Understanding and Preparing for Human Bias in the Assessment of Risks

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i. Abstract

Successful EHS practitioners and managers should be cognizant of the effects that human biases play in their own decision-making process, as well as the decisions and recommendations of their employees, co-workers, and managers. Developments in behavioral economics and experimental psychology provide insights into how and when individuals may be biased and under-predict or over-predict the risk of an uncertain future event. By developing the understanding of when one’s own intuition may falsely indicate safety when a situation is dangerous or danger when a situation is safe, EHS personnel can better employ their skills to mitigate risks and communicate about those risks in their organizations. This chapter describes the type and nature of common biases in decision making, their implications for EHS personnel, and methods for countering or mitigating them.

ii. Learning Objectives

After studying this chapter, you should be able to:

1. Recognize the types and sources of human bias.
2. Anticipate the likely effects of different forms of bias on EHS risk assessment.
3. Explain how to mitigate bias in one’s self or others in the context of risk assessment.

iii. List of Defined Words

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Anchoring</td>
<td>Basing an estimate of an unknown value on another known value whether or not the two are actually related to one another.</td>
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<tr>
<td>Assessment</td>
<td>An analysis that aims to evaluate the causes, consequences, and likelihood of a potential future event.</td>
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<td><strong>Behavioral Economics</strong></td>
<td>The study of how individual psychological processes lead to economic decisions, usually focused on choices that seem to be irrational under traditional economic understanding.</td>
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<tr>
<td><strong>Bias</strong></td>
<td>A tendency to consistently misestimate an unknown value to be higher or lower than its actual value.</td>
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<td><strong>Certainty</strong></td>
<td>A measure of how accurately a value is known at a given point in time.</td>
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<td><strong>Confidence Interval</strong></td>
<td>A range of values such that there is a specified probability that a population parameter (for example, and average or mean) lies with that interval.</td>
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<td><strong>Error</strong></td>
<td>A measure of the difference between a prediction for a value and the actual value.</td>
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<td><strong>Experimental Psychology</strong></td>
<td>The study of mental processes and behaviors under controlled conditions.</td>
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<td><strong>Hindsight</strong></td>
<td>The act of considering a particular outcome and tracing the history of how that outcome came to be.</td>
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<td><strong>Likelihood</strong></td>
<td>The probability of an event occurring over a certain amount of time.</td>
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<td><strong>Mitigation</strong></td>
<td>Reducing the severity of a potential negative event such as a worker safety incident.</td>
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<td>Term</td>
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<tr>
<td>Overconfidence</td>
<td>Believing one’s information or opinion to be truer and more specific than a strict examination of the evidence would suggest.</td>
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<td>Risk</td>
<td>A measure of exposure to negative outcomes calculated as the severity of an event multiplied by its likelihood.</td>
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<td>Severity</td>
<td>A measure of the consequences of a particular outcome.</td>
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<td>Survivor</td>
<td>A discrete set of units or outcomes that have not experienced a particular negative outcome.</td>
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<tr>
<td>Uncertainty</td>
<td>A measure of how much variability an unknown value may have.</td>
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1. **Introduction: The Consequences of Biased Risk Assessment**

Some human biases are unavoidable—the result of our brains being optimized to pick out patterns even when none exist depending on scant information to predict the future and enhance the survival of ourselves or our families. Other forms of bias are learned via direct experience (getting hurt as children on playground equipment) or learned from the instruction of family, mentors, and teachers. These differ from motivated biases where we too easily allow ourselves to be persuaded by what we want to be true in the face of contrary evidence, such as the cost and schedule of projects that are regularly underestimated [1].

The forms of bias we will be discussing in this chapter are entirely unintentional and unmotivated, yet they affect almost every one of us to varying degrees unless and until we have been trained to counter them. The biases we will discuss in this chapter are ingrained mental shortcuts that all people share. Perhaps they were valuable to our ancestors long ago in helping us to more quickly discern patterns in the world. However, today, as we seek to eliminate worker
and public harm due to our uses of technology, harms that thankfully are increasingly rare, these biases can prevent us from correctly identifying problems and solutions and leave us expending resources without any real benefit.

As EHS personnel and managers, we must be prepared to identify situations where bias is likely to arise and take steps to counter that bias in our own thinking and the judgments of others.

