

TOWARD BETTER DECISION-MAKING: RECOGNIZING THE EFFECT OF SELECTION BIAS IN THE ANALYSIS OF RECREATIONAL AVALANCHE DATA

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ABSTRACT: A number of decision-related “urban myths” have taken hold in avalanche education as a result of statistical analyses of recreational avalanche accidents. We discuss the limitations that the self-selecting nature of accident reporting place on the use of the conclusions of such analyses in avalanche decision-making and education. We suggest that one conclusion in particular – that avalanche victims’ familiarity with a slope seems to negate the benefits of training and experience – may be an artifact of a peculiar form of base rate neglect.

We then propose an alternative approach to avalanche decision-making that is based on Bayesian statistical methods. This approach is particularly appropriate in situations where one wants to understand the effect of new evidence on the decision-making processes of people with varying levels of training and experience. It has the added benefit of being intuitively accessible to recreational users.

KEYWORDS: Avalanche Education, Decision-Making, Accident Case Studies, Statistical Analysis

1. INTRODUCTION

When most people use the word statistics, they refer to the process of organizing and summarizing numerical information – *e.g.*, reporting the number of skier days, or the number of avalanche accidents in a season. If one wants to do something with numerical data beyond simple description – *e.g.*, predict the number of skier days next season based on interviews with a sampling of this season’s skiers – one uses the tools and techniques of statistical inference. But the ultimate utility of statistical inference depends on the nature and quality of the data, and the specific statistical techniques employed. For this reason, researchers are careful in publications to discuss their data and methods, and to emphasize the caveats that qualify their conclusions.

As the conclusions pass from the researchers to intermediaries such as general practitioners or educators and on to the general public, however, the caveats and cautions are often lost, leaving the conclusions with a sometimes undeserved air of certainty.

1.1. *The Use of Inferential Statistics in the Avalanche Community*

To generally illustrate this point, look at how three different communities use inferential statistics and communicate the conclusions of their analyses.

Physics researchers, for example, are relatively uniformly fluent in the statistical methods that are used in their investigations. This means members of the community not only understand the results of a particular experiment, but they can each critically examine the data, analytical methods, caveats and conditions. Knowing their conclusions will be subject to thorough peer scrutiny, physics researchers don’t need to over-advertise the potential biases in their data or uncertainties in their analyses when they present their conclusions.

The situation in the medical realm is more complicated. A relatively small group of researchers performs complex statistical studies relating to drugs, treatments and diagnostic techniques. The studies are published in peer-reviewed journals, and the resulting drugs and devices are subjected to thorough regulatory review before being made available to consumers through their doctors. For these researchers, much of what was said about physicists’ statistical fluency applies.

There is a second group of professionals within the medical community – doctors – which acts as an intermediary between the researchers and consumers. Medical doctors are taught statistics in school, and see many

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statistical studies over the course of their careers. They often develop an instinctive sense of when a study might be questionable – due to small sample size or unusual methods, for example. The advice they offer their patients is based more on this instinct than on detailed consideration of the specific statistical methods of a particular study or paper.

The largest group in the medical community – consumers – is manifestly unequipped to understand details relating to sample size, data biases or analysis methods. They rely on doctors for guidance when it comes to understanding the implications of statistical studies on their medical choices. And yet – even with the availability of statistically trained intermediaries and a demanding regulatory process – consumers regularly fall victim to media reports and advertising that present as fact the very conditional results of statistical studies. It is no wonder that consumers experience a cycle of excitement and disappointment as one study is superseded by another. This is a significant effect, given that one third of the major medical studies reported between 1990 and 2003 were overturned by subsequent research (Ioannidis, 2005).

Now consider the community of people engaged in recreational activities that put them at risk from snow avalanches. There is no reason to believe these people are any better trained in statistical methods and concepts than the general population. There does, however, exist within the community a small number of trained researcher/enthusiasts who employ inferential statistical methods.

In the avalanche community, educators play an intermediary role similar to that of doctors in the medical example. Unlike medical doctors, however, the training of the educators is not uniformly prescribed, so there is no guarantee that a particular educator will have studied enough statistics to appreciate the caveats and conditions contained in the papers written by the researchers. This – and the fact that effective recreational educational material needs to be concise, simple and entertaining – can lead to an understandable tendency to include the conclusions of the studies/papers in their educational material without reference to the assumptions on which the analyses were based. Moreover, only a fraction of those at risk from snow avalanches actually take a formal safety course. Any safety message aimed at this larger group via advertisements, trailhead warnings, website postings or

magazine/newspaper articles has to be very simple and almost slogan-like to be effective, leaving no room for caveats or conditions. The end result, then, is a situation where highly conditional conclusions from inferential statistical analyses can quickly propagate into the broader community as established truths.

