COMMENT

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Independence of events, and errors in understanding it

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ABSTRACT This article outlines errors that may occur when people predict event outcomes. The focus is on how our tendency to perceive independent events as connected, consistent with tenets of Gestalt Psychology, biases our expectations. Two well-documented phenomena that occur when people make predictions after a run of a particular outcome—the “gambler’s fallacy” and the “hot hand”—are used to illustrate the issue, and research is presented that highlights the importance of misperceptions of independence. Novel implications and hypotheses are presented that are generated from use of this gestalt approach.

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Random events should be determined by chance alone, and thus all outcomes have an equal probability of occurring, with the odds of any specific outcome determined by the method used (one in two for a coin toss, one in six for a roll of a die and so on). Although people generally understand this, interesting things happen when there are sequences of events. Perhaps the most famous example of people behaving as if outcome probabilities can fluctuate over trials is the “gambler’s fallacy”. This is a tendency to expect an outcome to be less likely to occur if there has been a “run”, such as expecting “heads” after a run of four “tails”. The gambler’s fallacy has been found in many contexts: choosing outcomes of randomly fluctuating binary lights flashing (for example, Nicks, 1959; Anderson and Whalen, 1960), coin tosses (for example, Roney and Trick, 2003, 2009; Roney and Sansone, 2015), roulette wheel outcomes (Sundali and Croson, 2006), playing blackjack (Keren and Wagenaar, 1985) choosing lottery numbers (Clotfelter and Cook, 1993) and also some naturalistic events which may not be truly random such as predicting births of boys or girls (McClelland and Hackenberg, 1978), and predicting performance in the stock market (Johnson and Tellis, 2005). Historically, the gambler’s fallacy has been explained by focusing on the misapplication of heuristics regarding random sequences of events, but in this article I will emphasize the importance of misperceptions about independence as a vital and under-examined aspect of these phenomena. Perceptual tendencies to perceive patterns rather than individual elements, as well as motivational tendencies towards closure, will be considered. Another tendency that occurs when non-random events show a run, the “hot hand”, will also be addressed later in the article, as it may also be relevant to discussion of perceived independence of events.

Perceptual grouping and the gambler’s fallacy

A frequently cited explanation for the gambler’s fallacy emphasizes misapplying a heuristic that works for predicting outcomes over large numbers of trials (a tendency for approximately equal numbers of all outcome possibilities) to an immediate context. Tversky and Kahneman (1971) called this “the law of small numbers”, and suggested that this heuristic leads people to view long runs of one outcome to be unrepresentative of random outcomes, and thus should be unlikely to occur (see also Kahneman and Tversky, 1972). The expectation for reversals when a run occurs would thus reflect the application of this heuristic, and the associated belief that outcomes should “balance out”, as they would be expected to over a large number of trials. This approach emphasizes expectations regarding the nature of random outcomes, but sidesteps another issue: why people behave as if independent events are related. Rabin (2002) restated the phenomenon slightly, noting that people behave as if outcomes were finite, and sampled without replacement; describing it in this way highlights event non-independence as an important aspect of the phenomenon, and the gambler’s fallacy would occur because the less frequent outcome has not been “used up” to the same extent.

Another way of thinking of the gambler’s fallacy brings the issue of the perceived linkage between independent events into sharper focus. Gestalt psychologists examined how disconnected elements come to be organized into a meaningful whole, at which point these elements cease to be perceived as separate and independent (see Kohler, 1947). For example, when viewing a series of disconnected contours in a visual image, the independent contours are sometimes grouped together to form an object, in which case those contours come to be seen as part of a larger whole. They discovered a number of principles that determine which items are grouped together to form a unit. Just as two examples, when the contours are similar to each other, and are

positioned close together, they tend to be grouped perceptually to form a meaningful unit, as part of a larger object. We draw on similar ideas, and suggest that when people observe a number of similar events relatively close together in time (such as a series of coin tosses) there is a tendency to perceive them as connected sequences or “episodes”, in which patterns may be seen. As I will discuss below, this approach provides novel predictions as to when the gambler’s fallacy will, and will not, occur, as well as possibly providing a new explanation for the phenomenon.

Roney and Trick (2003) demonstrated that the gambler’s fallacy could be produced or eliminated by arbitrarily altering whether participants saw a critical coin toss trial (after a run of heads or tails) as being part of the first block (the final trial in an episode where there was a run), or as the first trial of a new block (the beginning of a new episode). In the former case there was evidence of the gambler’s fallacy, but in the latter, where the event was presented as belonging to a separate block of trials, the run did not result in expectation for a reversal. Building on Rabin’s description of behaving as if there is selection without replacement, arbitrarily labelling a trial as the first of a new block appears to work as if the “bin” has been refilled with equal numbers of heads and tails. In reality, of course, the probability is 50% for either outcome regardless of the prior outcomes, or whether the trial was labelled as the last of the previous block of trials or the first of a new block. This framing of the gambler’s fallacy emphasizes some of the less “rational” aspects of it, not simply as a reflection of a heuristic that runs are unlikely in random outcomes, but as a phenomenon where independent events seem to be perceived as if they were connected.