So what happens if we are biased in our risk assessments or we choose to act on the biased assessment of others who work with us? If we think that a particular possibility (say a safety incident, hardware failure, or excessive environmental discharge) is less likely than it really is, we will neglect to focus attention and resources on mitigating that risk.

2. Types and Sources of Bias

“Perceptual bias can affect nuts and scientists alike. If we hold too rigidly to what we think we know, we ignore or avoid evidence of anything that might change our mind.” – Martha Beck [2]

We should recognize that many tasks in EHS are prone to possible introduction of bias. While strict statistical analysis may not be susceptible, the most critical EHS decisions regard the application or not of specific controls, which have limitations to their effectiveness, to potential, but not certain, future events. Since, we often cannot possibly know when and where the next injury, vehicle accident, chemical spill, or fire will occur, the uncertainty surrounding these possibilities is the key determinant of the amount of risk they pose. Our estimates of those future unknowns are then susceptible to errors of thinking—both conscious and unconscious—including systemic biases that may constantly influence our predictions in a particular way. There are several sources of bias that may influence the decision making of individuals, and possibly even more if we were to consider biases related to interpersonal and social interactions.
They have a variety of names and are relevant to a series of different situational contexts, however this chapter will discuss four specific individual biases that fall into two categories: assuming we know more than we do; and framing our problem or question incorrectly.

One of the most common sources of bias is thinking that we know something to be true when we do not actually have the evidence to back up that claim. Most often, it is a matter of having some uncertain evidence in support of what we believe, but then treating that evidence as more conclusive than it actually is. What is most troubling, however, is that our human minds can take entirely unrelated information and use that on which to base a prediction. This chapter will closely examine two main forms of this bias, one called anchoring bias, and the other called certainty bias.

The other typical human bias relevant to risk assessment involves seeking the wrong kind of information either through incorrectly describing the problem or by incorrectly identifying the set of solutions we are looking for. This chapter will describe the implications of two main forms of this type of bias, one called hindsight bias, and the other known as survivorship bias.

Hindsight bias is a particular error observers make when examining the past and imagining after the fact that certain eventual outcomes should have been more foreseeable than available data would suggest [7]. Perhaps counterintuitively, this bias is increased when the outcome was unexpected; and greatest when that outcome was negative [8]. Certainly safety and environmental incidents fall into this category of being relatively rare and also very negative events.

3. Anchoring Bias

“Once an idea gets into your head, it's probably going to stay there.” —Eliezer Yudkowsky [9]
Anchoring bias is an error by which we estimate a specific quantitative value as being similar to the last quantitative value that we noticed or studied. This category of errors is also sometimes known as “recency bias”, “priming bias”, or the “availability heuristic”. It is an error based on a tendency of people to modify some value currently in their heads to answer a new question rather than starting with a blank slate, and unfortunately, most people cannot sufficiently adjust the initial value leaving their estimate biased.

You can demonstrate this bias yourself. In a room of people, divide them into 2 groups and ask them to estimate how many worker deaths due to falls occurred in the United States in 2014 (the true value is 359) [3]. But before you ask that question, provide the groups with different pieces of paper. One sheet will include the fact that the number worker deaths due to electrocution in the same year was 74, while the other group will be informed that the number of deaths in the U.S. due to diabetes was 75,578 [3, 4]. Once everyone has made their estimate, compare the resulting guesses. The group provided with the fact about electrocution deaths will probably estimate a lower number for deaths by falls than the group provided with the number of diabetes deaths. Both groups will have been primed to anchor their estimates of deaths from worker falls on the unrelated information on electrocution and diabetes.

As M.F. Weiner said, “don’t waste a crisis” [12]. We often use recent events and our temporarily changed perceptions about the likelihood or severity of those events to make changes to mitigate real problems. This can be a useful reaction to a point, especially when these severe unwanted outcomes are directly related to much more common outcomes. For example, fatal automobile crashes are vastly outnumbered by non-fatal injury car crashes and property damage car crashes, yet are all mitigated by the same countermeasures. However, investment to strengthen roofs to withstand strikes by meteors in the aftermath of a meteorite-caused fatality [13] would likely be
a poor allocation of resources when the same level of investment might provide many more buildings with earthquake or fire resistance.

