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# Learning to Avoid Luck Traps in Contexts of Uncertainty
## A Review of Jeffrey Rosenthal's *Knock on Wood: Luck, Chance, and the Meaning of Everything*

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## Everyday Probabilistic and Statistical Literacy

In the field of probability instruction, much has been written about the increasingly important role of uncertainty and probability in our everyday lives. This work similarly highlights the key role that probability plays in a growing number of professional areas.

Several education systems now place special emphasis on the teaching and learning of probability (Batanero, 2014; Jones, 2005), at least at the high school level, for example in France (Parzysz, 2017) and in the United States (Langrall, 2016), and even as early as elementary school, as is the case in Québec (Martin et al., 2019), Spain (Batanero et al., 2013), Italy (Gattuso & Vermette, 2013), the United Kingdom and Australia (Jones et al., 2007). This focus on probability (often in conjunction with statistics) in curricula is generally justified by the importance of supporting the development of probabilistic (or statistical) thinking in the citizens of tomorrow. This echoes the idea of statistical literacy put forward, notably, by Garfield and Ben-Zvi (2004) and more recently by Sharma (2017). Gal (2004) defines statistical literacy as:

> people's ability to interpret and critically evaluate statistical information, data-related arguments… to discuss or communicate their reactions to… statistical information, such as their understanding of the meaning of the information, their opinions about the implications of this information, or their concerns regarding the acceptability of given conclusions. (p. 49)

Statistical literacy thus entails that citizens are able to challenge assertions in social contexts such as media productions (Gal, 2004; Watson, 2006). This is the context of

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emergence of *Knock on Wood: Luck, Chance, and the Meaning of Everything,* a general-interest nonfiction book on probability published in 2018 by Jeffrey S. Rosenthal that aims to help readers develop probabilistic (and statistical) thinking. *Knock on Wood* is Rosenthal's second popular work on the topic, after his first and best-selling book, *Struck by Lightning: The Curious World of Probabilities*, published in 2005.

With this new release, the University of Toronto statistics professor sets out an original and entertaining perspective on a plethora of probability and statistics-related topics drawn from the everyday lives of adults in modern societies. The author takes on and adroitly explodes widespread myths in the areas of sports, polling, superstition, lottery, astrology, divine intervention, and others. The book comprises 271 pages, in addition to an index and a brief glossary of chance and luck-related expressions. It also includes some 45 pages of endnotes. These include explanatory notes, as well as references to scholarly publications and press articles in support of the author's statements. His frequent references to a myriad of press articles and to events in his own personal experience illustrate how his examples are indeed taken from everyday life.

## Sidestepping Luck Traps to Develop Critical Thinking Skills

From chapter to chapter, Rosenthal has readers learn and reflect on the fields of probability and statistics, while helping them develop critical judgment in the face of situations of uncertainty. He presents fourteen luck traps relating to such situations. To set the stage for these luck traps, the author begins with a hypothetical situation in which he is seeking out a sharpshooter for a shooting contest. After a candidate is spotted during free practice, their skills are assessed in light of these luck traps, since mastering them can help avoid many errors of reasoning in situations of uncertainty. According to the author, keeping these luck traps in mind can maximize the odds that the successful candidate will indeed be a sharpshooter. The luck traps are "alternate cause," "biased observation," "different meaning," "extra-large target," "facts that go together," "to multiply or not to multiply," "false reporting," "hidden help," "lucky shot," "many people," "out of how many," "many tries," "placebo effect," and "shotgun effect." These traps are

defined early on and are central to the book. Throughout the ensuing chapters, they are frequently mentioned as the author addresses various topics and examples.

As such, they make up an interpretive grid for observing and evaluating situations and contexts of uncertainty. These traps enable the reader to take a critical step back and position themselves rationally on the exceptionality (in the sense of the rare, unexpected or unusual nature) of some observed outcomes, showing how they may hold special significance (linked to karma, destiny, a belief or a mysterious effect) or be due to nothing more than dumb luck. In the case of the sharpshooter, the informed citizen could exercise critical judgment by referring to luck traps in order to tell a genuine sharpshooter from a lucky average shooter or even an impostor.