1.2. A Case in Point: Does Familiarity with a Slope Negate the Benefits of Training and Experience?

We turn to a concrete case to make clear the relative ease with which the conditionality associated with a statistical analysis is lost as the conclusion propagates thru the avalanche community. Consider the series of papers that statistically analyzed recreational avalanche accident data in order to examine decision-making in avalanche terrain (McCammon 2002, 2004).

The analyses resulted in a number of interesting and compelling observations about victim behavior, including the following: *“It thus appears that, in victims with advanced training, familiarity with a slope tended to negate the benefits of knowledge and experience”* (McCammon 2002).

The analysis that underlies this conclusion were well documented, and the in most cases the caveats and conditions on the conclusions clearly identified*. The primary condition, of course, is that the conclusions apply only to avalanche victims for whom accident reports were filed. That the conclusion did not necessarily apply to backcountry users in general was stated by the author in a paper aimed at a technical audience:

“The study focused on accidents, and thus can only identify what factors were present when accidents occurred. Such a study cannot, by itself, identify factors that were present when accidents did not occur, or what factors may lead to accidents not occurring. Such information is of course critical to successful avalanche education.” (McCammon May 2004).

* As a technical aside, we question McCammon’s rather arbitrary use of statistical tests. Generally speaking, decisions about when to use parametric or non-parametric tests should be made for an entire analysis, and not based on the normality (or lack thereof) of one data set.

As the conclusion began to appear in more popular media, however, the condition that the conclusion applies to accident victims who filed accident reports disappears, and (perhaps unconsciously), is generalized to “parties”. *“Remarkably, parties with advanced training that were traveling in familiar terrain exposed their parties to about the same hazards as parties with little or no training. In some respects, familiarity seems to have negated some of the benefits of avalanche training.”* (McCammon, Spring 2004).

And finally, in this example taken from a well known skiing website in 2006, the conclusion is presented as certain and general fact that applies to groups of skiers:

“It seems when we are skiing terrain we know well we let our guard down and ignore warning signs. When groups of experienced and inexperienced backcountry travelers were compared, experienced skiers were at a distinct advantage on unfamiliar terrain where they critically examined available data. On familiar slopes there was no difference between experienced and inexperienced groups.” (<http://pistehors.com/backcountry/wiki/Avalanches/Heuristic-Traps>).

The key point here is that the critical distinction between avalanche victims in particular and skiing parties/groups in general had been lost in translation. As the conclusion gained traction and distribution – from the researcher to educators and ultimately the media – the qualifications and limitations fell by the wayside.

1.3. Implications for Avalanche Education

Reasonable backcountry users or educators might view the previous discussion of the distinction between victims and users as splitting hairs. They might ask:

Why shouldn't we take seriously everything that is suggested by statistical studies? Isn't it better to propagate potential insights as broadly as possible?

And why shouldn't we just extend what we learn about victim behavior from avalanche reports to backcountry users in general? Why wouldn't we want to focus avalanche education on what we learn from avalanche reports? Aren't we all trying to avoid becoming victims of avalanches, after all?

These are good questions, and we will try and answer them below.

Speaking first to the general use of inferential statistical analysis in the avalanche community, we suggest that it is very important to avoid the cycle of excitement and disappointment that plagues media reporting of medical studies. For example, there are many dietary supplements (e.g., Echinacea, antioxidants, and B vitamins) whose promising health or performance benefits in small scale studies led many people to take them. Almost uniformly, however, their advertised effects were not seen in larger, more rigorous investigations. Nonetheless, many continue to purchase and consume them. Perhaps the most insidious effect of this cycle is that otherwise sensible people become suspicious of statistical and scientific methods, and come to rely on apocryphal information or simple force of habit.

From the point of view of effective avalanche education, letting the results of conditional statistical analysis morph into habits and rules of thumb is potentially much more dangerous than taking an ineffective dietary supplement. Once these take hold, they become embedded in avalanche education programs and materials, and ultimately in the decision-making process of individual users.

