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The Logical Probability Behind Lotteries and Raffles: Chance and Cognitive Bias from a Data Science Perspective

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Abstract. The entertainment activities such as lotteries and raffles are popular among people, but the cognitive bias of people may result in fluke mentality, leading to social issues like debts, problem gambling and behavioral addiction. This essay focuses on the logic of probabilities behind lotteries and raffles, talking about how data science deal with the chances and misconceptions of them. Our topics include probability, independent events, the expected value and so on. The method is based on overview analysis of previous resources. The study suggests that the huge prize money in lottery does not necessarily equate to high average returns, and past outcomes in independent random events do not affect future probabilities, When faced with low probability and high return events, people's judgments are often influenced by subjective weights and intuition, forming a sense of opportunity illusion. The conclusion of this study indicates that data science can help the public correct cognitive biases, enhance probability awareness and rational decision-making ability through objective probability, expected value, natural frequency, and large sample data analysis.

Keywords: probability, expected value, cognitive bias, gambler's fallacy, data science

1. Introduction

As we all know, society becomes more competitive with the appearance of new technology. In that case, people may seek some shortcuts to success. It is likely that gambling such as raffles and lotteries prevails among people. As a result, addiction to such gambling games may lead to some problems, such as health issues in teenagers. The scientific findings suggest that teenagers will experience sleep disorders, endocrine disorders, weakness of digestive function, and other negative impacts on their bodies [1]. What's more, gambling may also prevent the development of socio-economic cultures, since it seriously disturbs the national normal economic order, conflicting with national charity lotteries [1]. Therefore, it is clear that addiction to so many lotteries and raffle games will lead to some serious issues.

This article aims to present the basic concepts of probability and data analysis, describing the logic behind gambling like raffles and lotteries, which causes misconceptions among people. We would also like to present how the cognitive bias and illusions formed, like the gambler's mentality, and avoid such things happen by data science.

The methodology includes a literature review based on previous resources.

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Our research is aimed to help people obtain a deeper and better understanding of such haphazard events and decrease the number of serious issues resulting from cognitive bias.

2. Analysis of probability logic and data science

2.1. Probability, random events, and independent events

The basic mathematical concepts of lotteries and raffles are based on random events, probabilities, independent events, and so on. Random events represent all possible results with statistical regularity that result from haphazard events repeated many times under the same conditions [2]. Probability is a numerical value that measures the likelihood of a random event occurring, represented by P(A) ranging from 0 to 1. If the probability is close to zero, the event is less likely to occur, and vice versa. Specifically, in the lottery, '1,2,3..' the chance of each number appears as the winning lottery number is the same, so we could not predict them [3]. As a result, though the winning award is large, the probability for winning a prize is small and it is a typical small probability event.

What's more, an independent event is also an important concept for studying the randomness of lotteries and raffles. If the occurrence of one event does not have an effect on the other, these two events can be called relatively independent. For a properly designed lottery in which each draw is independent, the result of a previous draw generally does not affect the probability of a particular number appearing in the next draw. In other words, even if a certain number has not appeared for many consecutive draws, this does not mean that its probability of appearing in the next draw will increase. Similarly, the fact that a number has appeared frequently in recent draws does not imply that it is more likely to appear again in the future. Understanding random events, probability, and independence helps explain the mathematical mechanisms underlying lotteries and prize draws, while also providing a theoretical foundation for the later discussion of expected value and probability-related cognitive biases, such as the gambler's fallacy.

2.2. Mathematical expectation and lottery returns

When we calculate the probabilities, it is inadequate to judge whether a random event has a high value if we only know a benefit from one result. The expected value in mathematics is a essential mean to measure the value of random variables on average [4]. The most common formula:

$$E(X) = \sum_{i=1}^{n} p_i x_i \quad (1)$$

x_i means the possible ith result, p_i means the probability that that result occurs. Therefore, the expected value not only includes the event that will bring the highest result, but also comprises all possible outcomes. It weights all possible outcomes based on their probability of occurrence to form a quantitative evaluation of the overall level of returns for random results.