To distinguish outcomes attributable to chance from those that appear to have an external cause (such as someone cheating), Rosenthal has us delve into the hypothetical case of five Craps (gambling game) players. The challenge is to find out who cheated based on some information. We are given each player's wager; number of bets, wins and losses; percentage of games won; and net profit. The author then explains that appearances can be deceiving—the cheater in this case is not the player with the highest percentage of wins or the highest net profit. Thanks to statistical analysis and calculating the p-value, we can determine which player would actually have a low likelihood of having won a little money after a large number of bets, in a context where probabilities are weighted against the player (i.e., playing Craps has a negative mathematical expectation, as is the case in all casino games). A team of researchers in mathematics education used a similar but somewhat simpler idea with middle school students to distinguish between the outcomes of balanced and loaded dice. Specifically, Lee et al. (2010) had students infer the quality of dice made by different companies based on a large number of simulator-generated outcomes. The students had to simulate numerous dice throws until they were able to tell whether certain companies produce loaded dice (i.e., when the relative frequencies of the faces of a die appear not to be 1/6). This simulation allowed for drawing two-way links between the observed frequency and probability, in addition to working on probability concepts such as variability, independence, and sample size (Lee et al., 2010). Thus, in this general-interest book as in the mathematics classroom, statistical analysis offers

powerful tools (such as p-value) for exercising critical judgment and detecting unlikely situations.

## Probabilistic Conceptions Through the Lens of Luck Traps

The luck traps presented by the author appear to be related to certain probabilistic or statistical conceptions that have been studied in psychology (Fischbein & Schnarch, 1997; Kahneman et al., 1982) and mathematics education (Batanero et al., 2010; Savard, 2014). These conceptions constitute specific (often incomplete or simplistic) probabilistic and statistical reasoning that can be adopted in a context of uncertainty. Therefore, they generally relate to luck, probability and randomness, as well as our relationship to these concepts. In general, these conceptions are frequent and can develop, but they appear to be difficult to change, as they often become entrenched in an individual's past experiences. Moreover, these conceptions can be found in children as well as adults, and in probability novices and experts (Tversky & Kahneman, 1971).

Three of the luck traps put forward by Rosenthal appear to be linked to the conception of sample size effect, which can lead someone to ignore the number of trials in their probability estimate (Fischbein & Schnarch, 1997; Kahneman & Tversky, 1972). This is probably why, in order to evaluate the likelihood of an uncertain event, Rosenthal draws the reader's attention to the importance of considering the possibility that:

- many different people have separately tried to achieve the same outcome (the "many people" luck trap);
- there are many distinct possibilities for obtaining the same or a similar effect (the "many tries" luck trap);
- many different possible combinations can produce a similar outcome (the "out of how many" luck trap), i.e., the number of possible cases (the denominator) should not be neglected in favour of the number of favourable cases (the numerator).

Next, two of the luck traps seem to be related to conceptions of simple and compound events and the conjunction fallacy. The former suggests (erroneously) that two combinations of events have the same odds of occurring in the case of sequences of

distinct events (e.g., obtaining two sixes versus obtaining a five and a six with fair dice) where the order of outcomes matters, thus leading one to see them as simple independent events rather than as compound ones (Fischbein & Schnarch, 1997). The conjunction fallacy, for its part, leads one to believe (wrongly) that the "probability of an event appears, under certain conditions, to be higher than the probability of the intersection of the same event with another" (Fischbein & Schnarch, 1997, p. 100). Regarding the relationship between distinct events, Rosenthal suggests paying attention to the "facts that go together" luck trap, which occurs when multiple outcomes are all closely related and therefore don't provide as much additional evidence as one might believe. He also warns against the luck trap involved when different data tend to go together and are therefore not independent, so that the probability of them all occurring at the same time is higher than a mere multiplication of their respective probabilities ("to multiply or not to multiply").

Finally, two of the luck traps seem to be related to the conception of availability (Fischbein & Schnarch, 1997), which leads one to estimate the probability of an event based on how easily specific examples of the event can be brought to mind, i.e., ease of recall, construction or association. On this topic, Rosenthal warns against the "shotgun effect," i.e., when there are many different ways of achieving a similar outcome, as well as biased observation, i.e., when some information is taken into account while other information is missing or left out.

