THE ROLE OF TRAINING IN RECREATIONAL AVALANCHE ACCIDENTS IN THE UNITED STATES

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ABSTRACT: Avalanche education has become widely available in the United States, and yet trained recreationists continue to comprise over a third of avalanche victims. Does avalanche education really make a difference? This study investigated the relationship between avalanche education and victim behavior in 344 recreational U.S. accidents, and found that victims with more avalanche training did in fact take fewer overall risks. However, all of the risk reduction in trained recreationists can be attributed to better mitigation measures taken by these victims. None of the risk reduction appeared to be the result of trained groups exposing themselves to less hazard. In fact, victims with basic formal training exposed themselves to more hazard than any other group, including those with no awareness of avalanches. In light of recent findings in decision science, these results suggest that behaviorist and naturalistic teaching strategies would be effective in improving avalanche education.

KEYWORDS: Avalanche accidents, avalanche education, human factors, decision making, heuristics, risk homeostasis, risk reduction, behavioral education, naturalistic decision making.

1. INTRODUCTION

On January 12, 1993, three skiers left the well-marked boundary of Vail Ski Area headed for the backcountry. The group had been warned of the dangerous avalanche conditions by the Vail Ski Patrol, but these skiers had just completed a two-day avalanche course and were confident that they could find safe skiing. Fresh slides were visible in the area, and a follow-up investigation indicated that the skiers probably experienced collapsing of the snowpack as they hiked. Despite obvious indications of dangerously unstable snow, the group chose to ski a steep, wind-loaded gully. The avalanche they triggered caught two of the skiers, burying and killing one of them.

Accidents like this one raise uneasy questions about the influence of avalanche education among recreationists. Does it really make them safer, or does it create overconfidence that lures them into more dangerous terrain?

This study investigated these questions in two ways: (1) by examining the relationships between avalanche victims' level of training and their behavior, and (2) by reviewing current research in decision science that applies to avalanche accident prevention among recreationists.

2. DESCRIPTION OF THE STUDY

To assess the effects of avalanche education on recreationists' behavior, I reviewed 546 avalanche incidents involving 1,050 recreationists. I looked at the hazards present at the time of the accident, the mitigation measures taken by the accident party, and the highest level of avalanche training present in each party.

To quantify the risks that led to each accident, I used a definition of risk from natural hazard analysis (Tobin and Montz, 1997):

$$risk = \begin{pmatrix} probability \\ of\ occurrence \end{pmatrix} \times (vulnerability). \qquad (1)$$

For each event, I assumed that the *probability of occurrence* was related to the number of indicators that a hazard existed at the time, expressed as a simple "hazard score." For example, an accident that occurred on an obvious avalanche path (a hazard indicator) that had been recently wind-loaded (a second indicator) during a time of high forecasted hazard (a third indicator) had a hazard score of 3. The higher the hazard score, the higher the probability of an accident occurring. Definitions of hazard parameters appear in **table A1** in the appendix.

Because I computed hazard scores from written accident accounts, the hazard score for any given incident may have been subject to various reporting biases. Such biases would arise from variations in rescuers' or victims' assessments and observations of the accident site. However, since six of the seven hazard indicators were verifiable by third-party accident reports and weather or avalanche forecasts, any reporting biases should be approximately uniform over all categories of victim training. The most potentially bias-prone hazard parameter, the presence of collapsing,

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does show an increased incidence with training (suggesting a possible reporting bias), but its overall effect on the relative risk values was minor.

For each event, I assumed that the *vulnerability* of the group was inversely related to the number of mitigation measures that the group took prior to the accident, expressed as a "mitigation score." For example, a group travelling with two or more people (one mitigation measure) wearing beacons (another measure) and exposing only one person at time (a third measure) had a mitigation score of 3. Definitions of mitigation parameters appear in **table A2** in the appendix.

Combining hazard and mitigation parameters with equation (1) gives a relative measure (or risk quotient *RQ*) of the risk taken by each group at the time of the (k^{th}) accident:

$$RQ_k = \frac{\Sigma h_{i,k}}{1 + \Sigma m_{i,k}} = \frac{HS_k}{1 + MS_k}, \qquad (2)$$

where $h_{i,k}$ are the hazard parameters, HS_k is the hazard score, $m_{i,k}$ are the mitigation parameters, and MS_k is the mitigation score, adjusted to avoid undefined *RQ* values for groups who took no mitigation measures.