An excellent example of the impact statistical studies can have on the entire avalanche community is the fact that the particular conclusion discussed above – a victim's familiarity with a slope negates the benefits of knowledge and experience in avalanche terrain – has raised serious questions as to the effectiveness of formal avalanche education itself (McCammon, Spring 2004).

Fortunately, we believe this particular conclusion is an artifact, as we will discuss in detail in Section 4.1.

With respect to the question of focusing avalanche education on the study of recreational accident reports, we will explore in Section 3 the rather counter-intuitive suggestion that examining the behavior of avalanche victims – in particular the level of risk to which they expose themselves – is not necessarily the best way to measure the effectiveness of avalanche training and experience. But first we must set the stage with a discussion of the biases inherent to accident reporting.

2. THE NATURE OF RECREATIONAL AVALANCHE ACCIDENT DATA

Researchers who study accident and incident reporting have identified a number of selection biases that can severely limit the inferential utility of statistical analysis based on accident reports (Johnson 2003). Generally speaking, data suffer from selection bias when some aspect of the way in which samples are collected or reported distorts the statistical analysis. Performing statistical analyses on biased data, or in a manner that ignores important elements of the data, can result in erroneously enhanced statistical significance or completely illusory effects. Of particular interest in the case of recreational avalanche accidents are self-selection bias and base rate neglect.

2.1. Self Selection Bias

Self-selection bias can occur whenever the subjects being studied have control over whether to participate in the reporting of accidents, or of what to include in the reports. Victims, bystanders and rescue professionals all contribute to self-selection bias in avalanche accident reports. Most obviously, if a subset of avalanche victims chooses not to file reports, the resultant sample will clearly be distorted, making it difficult to generalize to the larger population.

More subtle effects can also occur. Less knowledgeable victims or bystanders might not recognize important environmental factors that warrant recording, or might force the circumstances to fit the limited scenarios with which they are the familiar. Professionals might draw hasty conclusions about the preventability of the accident (hindsight bias), attribute the accident to a particular known risk or hazard (availability heuristic), or even pass judgment on the victims' behavior due to a documented (Holloway and Johnson 2006) human tendency to think accidents only happen to incompetent people.

2.2. Correcting for Self-Selection

It is possible to correct for self selection bias by separating the characteristics of the group or groups being studied from the effects of self-selection. Heckman (1979) developed a two-stage methodology, known as the Heckman's lambda or the Heckit method, for which he was awarded the Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel in 2000.

His approach has been applied extensively in micro-econometrics, sociology and management research, and most statistical software packages (e.g., SAS, SPSS, and Stata) allow for self-selection bias correction. Surprisingly, we have found no published attempts to correct for self-selection in the analysis of accident reports. We believe this is an interesting area for further investigation of accident reporting in general and recreational avalanche accidents in particular.

2.3. Base Rate Neglect and the Denominator Blindness Effect

When asked to estimate the chance that something might happen to a member of sample of a population (test positive for a disease, get in an accident), people tend to focus on information they are given about the sample (test sensitivity, number of accidents), and neglect the underlying frequency with which the event is known to occur in the overall population (disease prevalence, overall exposure to the risky activity). This behavior is known as "base rate neglect", and has been well documented (Tversky and Kahneman 1982).

A peculiar form of base rate neglect that manifests itself when people are asked to make judgments about the recklessness of a particular activity is called "denominator blindness" (Viscusi and Zeckhauser 2002).

Viscusi and Zeckhauser found that when people were asked to assess the risk level of an activity based on observed accident history, they made their judgments almost solely on the absolute number of accidents, and ignored the scale of the underlying activity. For example, Viscusi and Zeckhauser asked a number of jury-eligible people to assess whether a chemical company whose delivery operations had experienced a certain number of spills was reckless. They found that people's judgments of recklessness depended only on the number of spills, and did not change even when the number of deliveries for a fixed number of spills was increased significantly.

The denominator blindness effect is likely to appear in statistical analyses where one takes a sample of accident reports, divides it into sub-samples according to some variable of interest (e.g., training or experience), and then attempts to interpret deviations from the null hypothesis. Before attributing any significance in the differences to the apparent recklessness of different sub-groups, one must normalize by the scale of the underlying risk activity. In other

words, if one wants to speak to the effectiveness (or lack thereof) of training or experience, one must be sure to compare the rate of accidents, not simply the absolute numbers of accidents.