The mistake of anchoring bias will most often lead risk assessments to underestimate the most common occurrence and overestimate the least common occurrences. In general, individual estimates of risk tend to center around certain typical risks because the numbers that any of us may grab as an anchor vary by the day or hour. Overall, this effect means that in the absence of a strong proximate anchor, most people tend to overestimate the likelihood of very rare risks and underestimate the likelihood of very common risks as seen in Figure 1 [5]. This causes a misapplication of resources and attention from common issues that affect large numbers of people to uncommon outcomes that make a more emotional impact, because they seem so tragic and unexpected when they do occur.

3.1 Mitigating Anchoring Bias with Focusing

The section above discussed the implications of the anchoring bias in risk assessment, but those same cognitive processes that get negatively affected by anchoring can be positively influenced by anchoring if we select the best anchor—this technique can be called “focusing.” For instance, our team may not want to believe that our newly designed and installed redundant process control systems are at any serious risk of failure, however, providing our team the statistical information on past failures of other similar control systems can anchor the assessment of the likelihood of failure and the risk of the new system. It is possible that the new system will perform incrementally better than previous versions, but it is unlikely to perform dramatically better. So, using the power of anchoring bias in a controlled manner with relevant data, can improve the ability of EHS personnel to accurately gauge risk. Since, clearing one’s mind of all
numerical values is difficult at best, it is advisable to focus on the most relevant values we can find when evaluating risks.

4. Certainty Bias

“Being deeply knowledgeable on one subject narrows one's focus and increases confidence, but it also blurs dissenting views until they are no longer visible, thereby transforming data collection into bias confirmation and morphing self-deception into self-assurance.” –Michael Shermer [14]

Certainty bias is an error in thinking an uncertain or initial estimate of a value is more accurate than we have the evidence to suggest. This error is sometimes called “overconfidence bias”. Since uncertainty is one of the main sources of risk, underestimating uncertainty is the same as underestimating risk. Certainty bias is an error of assuming our best guess is a better representation of reality than we ought to. For instance, if we need to plan for an outdoor installation of some equipment that is sensitive to temperature, and we must prepare for the installation months in advance before the weather can be precisely known, we ought to estimate a very wide range of possible temperatures and make plans accordingly. The certainty bias will lead us to minimize that range instead and increase the risk that we will allow our equipment to be damaged.

Figure 2 demonstrates how this works for a simple task of estimating the distribution of women’s heights in the United States. Data from the US census bureau is used to identify the true distribution [6], but without this information a group of engineering undergraduate students provided their best estimation of the mean and 95% prediction interval. As seen, the students’ estimates are fairly accurate as guesses of the true mean value, but they display a certainty bias expecting the range of heights to be closer to the mean than they actually are. Said another way,
the estimated range minimizes the size of the distribution tails. In other types of problems, the size of those tails indicate the measure of risk (e.g., strength vs. load distributions). When the need to predict a future uncertain quantity, certainty bias will lead one to underestimate risk. Uncertainty in engineered systems, human organizations, and the environment in which they operate is the primary source of environmental, health, and safety risks. If we knew exactly when failures were going to occur and when people would make mistakes, then we could prevent all negative outcomes. Instead, we have some information about the performance of our systems, our employees, the public, and the environment, but uncertainty remains. The certainty bias, however, means that we and others are likely to underestimate this uncertainty. Quantitatively, this means someone may be able to correctly state the average height for adult women, but that person is likely to underestimate the standard deviation—meaning that they believe most women will be closer to the average than is the case in reality. Or, when trying to estimate confidence intervals around an unknown specific quantity (e.g., how many local calls were made by people in the United States in 2007?) a person might estimate a range of values that is too narrow, say 30-90 billion local calls, when the actual value was 235 billion [15]. If I were to estimate ranges to include unknown values at a 95% confidence interval, I should only find 1 in 20 values outside of the estimated range. There is an exercise at the end of this chapter where you can test yourself for certainty bias with questions such as this. The study of the effects of certainty bias have focused predominately on economics, for example finding that individuals estimate too narrow a range of possible outcomes and the utility of those outcomes [16, 17]. Research has also shown that greater expertise does not appear to affect the degree of overconfidence: both novices and experts display similar tendencies towards overconfidence [18, 19]. While experts do know more, and are more likely to select narrower
ranges of values somewhat closer to the target, they continue to overestimate how much they know, and so are incorrect—the true value falls outside the estimated range—at the same rate as anyone from the general public [20, 21].

Many estimated and uncontrolled values are critically important to understanding the level of risk present in an operation from environmental conditions to equipment degradation to human choices. If we underestimate the range of conditions our equipment and people will be exposed to we will incorrectly underestimate the level of risk present in the system.