Lotteries and raffles are typical applications of random decision in reality based on the mathematical expected value. The expected value of lotteries is an important indication for analyzing lotto economical value [5]. From a mathematical perspective, even if the lottery sets a very high jackpot, if the probability of winning this prize is extremely low, the contribution of this result to the overall expected value may still be very limited. If there are multiple possible outcomes in a lottery, each prize amount needs to be included in the mathematical expectation according to its corresponding probability. If participants still need to pay for ticket purchases or participation costs,

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this cost needs to be further considered when analyzing the actual benefits. As a result, "highest possible return" and "average expected return" are two different concepts. The fact that an event can provide a huge bonus only indicates the possibility of obtaining high returns, but cannot directly indicate that the participants have a high average profit level. Scientists then provide an approach indented to convert 'chance' to quantifiable data: focusing more on the objective probability instead of paying attention to the highest awards.

3. Probability cognitive bias and its avoidance

3.1. The subjective overestimate of low-probability event

The expected value is able to measure outcomes of raffles and lotteries from an objective perspective, but when people face events which have low probabilities and high benefits, their cognitive perceptions may be systematically biased, leading to irrational decisions. To be more specific, chances in risk decision-making can be converted into decision weights, whereas these kinds of weights may not be consistent with the objective probabilities [6]. In that case, people may impose relatively high weights on some events that have a low probability of occurring, and this also explains why high returns with extremely low chances have strong appeal to people.

3.2. The gambler's fallacy

The gambler's fallacy is also a representative cognitive bias in lotto activities. It means that an individual incorrectly thinks that past random outcomes will change the future random results. For instance, after a number does not appear multiple times in a row, people may think that the number is 'about to appear', On the contrary, numbers that have just appeared may be considered unlikely to reappear in the short term. However, in independent random simulations, past results do not have an impact on subsequent returns. Clotfelter and Cook analyzed lottery data from Maryland in the United States and found that after a particular number was drawn, betting on that number declined noticeably and then gradually returned to its previous level [7]. This finding provides empirical evidence of the gambler's fallacy in real-world lottery behavior.

3.3. The illusion of control

The illusion of control indicates that individual may overestimate their ability of self-control [8]. According to some findings of raffle experiments, when participants can choose one of the lottery numbers by themselves, they will show strong confidence though the outcomes are still haphazard. As a result, choosing numbers by their own, familiarizing oneself with certain numbers, or investing more attention may not change the objective probability of the random event itself, but may enhance an individual's subjective perception of the controllability of the outcomes.

3.4. Avoidance

In order to reduce these biases, it is important for people to focus on objective data instead of their intuitions. First of all, when we think about random events, we are expected to consider probabilities to win, the expected value, and costs, rather than noticing the highest returns. What's more, it is useful to present chances in some direct ways, like presenting '1 in 1000' rather than'0.1%'. Converting probability information into natural frequency formats can improve judgment performance in some probabilistic reasoning tasks. Lastly, we should distinguish between past

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patterns and future regularity if we are analyzing continuous random outcomes, instead of just based on short-term inference.

Therefore, the "illusion of opportunity" in lotteries and draws is not a change in objective probability itself, but rather stems from individuals' subjective interpretations of probability, randomness, and outcome value. By utilizing mathematical expectations, natural frequencies, and large sample data to represent this information, the intuitive impact of extreme results can be reduced, making the judgment of random events closer to their true probability structure.

4. Conclusion

In conclusion, although lotteries and raffles appear to depend mainly on "luck," they are actually governed by clear probabilistic principles. Concepts such as random events, independent events, and expected value show that a large jackpot does not necessarily mean a high probability of making a profit. To evaluate a random activity more accurately, the probability of winning, potential returns, and participation costs should all be considered together. From the perspective of data science, large amounts of historical data can help people understand the long-term patterns of random events, but they cannot make a single independent outcome accurately predictable.

However, when people face low-probability and high-reward events, their judgments may be affected by cognitive biases such as the gambler's fallacy, the illusion of control, and the overestimation of small probabilities. These biases may further create an "illusion of opportunity." Therefore, reducing such misconceptions requires greater reliance on objective probabilities, expected values, and large-sample data rather than personal experience or intuition. Presenting abstract probabilities in more intuitive forms, such as natural frequencies, may also help people understand risk more accurately. Overall, data science not only explains the mathematical mechanisms behind lotteries and raffles, but also provides useful tools for improving probability awareness and rational decision-making.

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