The probabilistic conception of the illusion of control, even if not specifically related to luck traps, also seems in our view to connect with some of the ideas presented in the book. This conception is related to the belief that practice and experience with gambling will enable someone to control or influence the outcomes of random games thanks to acquired skills and strategies (Langer, 1975; Rouan & Pallascio, 1994). As Rosenthal notes, "not everyone wants their random games to be truly random. They want the luck of games to be meaningful luck, something they can control and influence in mysterious ways" (p. 40). Might this conception, then, help reduce anxiety by giving people a sense of control, or increase it by making people feel more personally responsible for the outcome of their gambling?

## Spin-offs (or Extensions) of the Book for Mathematics Education

Also, in connection with the field of probability instruction, Rosenthal's popularization contributes to our own activities as educators and researchers. In both its form and its content, the book appears useful for convincing pre-service and in-service teachers of the value and social usefulness of teaching and learning probability. This perception of usefulness, which is not always very prominent among elementary and high school teachers (Martin & Thibault, 2017), is important in justifying probability teaching and learning in schools. The author argues that the topics of statistics (and probability) is important to many professional fields, but that many people dislike learning it. He suggests that this aversion to statistics may come from getting overly technical in the classroom. An alternative could be to use everyday situations to get students thinking, as Rosenthal does in his book. Additionally, it seems to us that this book can help inform teacher professional development in the topics of probability and statistics teaching and learning; p-value would be a good example. When exceptional outcomes occur (i.e., effects that are out of the ordinary in that they are somewhat unexpected exceptions), they can be analyzed with the help of statistical thinking. The notion of p-value, even if it is not studied before post-secondary education (at least in Québec's context), is very effectively popularized by the author. He uses it when making decisions in a situation of uncertainty, i.e., to determine whether an observed outcome is merely due to chance or whether it seems rather reasonable to believe that there are external forces behind it. The author thus opts for thoughtful, calculated decision-making, as opposed to randomly "[flipping] a coin to decide whether or not to proceed" (Rosenthal, 2018, p. 42), as in the novel *The Dice Man* by the enigmatic Luke Rhinehart (1998). This critical outlook based on p-value serves as a jumping-off point to challenge certain myths or coincidences, which the author does with brio. The book is peppered throughout with many coincidences that he himself points out (often while revising a chapter), to show how coincidences occur naturally and don't always have deeper meaning.

Also, on the subject of p-value, the author discusses the significance (or lack thereof) of research findings in different fields, including medicine and pharmacology. To avoid jumping to conclusions—among other things, when testing medical or pharmaceutical treatments—the author argues in favour of replicating studies, i.e., repeating research in

order to make sure a result was not simply due to chance (or to certain luck traps). In our opinion, this notion of the reproducibility of research, which is uncommon in mathematics education, offers an opportunity to reflect on the validity criteria applied to the research in our field. The author's reflection is all the more topical (in Québec's context, among others) as researchers in mathematics education are gradually being led to take a stance on the current of evidence-based data (Bednarz & Theis, 2018).

In addition, the book uncovers potential links between many situations from everyday life and the three probabilistic approaches identified in the research on probability teaching and learning (Batanero, 2014; Chernoff & Sriraman, 2014), namely the theoretical approach (essentially calculation-based), the frequentist approach (experimentation-based) and the subjective approach (based on intuitive analysis of available information). The author's statements are firmly rooted in the frequentist approach, sometimes giving the book a decidedly statistical flavour. This is not necessarily surprising, since even if the author declares himself to be an expert in probability theory (his thesis dealt with a specific aspect thereof), he is nevertheless a professor of statistics. This approach comes to the fore when the author refers to previous lottery results to establish the odds of winning. Although the frequentist approach offers several interesting avenues for probability teaching and learning, for example allowing us to consider the variability of data and the non-deterministic nature of probability (Batanero, 2014), it is interesting that Rosenthal makes more explicit links with the theoretical and subjective approaches, especially since the latter appears to be closely connected to reasoning used in everyday life (Batanero, 2014; Kazak & Leavy, 2018). Indeed, the subjective approach is highlighted when the author sets out to estimate the probability of a situation, such as two half-brothers meeting by chance on a beach in Hawaii after having lost sight of each other for decades. Finally, the theoretical approach can be seen when the author calculates the p-value to determine the odds that a new drug will actually cure a higher percentage of patients than a placebo. In the course of examples and situations of uncertainty, the author often (implicitly) draws on more than one of these approaches, which is in line with the connection of probabilistic approaches advocated by a significant number of researchers in the topic of probability teaching and learning (Jones & Thornton, 2005; Prodromou, 2012).