4.1 Mitigating Certainty Bias

A formal approach towards reducing certainty bias in forecasts on currently unknown values is called expert elicitation. In order to ascertain the level of uncertainty that a person actually perceives, it is useful to conduct a formal expert elicitation process whereby they will provide the likelihood or frequency distribution they expect from the value in question. This process involves stating various values and asking the expert for an estimate of probability of the actual value being less than or greater to the estimate. For example, what is the probability that a randomly selected American woman will be taller than 5’7”? As these questions are asked and the shape of the distribution is being completed, the interviewer returns to the tails of the distribution and asks if the expert could posit any scenario whereby the value could be even higher than their previous maximum or lower than their stated minimum. However, if the interviewer only asks for best guesses or confidence intervals, the experts are likely to be overconfident in the same way as any layperson [43, 44]. Requesting the likelihood of a value usually produces more accurate answers than requesting a value for a given likelihood” [45]. So, walking carefully through the interview with the aim of understanding the tails of the distribution by asking for the probability of certain plausible outcomes is a method for improved ascertainment of the risks. These techniques make
the expert elicitation process lengthier and more expensive than many might first suspect, but the level of accuracy has shown to be significantly increased [46, 47]. Since the goals in the situations where one might use expert elicitation involve significant risks and values that cannot be known (e.g., related to the first time a new technology is operated in space), it is important to maintain this method in the toolbox for these circumstances, and not view it as an easy way to forecast unknowns that might be addressed with better data collection, which is not nearly as susceptible to biases [46].

Response mode changes, another method for improving the elicitation of forecasts and uncertainty from experts, involve altering the way that we request information or estimates from individuals [45]. This can be as simple as conducting a paper elicitation followed by an in-person elicitation for the same information, or both paper and in person methods can use multiple question types to address the same unknowns. The “mode effect” documenting changes in answers depending on how the questions are asked has been well documented in a number of fields [48–50]. This technique was originally developed in psychology as a way to ensure that the responses from a person to an interview question were consistent with what that person actually felt or thought [51]. For example, many experts and laypeople will, at first, drastically overstate the probability of a 50% likelihood between two events—the “fifty-fifty” response [52]. The interviewees make this response to reflect some measure of uncertainty, rather than an accurate depiction of the odds. Changing the response mode during the interview and repeating the process to obtain the same information in a different way can combat some of the biases possible in the expert elicitation process.

5. **Hindsight Bias**

“Hindsight bias makes surprises vanish.” –Daniel Kahneman [22]
So, how does hindsight bias work? Let’s say that I inspect the tires on a truck before driving 100 miles and making a delivery, and happen to notice that one of the front tires is showing some obvious indications of wear. The measured amount of wear still rates as acceptable with only a 0.01% probability of failure in the next 100 miles according to our company’s maintenance records, and I have personal experience driving 10,000 additional miles on tires with a similar level of wear. So, I make the delivery, but on the return trip the worn tire experiences a blowout, and I subsequently crash the truck into the concrete barrier wall along the side of the highway, but suffer no serious injuries. In an investigation of such an event after the fact, it is a common application of hindsight bias to focus on the decision to drive with the worn tire, and say that we should have known better. In truth, the risk of a safety critical incident was actually low, but the incident occurred anyway. We may then devote large amounts of resources inspecting for and taking action in response to this particular indicator, when the indicator itself is actually a highly unreliable marker of risk.

After the fact, everything seems perfectly clear: what we all should have seen coming and why. Before the fact, we all seek to divine the next outcome from a set of uncertain and constantly changing signals, a cloudy haze of possible but usually unreliable indicators (see Figure 3). Some EHS disciplines such as root cause analysis and other forms of failure or incident investigations can exacerbate the likelihood of hindsight bias and render our conclusions ineffectual.

Hindsight bias has proven to be especially persistent even when individuals are given access to information on their actual predictive probabilities [23]. While there are researchers who have identified aspects of motivated thinking influencing the degree of hindsight bias [24, 25], some researchers believe that this bias is predominately based on the availability of information after an event has occurred [26].
While hindsight bias has not been studied in EHS professionals and engineers, it has been studied in business school students making investment decisions [27], jurors reviewing corporate audits [28], and in medical doctors making diagnoses [29, 30], among others. The effects of hindsight bias on safety management in general tend to focus more attention on behavioral aspects of individual workers [31].

