short period of time.

The work on learning from sequences of events is old and extensive but still open to interpretation (see, e.g., Vulkan, 2000). Clearly, people's reaction to the sequences of events they experience does not depend only on how random the generating process is, but also on other reasoning, learning, and memory processes. However, our results suggest that one important factor influencing how people interpret sequences is how random the generating mechanism is, or at least how random people think the mechanism is.

Whereas our data showed that we could successfully predict the likelihood of participants' continuing a streak on the basis of how nonrandom a scenario was, other factors also almost certainly affect people's use of information about streaks. This may be one reason why the correlations between the randomness scale and people's decisions regarding continuing streaks were not high, even when measured across scenarios. The imprecision of the randomness scale probably contributed to this result, but so should the likelihood that other factors affected people's decisions. Some of these factors may have had nothing to do with streaks at all—for example, some of the participants stated that they picked red/black in the roulette scenario because that was what they always did. However, some other potential factors may be critical to understanding how people interpret streaks—in particular, the way in which people think nonrandomness is violated. A participant who assumed a negative contingency between successive events should tend to go against a streak that he/she thought was generated by a highly nonrandom process. This illustrates a more general point, that the critical factor for how people interpret streaks is how they represent the process. Other aspects of that representation should be important, not just whether it is judged to be nonrandom—for example, whether it contains feedback loops or the nature of any possible dependency. However, randomness judgments may be a particularly useful aspect of this representation, because it seems that people are attuned to the existence of a cause (Rakison & Poulin-Dubois, 2001), which implies nonrandomness. In the absence of any other information (such as the direction of any possible dependencies), Burns's (in press) analysis suggests that for scenarios considered to be nonrandom, a bias to continue a streak is beneficial.

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## APPENDIX

The following are the *future* and *past* versions that the participants read for the three scenarios: Vegas (random), Sister (noncompetition), and Friend (competition).

### Vegas (Random/Future Condition)

It is the week before finals, and as you decide that none of your professors are going to be teaching anything new, you decide to skip town for a couple days and go to Vegas. While there, you become fascinated by the enticing game of roulette. In roulette, you can bet on a specific number or a color (red or black). Before you approach the wheel, you stand by and watch how things are done, so you don't make a fool of yourself and look like an amateur when you place your bet. You watch 100 spins of the wheel, and exactly 50 of those times ended up black and the other 50 red. As you approach the wheel, you are going over those last 100 spins in your head and you realize that the last 4 spins in a row came up red. (Assume that all spins come up either red or black)

### Sister (Noncompetition/Future Condition)

Your little sister is a huge basketball fan, and is often seen playing basketball with her friends. Unfortunately, none of her friends seem to be able to play today and you are stuck in some psychological experiment and don't have time to play with her either. When you get home, you see her shooting around in the driveway by herself. It looks like she is practicing her foul shots and you decide not to bother her just yet. You know that she has been trying to improve her percentage from the line so she has been keeping track of her record for the last couple days. While you are watching, she makes 4 in a row. After she makes the fourth shot, you ask her how she has been doing that night and she says she made exactly 50 of her 100 shots.

### Friend (Competition/Future Condition)

Your best friend works for a large car company as a salesperson, and as a salesperson she has to work on commission. This friend of yours has some serious competition at her place of work, including one man who races neck to neck with her every week for most cars sold. For about a year, the two would trade off who would be number one, your friend some weeks and her competitor others. However, your friend is up for a promotion and her boss has been reviewing her record and has discovered that for the last 100 weeks her competition has been number one for 50 weeks and she has been number one for 50 weeks, but for the last 4 weeks out of those 100 weeks, your friend, to her delight, has consistently had the most sales per week.

### Vegas (Random/Past Condition)

Over summer break, you find a job in Vegas where you will be an undercover security guard dressed as Elvis at some casino. After the management hands you the brightly sequined jumpsuit and fake sideburns, he tells you that your job will be to watch the roulette table. He gives you a brief description of roulette and tells you that there are basically numbers and colors (red or black) you can bet on. After your first day on the job, you are told to watch the security tape of that night's business. You know that, throughout the night, 50 out of 100 of the times the wheel stopped on red. About halfway through the tape, your boss comes in to give you a cup of coffee and keep you company. While you are watching the tape, the wheel lands on red the next 4 times in a row.

### Sister (Noncompetition/Past Condition)

Your little sister is a huge basketball fan, and is often seen playing basketball with her friends. Unfortunately, none of her friends seem to be able to play today and you are stuck in some psychological experiment and don't have time to play with her either. You know that she has been trying to improve her percentage from the line so she has been keeping track of her record for the last couple days. When you get home, she is in the middle of watching a videotape she made of herself so that she could improve her form. She tells you that over the course of that night, she made exactly 50 out of 100 shots. While you are watching, she makes 4 in a row on the video.

### Friend (Competition/Past Condition)

Your best friend works for a large car company as a salesperson, and as a salesperson she has to work on commission. This friend of yours has some serious competition at her place of work, including one man who races neck to neck with her every week for most cars sold. For about a year, the two would trade off who would be number one, your friend some weeks and her competitor others. However, your friend is up for a promotion and her boss has been reviewing her record and has discovered that she has been number one for 50 out of the last 100 weeks. While he is reviewing these 100 weeks, his wife calls and says she needs someone to pick up their sick child from school, and he says that he'll leave in a couple minutes. The boss decides to look over a couple more of the 100 weeks of sales before he leaves, and as he is walking out the door, he realizes that your friend was number one for the last 4 weeks he looked at.

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