Motivation for closure and the gambler’s fallacy

In addition to highlighting perceptual issues of grouping, some research stimulated by Gestalt Psychology emphasized motivational elements associated with a need for closure. One famous example of this is the Zeigarnik effect, whereby people demonstrate a motivational tendency to be distracted by intrusive thoughts if a task is interrupted; this is viewed as providing evidence for a psychological state of need that engages when a situation is left without closure. Similar logic, some form of “need for closure”, may also be relevant for understanding the gambler’s fallacy. This is not in opposition to the perceptual grouping issues discussed above, but goes further, not only predicting when the gambler’s fallacy occurs (that is, when conditions encourage the perception of the present and past events as a “group”), but adds a possible explanation as to why it occurs.

Whether focusing on beliefs about probability or a tendency to see sequences of events as interrelated, the issue of central importance is the recognition of “runs” within a sequence of random outcomes (such as coin tosses coming up tails four times in a row). Following from Tversky and Kahneman (1971), it has been well documented that people do not see sequences of outcomes that include long runs as representative of what should occur in random outcomes. A gestalt approach emphasizing perception of patterns rather than individual events also emphasizes runs, as runs provide the most easily recognizable pattern among sequences of outcomes. Research does suggest that we are particularly sensitive to outcome runs, even demonstrating unique patterns in brain response to them (Huettel *et al.*, 2002). Roney and Sansone (2015) suggested that the gambler’s fallacy may be understood as a “closure” phenomenon (expecting closure in a run, leading to expectation of a reversal), as opposed to reflecting application of a heuristic regarding randomness. It is well documented that the gambler’s fallacy is stronger the longer the run of a specific random outcome, up to a point (Rabin, 2002; Asparouhova *et al.*, 2009), consistent with the possibility that our expectation for closure increases as the pattern

(run) goes longer. Roney and Sansone conducted an experiment where participants betting on coin tosses experienced an imbalance of one outcome or the other. Consistent with the closure hypothesis, however, the gambler's fallacy was only observed when there was an ongoing "open" run (the last four outcomes were THHH), as opposed to a run having been closed (the last four outcomes were HHHT); in both cases the prior eight trials were identical, with 5H and 3T, meaning that there were always 8 Heads and 4 Tails. In this latter condition, although there were still twice as many heads as tails overall, and a memory test revealed that participants were aware of the imbalance, they were not more likely to choose heads. This suggests to us that the gambler's fallacy does not simply involve an expectation that random outcomes will "even out", but is specific to experiencing of a sequence of one outcome, possibly creating a need, or at least an expectation, for closure.

Although the Roney and Sansone findings are consistent with a closure explanation for the gambler's fallacy, it cannot rule out a more cognitive explanation altogether. There are other findings, however, that seem to me to be consistent with some type of closure explanation. For example, I would expect that a "need for closure" would primarily occur when observing an ongoing sequence of outcomes as they occur, but would not be experienced if presented as "historical" information all at once, because the current event has been separated from the prior ones. Consistent with this, Barron and Leider (2010) found that the gambler's fallacy is much stronger when participants observed and made choices for each event as they occurred than when it involves presenting a description of all of the previous outcomes as once (such as HTHHTHTTTT). In the latter case, I would suggest that "closure" has already been provided by history and the nature of the presentation, and there will be no experiential feeling of a lack of closure, as would occur if observing the run occurring outcome by outcome.

Perhaps even stronger support for a motivational explanation of some type is provided by research demonstrating that individuals' own outcomes while predicting outcomes can influence the likelihood of demonstrating the gambler's fallacy. Boynton (2003) found that people choose in the direction of the gambler's fallacy more when the run of a particular outcome also corresponded with failed guesses to predict those outcomes; this tendency was also replicated in three experiments by Mossbridge *et al.* (2016), as well. A run of a particular outcome, combined with a run of us guessing incorrectly on each of those outcomes, seems to be particularly potent for eliciting choices consistent with the gambler's fallacy. Although it is not clear precisely why this is the case, this finding does strongly suggest a motivational aspect, possibly reflecting a combined expectation regarding closure: that the outcome, as well as our luck, is due to change.