It is important to keep in mind that hindsight in the general sense, is not something to be strenuously avoided. Failure and incident investigations that trace the path from a set of initial conditions through all of the human decisions to an eventual end are a critically necessary part of learning from past accidents and disasters, but as Sydney Dekker explains, hindsight bias makes these investigations prone to judgmentalism and preoccupied with placing blame [32]. Careful pains must be taken to structure investigations to avoid focus on decision making by individuals, which is prone to reinforcing hindsight bias, and instead focus on observations made at the time [32].

The problem arises when we stop considering alternatives that could have also let to the event in question and that could have been present in the minds of the individuals involved. Sometimes called “restoring foresight”, techniques have been tested to mitigate this hindsight bias in psychology experiments, legal proceedings, and even technical decision making on patents [33–36]. Without mitigating hindsight bias, we place ourselves at risk of learning the wrong lessons from each investigation, and those incorrect lessons learned will do little to prevent the next occurrence.

5.1 Mitigating Hindsight Bias

Hindsight bias has been mitigated when people are most familiar with the causes and related outcomes of particular events and the probability at which those outcomes occur [39]. Of course,
knowledge and experience can just as easily lead to jumping to the wrong conclusions as well as any untrained and inexperienced person as well have seen. So, how can that expertise be put to positive use? Through a series of techniques called *structured investigation* [40]. These techniques are taught through effective team design courses and six sigma courses, but not always consistently applied in the course of root cause investigations, where many begin with an assumption of human error [32]. As the field of medicine has incorporated more systems safety processes to reduce medical errors, these techniques have become more prominent there [41, 42]. The key in these investigations is to focus on the complex web of inputs and outcomes without assigning blame or responsibility to individual decisions or equipment failures, only seeking to understand each piece of the puzzle, what could have happened, and why. A review of this web of causes and effects can identify weaknesses in the current system and permit decision makers to reduce the number of critical failure points and make the system more robust.

6. **Survivorship Bias**

“All of us show bias when it comes to what information we take in. We typically focus on anything that agrees with the outcome we want.” – Noreena Hertz [37]

Survivorship bias is an error of focusing on an incomplete set of events and then using characteristics of that incomplete set to make generalizations about a larger population. It is important to note that survivorship bias in EHS could also be known as “negative selection bias”, since in many cases, we are examining a small population of failures or problems rather than a small population of good outcomes. Survivorship bias comes from looking at a small population of survivors like people who live to 100 years of age, or companies that have consistently returned profits for each of the last 40 years and then misattributing the unusualness of their survivorship to any common characteristics among those centenarians or high performing
companies—we ascribe the observed outcome to a particular circumstance or set of circumstances that are, in fact, unrelated to that outcome. That is, most non-centenarians and most failed companies may also have these characteristics. Instead, we need to know the differences between the two groups, rather than what is common among the “special” group of interest.

In EHS, survivorship bias could operate something like this (see Figure 4): at a chemical processing facility we have experienced 20 valve failures in the last year resulting in small releases of chemicals. There is a population of over 500 valves in total at the facility of similar design which have not experienced leakage. Seeking to understand the problem, we disassemble the failed valves and identify metal oxide particles from corrosion covering the valve seals as well as pitting and cracking in the seals. There are other signs of wear on the valves that are not in common among all of the failed units.

If one looks at a set of machines that outlived all of their peers and then looks for commonalities between them in order to explain how they survived so long, they are falling victim to the survivorship bias. What is common among the survivors may also be common among the failures as in Figure 4. It should be noted that this bias works in the same way if one is only considering failures or only considering situations where worker injuries occurred. The issue is that in training attention on only the failures or only the survivors, which are often in the minority, one is neglecting the majority of the available information. This is important in EHS, since we might incorrectly target an entirely unrelated indicator that is not at all predictive of the true risk being faced.