2.4. Correcting for Denominator Blindness

In order to correct for denominator blindness when analyzing accident reports, we need some quantitative measure of the underlying scale of risk activity. Ideally, this would be contained in the accident report – *i.e.*, each report would record the amount of activity (*e.g.*, average days worked per month in the risk environment, or days backcountry skiing in familiar terrain per month) along with the details of the particular accident.

Unfortunately, it does not appear that such information is consistently recorded in recreational avalanche accident reports. It would seem to us that avalanche professionals might want to consider recording this information in order to make future analyses more powerful from an inferential standpoint.

Absent quantitative metrics on the scale of activity in the accident reports themselves, we propose a correction methodology that borrows liberally from Heckman's two-step approach to correcting for self-selection bias (Heckman 1979). We first model the scale of the underlying risk activity as a function of the variable we want to study. If, for example, we want to study the characteristics of recreational avalanche accidents as a function of the skill or training level of victims, we estimate the amount of time each skill group spends on average in the backcountry. The second step involves renormalization of the data, or re-scaling of the results, depending on the situation. In Section 3.1 we apply this approach to the claim that for victims with advanced training, familiarity with a slope tends to negate the benefits of knowledge and experience.

2.5. Relating the behavior of accident victims to that of the general user population

Even if we are able to correct recreational avalanche accident report analyses for biases such as self-selection and denominator blindness, we still can't automatically extend the conclusions from victims to backcountry users in general. To do this would require that we first establish a commonality of root cause between major accidents, minor accidents, near misses

and accident-free behavior – *i.e.*, establish that the paths to a near miss are similar to those of actual accidents – and then connect the near misses to accident-free behavior.

In some contexts – *e.g.*, industrial accidents – safety researchers have used the frequency of minor incidents or near misses to successfully predict the rate of more severe accidents. This common cause approach was first proposed by Heinrich (Heinrich 1931). A recent review of the literature (Wright and van der Schaaf 2004) seems to provide qualified support for the common cause hypothesis in at least one particular accident realm (railways).

Unfortunately, we do not have access to a coherent body of avalanche near miss data, so we cannot – as most industrial accident researchers can – connect the body of accident data to near miss data to usual behavior in order to test for common cause. We are essentially forced to reverse the process, and try and say something about the characteristics of avalanche near misses and accident-free behavior from avalanche accident data.

If the common cause relationship holds true for recreational avalanche accidents, we would expect that any measurement of assumed risk (*e.g.*, McCammon's hazard indicators) would be similar – but perhaps slightly reduced – for near misses as opposed to actual accidents. This is topic that we believe warrants further research.

3. MEASURING THE EFFECTIVENESS OF AVALANCHE TRAINING AND EXPERIENCE

Since accident reports by definition focus on exceptional situations, if they include no measure of the scale of the underlying activity (*e.g.*, how often victims went into the backcountry), it will be difficult to say anything about the rate of accidents. And it is the *rate* of accidents, not the comparison of absolute number or severity among different sub-groups of victims, that is most relevant to safety researchers and professionals when evaluating the role of mitigation (*e.g.*, training, education, equipment) (Johnson 2003).

The first question for avalanche educators, then, would seem to be: How do we reduce the rate of recreational avalanche accidents? It is possible that the hazard profiles of major accidents, minor accidents, near misses and accident-free are similar (as discussed in Section 2.5). If so, then studying the behavior of

accident victims would probably help develop training and education programs.

But what if there is a strong discontinuity between accident-free behavior and the behavior of victims? What if, due to focused training or just good judgment, accident-free users consistently back off when one or two hazard indicators are present, and only a small, persistent segment of the population exposes itself to situations with multiple hazard indicators? This would imply that accidents were most likely to occur among people (experienced or inexperienced) who consistently push the risk envelope. In that case, looking only at the risk tolerance versus level of training or experience in avalanche accident victims might lead us to incorrectly question the effectiveness of education, while examination of the *rate* of accidents among the groups would indicate that training and education were in fact effective.

This suggests to us that recreational avalanche education and training may be most effective when designed to reduce the rate of accidents by convincing backcountry users to step off the “hazard indicator” escalator early on. If one accepts this observation, then studying the behavior of different classes of accident victims might be less important than studying the behavior of experienced users who *don’t* have accidents!

Since there will always be users who consistently push the risk envelope independent of training and/or experience, addressing these users will likely require an educational program that focuses less on the nature of objective avalanche hazards and the adoption of “rational” decision frameworks and more on exposing the underlying personal beliefs that lead such individuals to take significant risks in the first place. We will return to this point in Section 4.