Perceptions of non-random events

The gambler's fallacy provides one example of people's tendency to perceive independent outcomes as if they are connected, and we have suggested that this may involve processes like the gestalt principles that cause us to perceive a series of events as linked elements of larger structures or sequences rather than as separate independent elements. In my opinion this also highlights less "rational" aspects of the phenomenon, seeming to behave as if a random process will somehow act differently depending on different patterns of outcomes that have already occurred. The "rationality" of people's perceptions are more difficult to discern when outcomes result from a non-random process, because the expected outcome probabilities cannot be ascertained with the same certainty. For example, if a basketball player sinks four baskets in a row, unlike with random events, there may be an

explanation for the run. Research (Ayton and Fischer, 2004; Burns and Corpus, 2004) has demonstrated that in situations where agency can be inferred in explaining an outcome (such as, that that player is "on a hot streak"), then the opposite of the gambler's fallacy will occur and people expect continuation (that is, that player is now *more* likely to hit a fifth shot). Although we may not be inclined to see this tendency as a violation of principles of logic, Gilovich *et al.* (1985) did careful analyses of basketball shooters and golfers, and concluded that, controlling for the player's skill level, a player who has a run of successful outcomes (for example, hit five baskets in a row in basketball) is no more likely to sink the next basket than is a player who is not on a run: in other words, the belief in the "hot hand" is a fallacy. It is beyond the scope of this article to review the literature on that issue (there is debate, but the Gilovich *et al.* conclusion has not been disproven; see Alter and Oppenheimer, 2006). The relevance to the present article is that, although the trend runs opposite to the gambler's fallacy in predicting a continuation of a run rather than a reversal, it again may illustrate a tendency to exaggerate the connections between outcomes. It is not illogical to believe that a specific event such a shot in a basketball game may be understood in the context of previous outcomes—these are no longer purely independent events in the same way that coin tosses are. It is interesting, however, that a noticeable pattern in previous outcomes (hitting a number of shots in a row) may create an illusory, or at least exaggerated, sense that an upcoming event can be predicted by immediately preceding ones. We may overestimate the extent to which these non-independent events are related in much the same way as the gambler's fallacy leads us to behave, as if independent random events are linked when they are not. Although it is yet to be studied, one question raised by the present gestalt-influenced approach is whether a hot-hand bias is observed in any situations *other* than ongoing runs (for example, if the person has hit six of their last seven, but missed their most recent shot). I would predict that the hot-hand bias would dissipate rapidly when the streak ends if grouping and closure are relevant in this context as well, much as Roney and Sansone (2015) demonstrated for the gambler's fallacy. It is unclear whether or why another theory would predict this, as the nature of the beliefs that might underly the hot hand (for example, growing confidence) have not really been addressed. At the very least, research investigating how and when previous outcomes of this type are seen as relevant in predicting a current event may shed light on the nature of this phenomenon.

One important difference between the random and non-random cases is that plausible narratives can come into play in the non-random case (such as, a player being "hot", "locked in" and so on). Other outcomes allow even more complex narratives, such as predicting outcomes in the stock market. For example, Johnson and Tellis (2005) found that people buy "hot" stocks, and sell "cold" ones. They also found that eventually as the run length increases this eventually attenuates and reverses, with people selling the successful stocks and buying the unsuccessful ones. It thus appears that people expect continuation of short-term runs, perhaps believing that this will reflect the true value of the stock, but seem to mistrust longer upward or downward trends. Clearly it is debatable as to whether this is sound strategy, or overestimating the interconnectedness of past and present outcomes, but Johnson and Tellis discuss finance research suggesting that sequences of past performance are not useful in predicting tomorrow's prices, other than today's prices.

Possible explanations and directions for future research

In seeking to understand phenomena like the gambler's fallacy and the hot-hand fallacy, there are a number of different aspects

to be consider. For example, we may examine the “narrative” that people use to explain streaks (for example, “these coin tosses are random, so heads and tails should balance out”, “that player is really in the zone”, or “that stock has risen for three days, so the people buying it must know something about it”). The approach emphasized in this article does not contradict that approach, but rather refocuses what it is that needs to be explained, namely, why do we act as if independent random events are related, and possibly exaggerate the extent to which non-random events are related, especially when there is a specific consistent pattern as with runs?

By definition, random independent events cannot be predicted with certainty. People have been found to exaggerate the extent to which they have control over outcomes, and it has been proposed that this reflects a desire or need to feel in control (see Thompson *et al.*, 1998 for a review). Viewed in this light, the phenomena described here are readily understandable; beliefs about linkages with previous outcomes may provide a valuable (or in the case of random events, the only) possible source of information as to what is likely to happen in the future, and increase our sense of predictability. This refocuses the “rationality” issue implied by the term “fallacy” as well, as we may then question whether it is so illogical to behave as if previous outcomes help us predict future outcomes. In everyday experience this tendency may typically serve us well. We might think of this in terms of potential costs. If some event occurs that has potentially important consequences (for example, I am bitten by a snake and became ill), is the cost higher of falsely assuming that this is an isolated and independent event (and hence I will not avoid the snake in the future), or of falsely assuming a connection (and hence I expend energy and emotion avoiding a harmless snake)? I suspect that in most instances in our daily lives there is an asymmetry such that the costs are higher for incorrectly assuming independence—until the truth can be ascertained. Having said that, however, these errors can have negative consequences in some current contexts. Exaggerating the extent to which we can predict outcomes may contribute to problem gambling behaviour (see Marmurek *et al.*, 2014, for example). Perhaps most perniciously, beliefs like those discussed here may always provide a reason for continuing; if I am winning I should stay because I don’t want to end my “hot streak”, while if I am losing I will continue because my luck is about to change. Our penchant for games of chance creates a context where the costs of failing to recognize independence are increased. Another example may be investment in the stock market if Johnson and Tellis (2005) are correct, as discussed previously. This may be a situation where overestimating the role of previous outcomes contributes to the overvaluing of stocks, and lead to negative financial consequences.