This process will usually play out in one of several ways: the first being that EHS personnel focus on something in common among worker injuries (e.g., they all occurred on days when it
rained) that sounds plausible, and so the investigation stops prematurely without continuing on to identify the true causal factors in the injuries, which may have been 50% higher workload on those same days. If the common factor among the injuries is not tested against all of the cases where injuries did not occur (i.e. EHS personnel do not bother to check all rain days and compare the injury rates to the injury rate on dry days), then the true cause and method for reducing risk will remain hidden until more costly injuries have occurred. The second common manifestation of this bias occurs when considering successes, such as evaluations of investment in risk reducing products (e.g., safety monitors or high reliability components). If successful survivors of field trials happen to mostly be all of one particular brand, are those components truly more reliable than their counterparts? In controlled laboratory investigations, this question may be easy to answer, whereas in the field it can be difficult to track and record differences in the environment and use profile of all tested components. It could be that ease-of-use issues led to the survivors accumulating less wear than the alternatives. Careful evaluation of the use and environment of all surviving and failed systems is necessary to counteract the tendency towards survivorship bias and prevent the associated waste of resources and lost opportunity for risk reduction.

6.1 Mitigating Survivorship Bias
Survivorship bias is based on an incorrect demarcation of mental borders we draw around a problem. So, the mitigation for survivorship bias is a rule of thumb in any investigation to widen those borders until it is no longer logical to do so. People often call this “stepping back” like in the context of stepping back in search of a broader perspective—a bigger picture. Ensuring that we or our coworkers are not carried away by survivorship bias requires constant challenges to step back and make certain that we are not too narrowly focused. If one person is injured when
performing a certain task even while dozens or hundreds of others completed the task without problem, or when one monitoring device fails at the same time fifty others continue their functions without problem, the issue may not lie solely with the injured person or the failed device. If we focus on finding differences or indicators related to that one device or that one person or among a small number of unusual cases, we increase the chance that we will be misled by survivorship bias and come to the wrong conclusion. Stepping back to look at the risk in the context of all the monitoring devices or all the personnel performing the task will help to counter this bias.

7. **Practical Examples**

1. A guide cable breaks during a lift at a construction site injuring a worker when the load turns on the main cable. A forensic investigation shows that the cable had a manufacturing defect. The company operates nearly thirty lift cranes at various worksites, and uses the same cables for all of them, and has been using the same manufacturer for years. The safety department had been in the process of investigating a series of fires and near fires that have occurred in the storage areas of three different construction sites. None of these fires or possible fires had led to any serious damage or worker injuries. The owner, however, tells his safety manager to put all safety personnel on the lift cable investigation so it can be solved as quickly as possible.

   The safety manager notes that this request is likely due to anchoring bias—the owner has reevaluated the probability of a cable problem based on the recent issue. The real probability of another problem with the cables in the near future is lower than he is currently estimating. The safety manager prepares data on the company’s use of the cables and their own safety tests, and brings that to the owner along with information on
the potential severity of the unresolved fire problem. The safety manager succeeds on getting the owner to keep most safety personnel on the fire problem, while they also continue the investigation on the cables.

2. Some liquid drips onto the sleeve of a maintenance worker at a chemical plant damaging her protective clothing. She was uninjured, but reported the incident to her supervisor and the safety representative, and they initiate an investigation and find a second flange seal that is currently leaking. Both seals are replaced and the leaking seals are examined in the lab. Both seals appear to be contaminated with silica particles (sand). Some of the maintenance personnel interviewed tell the investigators that the seal materials sometimes attract sand particles due to static charge created when removed from the packaging. The investigators report back to their manager and recommend that anti-static measures be taken on future flange installations.

The manager warns the investigators against survivorship bias, and asks them to take a wide random sample (at least twenty) of other seals in the plant as they are removed for maintenance and compare their characteristics and environments to the failed seals. This line of investigation reveals that over half of the seals have similar sand particle contamination, and the factor that sets the failed seals apart is their higher than average operating temperatures (only one of the other twenty seals operated at such high temperatures). The operating temperature was within the manufacturers specifications, but queries to maintenance contractor companies suggests that the seals may be less reliable near their maximum operating temperature.

3. An engineering team is designing a lightning protection system for an airport radar that will help reduce the odds of any aircraft-aircraft or aircraft-ground vehicle collisions on
the runways and taxiways. One of the engineers calls a local meteorologist to request information on the electrical current typical in local lightning strikes. The meteorologist looks up information from the last year on recorded lightning strikes and tells the engineer that at the airport, lighting strike current has been averaging 30,000 Amps, with the top recorded strike being 150,000 Amps last year. The engineer reports back to the team that the design should be able to withstand 150,000 Amps to ensure protection of the system. The design proceeds forward on that basis until the formal customer design review.