3.1. Familiarity with a Slope Negates the Benefits of Training and Experience: An Artifact of Denominator Blindness?

Leaving our general discussion of avalanche education for the moment, we revisit the conclusion (McCammon Spring 2004) that for victims with advanced training, familiarity with a slope tends to negate the benefits of knowledge and experience.

We are not yet equipped to quantitatively address self-selection bias in the recreational avalanche report data, but suspect that in the case of this particular conclusion, base rate

neglect (denominator blindness) is the primary bias.

The first indicator that denominator blindness may be at work is McCammon’s assumption that because a large number of analyzed accidents happened in familiar terrain, that victims greatly overestimated the degree to which familiar slopes were safer. Occam’s razor suggests an alternative explanation: familiar slopes become familiar by skiing on them very often. Thus, the bulk of the underlying risk activity would naturally occur on familiar slopes.

In order to make this more quantitative, we need to estimate the scale of the underlying risk activity (backcountry use), ideally as a function of each training and experience level identified in McCammon’s analyses (None, Aware, Basic and Advanced). Fortunately, there exists an independent survey of backcountry users (Tase 2004) that employs the same ordinal descriptors as McCammon. The relevant data from Tase 2004 are shown in Table 1.

TRAINING LEVEL	USE FREQUENCY			Total
	Not Often	Often	Very Often	
None	14 48%	9 31%	6 21%	29
Aware	127 25%	239 46%	149 29%	515
Basic	54 14%	195 50%	143 36%	392
Advanced	13 3%	116 29%	276 68%	405
	208 15%	559 42%	574 43%	1341

Table 1: Frequency of Backcountry Use vs. Training Levels (Tase 2004). The table shows the absolute number of survey responses, as well as the percentages in each Training Level category.

We need only convert the ordinal Use Frequency descriptors to numbers in order to make a “denominator” correction to the absolute accident count used by (McCammon Spring 2004 Figure 3.). Based on personal experience and an informal survey of backcountry skiers, we assume that “Not Often” = 1 trip/month; “Often” = 4 trips/month; and “Very Often” = 8 trips/month.

Combining these with the Use Frequency percentages from Table 1, we find that victims with Training Level Advanced take two times as many trips per month as victims with Training Level None (6.6 to 3.4), and 1.5 times as many as victims with Training Level Aware (6.6 to 4.4). Yet, in McCammon’s analysis, the three Training

Levels experience almost equal numbers of accidents (49, 48 and 50). This means that the accident rate for victims with Training Level Advanced is half that of victims with Training Level None, and two thirds that of Training Level Aware.

We suspect that the accident rate for Training Level Advanced versus Training Level None or Aware may be even smaller than stated above. One wonders, for example, what victims with no or little experience mean when they call a slope familiar. A familiar slope to novices could be one that they skied only once before, while a familiar slope to experienced mountain residents could be one that they ski a couple of times a week throughout the season.

We suggest, then, that a *rate-based* view of the relationship between victims' training, experience and slope familiarity says something positive about the role of avalanche education, training and experience, *even if* groups of victims with different Training Levels exhibit roughly the same risk tolerance.

4. BAYESIAN METHODS AND AVALANCHE DECISION-MAKING

As should be apparent by now, we are of the opinion that using classical statistical methods (*i.e.*, significance or hypothesis testing) to analyze recreational avalanche accidents and then working backwards to develop rules of thumb and principles for general user decision-making may not be the most effective way to approach avalanche education.

At one level, this is due to the fact that we question the pedagogical utility of conclusions that result from statistical analysis of data which are biased by their very nature (accident reports). Essentially, by the time the conclusions are reduced to digestible rules of thumb, the necessary cautions and qualifications are almost invariably lost.

More fundamentally, however, we are drawn to the idea that the frequency of recreational avalanche accidents can be more effectively reduced by learning from the behavior of experienced users who *don't* have accidents, as opposed to comparing the apparent risk tolerance of various groups of victims.

In addition to the fact that accident reports are the only substantial body of data available to analyze, we suspect two other aspects of human nature for the focus on accidents in avalanche safety education. First is the simple truth that people like a good disaster story. We pay more

attention to a tale of survival and tragedy than an account of an uneventful trip. Second is a cultural fascination with risk takers. The commercialization of extreme sports and the ubiquity of "ski-porn" leave many already risk seeking people with a distorted view of the risk-return equation in avalanche environments.