A range of novel research questions may be generated by adopting the present approach. For example, the research on perceptual grouping of events raises questions about what factors determine when a current event is perceived as part of a “whole” with previous events. Gestalt Psychologists presented a number of factors that influence grouping in visual perception, but it is unclear which are more or less relevant in the grouping of events. There are also potentially unique issues that may be in play with sequential events. As Roney and Trick (2003) demonstrated, grouping can be interrupted by arbitrarily labelling the events in terms of separate “blocks”. In some contexts these “blocks” may be formally constructed (for example, two halves in a basketball game), but we may often create them ourselves (for example, a person playing a slot machine may group the events when they use a specific machine, perhaps broken by a lunch break). The possibilities become even more complex when we consider our own interaction with the “events” as with the slot machine example above. Are sequences perceived based on all outcomes

on a particular machine, or only those we bet on? If we play several machines simultaneously, are events grouped by machine, or by our own behaviour?

Complicating matters further, we can have runs of a particular outcome (black or red on a roulette wheel), and of our own outcomes (winning or losing bets) simultaneously. The studies by Boynton (2003) and Mossbridge *et al.* (2016) found that these combine such that the gambler’s fallacy occurs most strongly during a run of a particular outcome that we have unsuccessfully bet on (that is, three heads when we bet tails each time), but further research is needed to understand why this occurs; does this combination create a particularly strong desire for closure? If a “closure” explanation for the gambler’s fallacy is viable, what is the nature of this tendency? It seems more likely to be motivational than perceptual, particularly given its greater prevalence when paired with losing, but this remains to be seen. It will be challenging to test a closure explanation definitively, as it remains a possibility that the “open set” (run) also serves as a trigger for the use of the law of small numbers heuristic. One possible approach could be to use a developmental paradigm, testing to see whether something akin to the gambler’s fallacy emerges before the development of an understanding of the properties of randomness. In any case, I would argue in the meantime that a closure explanation is the most parsimonious for phenomena such as the gambler’s fallacy only occurring when a run is ongoing (Roney and Sansone, 2015).

Although I have proposed that a closure explanation for the gambler’s fallacy is plausible when sequentially experiencing outcomes one at a time, this does not preclude the possibility that heuristic or “narrative” explanations apply in other situations. In fact, much research does find evidence to support these, but the grouping phenomena described here would still apply; if the events are not perceived as being connected then no narrative would be viable to explain patterns such as runs, and in fact it could be argued that the narrative may be created in order to plausibly explain or justify these runs *post hoc*, rather than influencing our interpretation of the events as they occur. The difference in these situations is that when presented sequentially a present event may be perceived as directly being part of the whole sequence, whereas when presented historically and all at once it is not—the sequence presented presumably ended some time ago, and thus closure would not be an issue. At the same time, in many contexts we may still view this information as relevant when making a present decision. For example, Johnson and Tellis (2005) manipulated information about the performance of stocks in a historic, all at once, manner in two of their studies, and found evidence for both a hot hand (for short sequences) and the gambler’s fallacy (for longer ones). This may plausibly reflect a different process than the gambler’s fallacy observed when gambling, however, it would be interesting to see if similarities emerge even in an investment scenario when decisions are made regularly based on sequential information, such as daily or hourly performance.

Some additional practical research applications also follow from this approach. For example, can we help prevent people from continuing to gamble based on hot hand or gambler’s fallacy logic (“I can’t quit while I’m winning”, or “I have to keep playing until my luck turns”, respectively)? Perhaps by encouraging people to set their own grouping *a priori*, such as taking a break every half hour, or taking a break after every 10 bets, these tendencies may be lessened, and perhaps people will make more unbiased decisions as to whether to continue gambling.

Overall, I believe that an approach focusing on perceptions of connectedness of events will prove valuable in determining when some types of error in judgement occur (that is, only when conditions are met that facilitate perception of patterns in event

sequences, such as when there are runs), and may also provide new insight as to why they occur (such as expectations for closure, or a desire to believe our environment is predictable).

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Additional information

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