At the design review, the chief engineer for the airport recognizes the weak assumption occurring due to certainty bias and asks a series of questions about the lightning protection system including: Why were only strikes at the airport considered and not anywhere in the country or the state? How many strikes were included in the data set of strikes at the airport? What is the estimated probability of a strike with more than 150,000 Amps? Is there strong confidence that no changes in lightning intensity will occur in the next 30-40 years (the lifetime of the radar system)? These questions lead the engineers to realize they may have underestimated the likelihood of a strike with greater than 150,000 Amps, and they modify the design accordingly.

4. A consumer purchases a tie-down strap to hold their dirt bike in the bed of their pickup truck. Before a trip, he loads the bike into his truck and installs the tie-down strap connecting it to eye bolts mounted in the bed. One of these is corroded, but no more than is common with this type of hardware. During the man’s trip, the truck travels over a large pothole in the road at highway speeds. The bolt breaks letting the dirt bike roll out of the back of the truck striking the road and a following vehicle. There was significant
damage to the bike and minor damage to the following passenger car—there were no injuries. When the man examines what has happened to the previously thought secure bike, he notices that the corroded bolt was the one that broke.

The consumer replaces all the eye bolts in his truck bed, and later tells his friend that he should have known that the corroded bolt was too weak. But, the man knew in advance about the corrosion and had evaluated it to be no more indicative of a problem than any other. He relies on hindsight bias to make a new rule about replacing the bolts at the first sign of corrosion, without any evidence that the observed corrosion was the actual cause of the problem. His friend notices the logical shortcut, and tells him that there are other possibilities including a manufacturing defect or an inadequate design for the tension in his new tie down strap. This informal structured investigation step of brainstorming other possibilities for the failure helps to not narrow the problem too quickly to the possibly unrelated corrosion observation.

8. **Reflection / Conclusion**

> “Fortunately for serious minds, a bias recognized is a bias sterilized.” –Benjamin Haydon

[38]

> “Two quite opposite qualities equally bias our minds—habits and novelty.” –Jean de la Bruyere [53]

As we have seen in this chapter, bias in assessing an uncertain future event is common and affects all of us, unless we are specifically aware of that bias and take preparations to work against it. These are not the only biases that EHS professionals may be affected by. Other interpersonal and group biases may also affect the assessment of risk in complex situations, but the biases discussed in this chapter affect individual judgments about risks. Though currently
lacking, future research may focus on the particular effects these biases have among engineers and EHS professionals when evaluating risks as well as the best mitigation techniques for these biases in the context of the unique, rare, and potentially severe negative outcomes we seek to protect against. Understanding when these biases occur is critical to self-calibration and good decision making to best protect the safety and health of workers and the public.

9.1 Further Reading

*Why We Make Mistakes* by Joseph T. Hallinan [54] is an approachable book discussing how people make errors in a variety of different circumstances, and the types of situations that most often set people up for making mistakes.

*The Field Guide to Understanding Human Error* by Sidney Dekker [55] points out why determinations of “human error” are often wrong and nearly always unhelpful to the prevention of future accidents, and how investigators can move beyond this as a conclusion.

*Human Error* by James Reason [56] is a discussion of human error from a systems perspective including cognitive biases as well as human-machine interfaces. Numerous case studies populate its pages outlining the opportunities for intervention.

*Risk Communication* by Regina E. Lundgren and Andrea H. McMakin [57] specifically addresses the planning, design, visual, and verbal communication techniques proven to most effectively provide the public and decision makers with information on risks.

9. Exercises

1. Without doing any research, estimate what you believe is a 90% confidence interval around the following values:
   a. The number of passenger cars in the United States in 2014.
   b. The average annual number of sunny days in Pittsburgh, Pennsylvania.
c. The average annual number of sunny days in Phoenix, Arizona.

d. The number of jobs created in the US in July 2007.

e. The number of named Atlantic hurricanes and tropical storms in 2011.

f. The number of inches of rainfall over the year 2006 in Atlanta, Georgia.

g. The total number of words in the English language.

h. The number of votes cast for the US presidential election in 1992.

i. The number of twin births in the US in 2014.

j. The total number of buses in the US in 2000.

Now, check your intervals with the true values. If more than 1 actual value falls outside your confidence intervals, then you have displayed overconfidence.