## Conceptual Shift to Avoid

The book also has certain limitations. For example, some passages show conceptual shift into determinism when approaching situations of uncertainty. Probability differs greatly from the other topics of mathematics, which are all deterministic (Savard, 2014; Scheaffer, 2006). Unlike arithmetic, for example—where the same operation will always generate the same outcome—random games do not always yield the same results from one try to another, even if they are carried out under the same conditions, because of sample variability. Nevertheless, the author suggests that a random event with "an unimaginably small probability … would never occur by chance alone" (p. 154), which is not entirely true. Very rare or unlikely does not mean never or impossible. This probabilistic conception has been noted by Fischbein et al. (1991), who pointed out that students can attribute different meanings to certain probability-related words, for example by confusing "impossible" with "rare," or "very likely" with "certain". We therefore believe in the importance of staying cautious when using wording or examples that could lead to such conceptual shift.

Another instance of conceptual shift where the book might mislead readers relates to what Rosenthal (2018) refers to as "Protected by Luck" as the title of a chapter which begins with these words:

> Our world is full of dangers. At any moment, a criminal could rob us. A terrorist could drop a bomb. The airplane we're flying in could crash. Our child could be abducted. So many bad things could happen, to such terrible effect. What can we do about it? Well, to some extent, we can take precautions. We can lock our doors, avoid dark alleys, stay out of war zones, and keep an eye on our children. But such steps only protect us so much. Fortunately there's another way to avoid trouble: luck. (p. 105).

Luck does not protect from or limit dangers; rather, the act of quantifying the low probability of various dangers can procure a sense of safety. In other words, there is some potential semantic shift here between the concepts of "chance" and "luck," which could lead to confusing the low likelihood of an event occurring with the good or bad luck that it will happen.

Finally, we find the book's title somewhat exaggerated, as the implication is that it deals with luck, chance, and the meaning of everything. Of course, even if the author's intent seems commendable—he does address and demystify a plethora of chance and luck-related subjects and examples—his book does not, strictly speaking, establish the meaning of everything. In our opinion, the title rather suggests that, if readers are willing to exercise critical judgment in situations of uncertainty as the author advocates, they will be well-equipped to interpret (just about) any uncertain situation. In the meantime, the author could also have dealt with other topics of chance (and luck). An example would be the field of meteorology, which the author touched upon in his first general-interest book (Rosenthal, 2005) in discussing the risks of being struck by lightning, which scarcely come up in this second publication. Indeed, meteorology brings into play its share of chance and probability, for example in the concept of the likelihood of precipitation.

Ideas relating to the field of sports analytics would also benefit from being further developed by the author. He already offers up some interesting reflections along these lines, through his March Madness prediction model or certain unlikely statistics connected to Joe DiMaggio, the New York Yankees baseball player, yet so much more remains to be said given the modern-day (/continued) popularity of field and ice sports. In fact, sports analytics is emerging as a promising avenue in the field of probability with what Chernoff (2019) calls sports analytics education:

> Slowly but surely, professional sports teams started to realize that deep diving into data, statistics, and utilizing analytics was almost as important for the team and the athletes practicing and making sure not to disrupt their circadian rhythms when travelling. Although it happened in the background for most teams, evidence of the importance of sports analytics would eventually be made for all to see when nearly every professional sports team added an analytics position to the team. (p. 11)

Perhaps Rosenthal might be interested in writing a new popularization book… to the delight of sports and statistics (and probability) enthusiasts alike.

## Concluding Remarks

To sum up, it is worth emphasizing the importance of such general interest works in popularizing probability, statistics, and related reflections. In Rosenthal's book, the author succeeds brilliantly in showing the general public how widespread probability and statistics are and how we can use them to our advantage in a variety of situations, providing us with a more critical eye in the face of the deluge of data confronting us on a daily basis. Having a critical outlook (or not) can have serious consequences, as Rosenthal illustrates through a number of examples where justice is served.

To conclude, we agree that "[t]here's a lot of randomness in the decisions that people make," to quote Economic Nobel Prize winner and cognitive psychology expert Daniel Kahneman, whose work has (partially) focused on what we refer to as probabilistic conceptions. This being said, as far as reading this book is concerned, we recommend that teachers and educators interested in probability not rely on chance but rather read it without delay. Within its pages, they are certain to discover interesting ideas and avenues of reflection for probability teaching and learning.

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