The real challenge in reaching highly risk seeking users may lie more in belief modification than in increasing their appreciation of objective avalanche dangers. It may also be the case that getting average users to step off the hazard escalator earlier is as much about explicitly addressing beliefs as it is about developing clever decision frameworks.

To this end, we ask whether we can learn something from the good Reverend Bayes. Bayesian methods have revolutionized many areas of human endeavor that involve decision-making under uncertainty by viewing probability as a subjective expression of belief, as opposed to an objective property of the environment (Winkler 2003). To be clear: our objective here is not to replace the classical significance and hypothesis testing of accident report data with Bayesian statistical tools. Instead, we will try to qualitatively apply the Bayesian interpretation of probability as measure of belief to individual decision-making in an avalanche environment.

4.1. Bayes Rule and the Role of Belief in Decision-Making

Bayes Rule can be used to update the probability P that an outcome O (*e.g.*, an avalanche) will occur given some new evidence E (*e.g.*, recent wind loading). The updated (posterior) probability $P(O|E)$ or chance of the outcome O given the evidence E is:

$$P(O|E) = \frac{P(E|O)P(O)}{P(E|O)P(O) + P(E|-O)P(-O)} \quad \text{Eq. 1.}$$

where $P(O)$ is the prior probability or overall chance of the outcome before the new evidence; $P(E|O)$ the likelihood that the evidence E can occur in association with the outcome O ; $P(-O)$ simply $1 - P(O)$; and $P(E|-O)$ the chance that the evidence can occur in association with any outcome *other* than O .

It is instructive to note that Bayes Rule was arrived by addressing the problem of Inverse Probability. In avalanche terms, this means that what we want to know – $P(O|E)$ or the chance of an avalanche given a certain hazard indicator like wind loading – is the inverse of what we can

most easily find out by studying avalanche environments, *i.e.*, $P(E|O)$ or the chance that a certain hazard indicator occurs in association with avalanches.

Although Bayes Rule may appear confusing at first, it is actually consistent with the way most people think. By equating probability to belief as opposed to a number that we get from a series of trials, we can discuss the probability of an individual event – something that is more natural to humans than thinking in terms of frequencies. This puts an interesting spin on the meaning of $P(O)$ and $P(E|O)$ in Eq. 1. Think of $P(O)$ as the instinctive feeling about whether to go on particular trip, and $P(E|O)$ as that feeling after looking at the morning avalanche report. In addition, the iterative application of Bayes Rule – where one incrementally readjusts one's thinking based on new information – seems consistent with human learning mechanisms.

Psychological research has shown, however, that humans are not good at making a clear distinction between beliefs and evidence, typically either under-adjusting for the impact of new information, or neglecting to take beliefs into consideration at all.

It is our contention – and indeed one of the central points of this paper – that if we can muster the discipline to independently catalog and acknowledge our beliefs, we can engage the iterative power of Bayes Rule to make better decisions.

We have not discussed evidence *per se* here, because in the avalanche context it seems to be generally available, and recent research indicates that both recreational and professional users seem capable of mastering the objective intricacies of avalanche hazards (Atkins and McCammon 2004).

4.2. Doing a Belief Inventory

Human beliefs have a variety of origins. We can believe something because we experienced it directly or vicariously. We can harbor beliefs that are religious, cultural or historical in origin. And we also have inherent, essentially genetic beliefs such as self-confidence, herd behavior, and the need find agents and causes for events that we experience. These inherent beliefs are thought to underpin the unconscious rules of thumb (heuristics) by which we seem to operate (Kahneman and Tversky 2000).

In the context of avalanche decision-making, we suggest that two categories of beliefs are dominant: personal/vicarious and

inherent/genetic. That the first is important is probably not surprising. It is clear that personal and vicarious beliefs represent an unconscious synthesis of information – particularly for experienced and well trained individuals, and as such should not be neglected. This personal/vicarious belief base is often referred to as “intuition”.

The second – in the form of heuristics – seems also to be at work in avalanche environments (McCammon 2002). We suggest, however, that casting the inherent/genetic beliefs as heuristics actually makes it harder for people to change their behavior. This is because heuristics are almost universally expressed as things that individuals do wrong with respect to some normative or rational ideal (*e.g.*, utility theory). And generally speaking, people pay less attention when told they are doing something wrong.