2. Find a small group of people and divide them into two sub-groups. Provide each group with the following prompt and question:

   a. In 2014, the state of North Dakota produced more than 394,000,000 barrels of oil and 462,000,000,000 cubic feet of natural gas. What do you estimate is the probability of experiencing a fatal car crash in North Dakota (expressed as 1 in N chance)?

   b. The state of Mississippi experiences an average of 113 sunny days and 54 inches of rainfall per year. What do you estimate is the probability of experiencing a fatal car crash in Mississippi (expressed as 1 in N chance)?

Statistically analyze the responses of both groups and evaluate whether either or both of the groups displayed any anchoring bias.

3. Your team needs to assess the risk of severe weather at a new location. No monitoring equipment has been installed previously at this location. Describe and research a set of
statistics that could provide a useful “good anchor” to your team’s analysis of the severity and likelihood of this hazard.

4. Interview a classmate or colleague and elicit their range of travel times between the two major cities that they travel most often between (by car or by air). Begin with an estimate of the mean travel time, then ask for a 90% confidence interval. Follow this by performing a likelihood estimation of various values you select for large travel times beyond their initially reported maximum value. Ask the interviewee to imagine a possible scenario whereby this higher value could be exceeded, and if they can imagine one, to estimate its likelihood. Construct a graph of this probability distribution.

5. Consider that you work for a forklift manufacturer. In conducting a risk assessment for a new model of forklift, you identify the need for a tilt gauge and alarm that is later implemented in the design. Previous forklifts experienced rollover incidents in 1 in every 12,000 worker-days, and the new indicator and alarm is expected to drastically reduce this risk if implemented correctly. Design an effective 1-page risk communication that counteracts the potential biases of the engineers and managers involved with the project.

10. References


Report. Washington, D.C.


46. Morgan MG (2014) Use (and abuse) of expert elicitation in support of decision making for


Hoboken
**Figure 1:** Actual annual fatalities due to various causes in the United States in 2014 and mean estimated annual fatalities by a group of undergraduate students in 2015. Commonly occurring risks tend to be underestimated, while uncommon risks tend to be overestimated.
**Figure 2**: Distribution of the heights of US women in 2000 and the actual and undergraduate student estimated 95% prediction intervals. The student estimated prediction interval is narrower than true in reality suggesting overconfidence in each individual’s knowledge.
Human Bias in the Assessment of Risks

**Figure 3:** Before an event occurs, there exists a complex set of circumstances, indicators, and possible choices, some subset of which may lead to a severe negative outcome (explosion). After this event occurs, hindsight bias leads us to focus on one specific “chain of events” to the neglect of other paths to the same outcome as well as contradicting indicators and uncertainty that existed at the time.
Figure 4: Out of 25 valves, the 5 failed valves share a common feature (indicated by the triangles). Negative selection bias might lead one to conclude that this commonality is the cause or at least an indicator of the reliability problem. All of the alternative valves survived (indicated by half circles). Do they represent a truly better product, or is it just an effect of the small sample size?
Biased risk assessment could lead to the wrong decisions on risk mitigation and management.

We must be aware of the situations where bias may arise and how that bias may affect our judgment.

Anchoring bias will lead us to underestimate the common events and overestimate uncommon events.

Expert elicitation can help us estimate the likelihood of unusual or extreme circumstances.

Hindsight bias puts us at risk of learning the wrong lessons.

If we focus too much on the unusual cases, we increase the chance that we will be misled by survivorship bias.
Questions with Answers

Q1: How would certainty bias decrease worker or product safety?
A1: Certainty bias leads individuals to underestimate the complete range of possibilities, making systems and processes unprepared for high or low extremes.

Q2: Does anchoring bias lead to overestimates or underestimates?
A2: It depends on the anchor, and whether that anchor is greater or less than the true value being estimated. On average, anchoring bias tends to push individuals’ estimates towards the mean (for example, the average probability of all accidents).

Q3: Stepping back to re-examine the big picture is a mitigation for what type or types of cognitive bias?
A3: This method is most effective at mitigating survivorship bias, but it can also be useful in counting hindsight bias.

Q4: Expert elicitation techniques are most focused on what part of value estimation?
A4: Expert elicitation is most focused on the tails of the distribution and the likelihood thereof. The probability of the more extreme or unlikely events, which tend to be underestimated initially due to certainty bias.

Q5: Which cognitive bias leads investigators to overemphasize human error as the cause of incidents?
A5: Hindsight bias tends to cause this effect, as it makes previous intuition regarding uncertainty about a situation seem less significant in retrospect.