If we can access our inherent/genetic beliefs in a more neutral way (*e.g.*, general confidence level, tendency to follow/lead), we are perhaps more likely to acknowledge them when making decisions. A belief-based approach might be more “actionable” for individuals making a decision than a list of all the “irrational” things they are doing. In addition, expressions of inherent belief are more easily related to personal/vicarious beliefs (*e.g.*, the extent to which one trusts a friend's evaluation of slope is a combination of one's confidence in the friend's judgment, and one's inherent tendency to follow or lead).

One can, of course, propose other methods of organizing beliefs. Our principal observation here is that the very act of explicitly acknowledging our belief base is in itself a huge step toward better decision-making.

4.3. Iterating Beliefs and Evidence

If we can succeed in cataloging our beliefs, the next step is to iterate them with the evidence. Formal Bayesian methods offer precise mathematical prescriptions for the iteration process, based on Eq. 1. The most effective non-mathematical representation of these methods that we have found for use in qualitative situations is the concept of negotiation.

In a negotiation, one usually submits an initial offer, and then considers the relevance and viability of each counter-offer in turn, to a point where the result is either acceptable, or it crosses the “walk away” threshold. An

examination of Eq.1 shows similarities if we view O as the outcome of a deal, and the evidence E as a given counter-offer.

4.4. A Bayesian Mnemonic: When Making a Choice, FIND the Answer

We offer here a simple mnemonic that (hopefully) captures what has been discussed in this Section. Designed to be of general utility in decision-making (DiGiacomo 2006), we suggest it is quite applicable to avalanche-related decision and education situations.

When faced with a choice, FIND the answer: Frame, Inventory, Negotiate and Decide.

Frame: Explicitly look at the choice from a Bayesian perspective by focusing first on your general beliefs about the choices without considering evidence, and then preparing yourself to consider each relevant piece of evidence in turn.

Inventory: Catalog your beliefs about the choices. Use the general categories of personal belief, vicarious belief, and inherent/genetic beliefs to get started.

Negotiate: See how your initial beliefs hold up to the first piece of evidence. Take the result of that negotiation (beliefs win, lose or draw), and consider the next piece of evidence. As you consider more and more evidence, does your feeling about the choice change? Does the evidence strengthen or weaken your confidence in your beliefs?

Decide: Did your initial beliefs survive the evidence, or did the evidence ultimately overwhelm them? Knowing this not only helps you to make the choice, but it gives you insight into *why* you made that choice, and an updated belief base with which to confront new evidence that might come along.

A note of caution: this is *not* a decision framework, but an educational and personal exercise that helps reveal the role that beliefs play in decision-making.

5. CONCLUSIONS

Be careful using the conclusions of inferential statistical analysis in avalanche education. Highly conditional conclusions from statistical analysis can easily morph into unqualified truths. Once these take hold, they become embedded in education programs, and ultimately in the decision-making process of individual users.

Be particularly careful if the analysis is based on recreational avalanche accident reports. Most accident report data suffer from selection biases that require some sort of correction. As an example, we examined the claim that, in victims with advanced training, familiarity with a slope tends to negate the benefits of knowledge and experience. After correcting for a base rate effect called denominator blindness, we found that victims with advanced training had half the accident rate of victims with no training. This suggests that, even though victims with varying degrees of training seem to expose themselves to similar levels of hazard, advanced training was effective in terms of the most generally accepted safety metric: accident rate.

It is very difficult to extend conclusions about accident victims to users in general. To do this requires demonstration of common cause between accidents, near misses and accident-free behavior. We suggest that more progress might be made in this regard by studying the behavior of experienced users who *don't* have accidents than by comparing the apparent risk tolerance of various groups of victims.

Understanding the role of belief may be the key to lowering avalanche accident rates.

The rate of avalanche accidents may be driven more by unacknowledged beliefs than a lack of understanding of objective hazards. This is almost certainly the case in highly risk seeking users, and may also be the key to getting average users to step off the hazard escalator earlier. The most relevant beliefs in avalanche situations are those that derive from our personal and vicarious experiences, and those that underpin the heuristic behavior that governs our unconscious responses.

Bayes Rule offers a simple and intuitive way to iterate beliefs and evidence to make better decisions. Bayesian methods have revolutionized decision-making by viewing probability as a subjective expression of belief as opposed to an objective property of the environment.

A simple mnemonic exercise might prove effective in avalanche education. When making a choice, FIND the answer. Frame the choice in Bayesian terms; Inventory your beliefs; Negotiate between your beliefs and the evidence; and then Decide.

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