To find the relative risk for each category of training (*c*), I combined the median hazard scores $M_{(HS)}$ and median mitigation scores $M_{(MS)}$ of all qualifying accidents involving victims with that level of training:

$$M_{(RQ)c} = \frac{M_{(HS)c}}{1 + M_{(MS)c}}. \qquad (3)$$

Note that *RQ* and $M_{(RQ)}$ are relative descriptive quantities used to compare the behavior of avalanche victims based on their training. They are not actual probabilities so they are not an absolute measure of risk. Definitions of the training parameters appear in **table A3** in the appendix.

The hazard and mitigation scores in this study came from avalanche accidents where the level of training of the victim(s) was known or could be reasonably inferred. Also, I considered only recreational accidents to minimize biases introduced by employment settings, highway incidents, in-area accidents or guided outings. Accident accounts came from the Westwide Avalanche Network, the Cyberspace Snow and Avalanche Center, records of the Colorado Avalanche Information Center, *The Snowy Torrents* (Logan and Atkins, 1996; Williams and Armstrong, 1984), and archived articles from various newspapers and journals. Results are from the winters 1972-73 to 1999-2000.

As with any analysis based on accident data, it is important to recognize that the results of this study apply only to a self-selected sample: those involved in avalanche accidents. Extending these results to other populations, such as all winter recreationists, may not be entirely valid.

3. RESULTS

Of the 546 recreational avalanche incidents that I reviewed, 202 involved victims with unknown training. In the remaining 344 cases, 30% of the groups had no training or awareness, 24% of the groups had a least one person with an awareness of the hazard, 31% had at least one person with basic formal training, and 14% had at least one person with advanced formal training. 90% of the avalanches were triggered by the victim or the victim's party, 6% were natural, and 4% had unknown triggers.

The frequencies of the seven hazard parameters for recreationists with no training appear in **figure 1**. Because these groups lacked even rudimentary hazard recognition skills, it is no surprise that most of their mistakes were made on high hazard days in obvious, recently wind loaded avalanche paths. A significant portion (29%) were buried or killed in terrain traps, and one in five groups had noticed recent avalanches, but were probably unable to recognize their meaning.

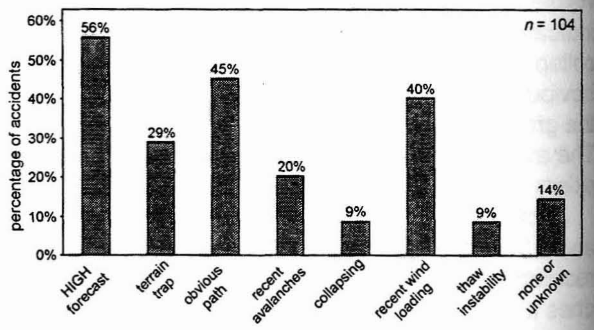

Figure 1. Reported frequency of hazard indicators for accidents involving recreationists with no avalanche training.

The frequencies of the seven hazard parameters for groups with avalanche awareness and formal training are shown in **figure 2.** These victims appeared more likely to heed forecasted conditions but surprisingly, they were not any less likely to avoid wind loaded avalanche paths. This may have been due to their higher level of skill at their sport and their tendency to seek out steeper and more hazardous slopes.

Hazard scores for each category of training appear in **figure 3**. Because each distribution of scores deviated significantly from normality (as

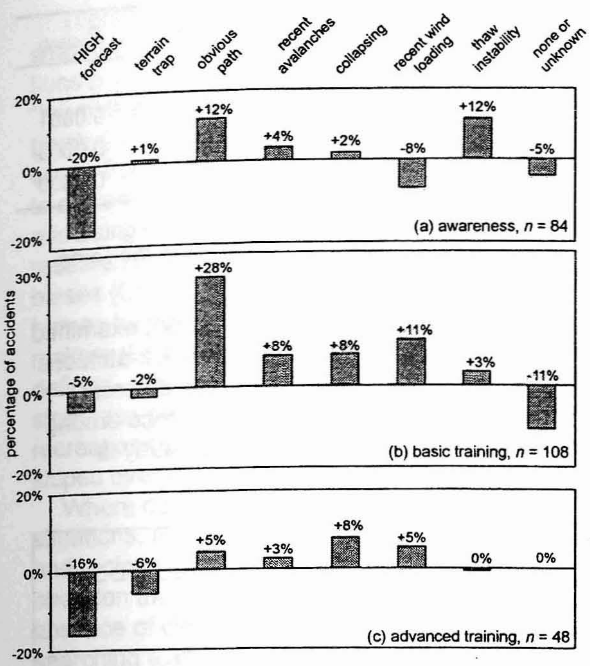

Figure 2. Reported frequency of hazard indicators for accidents involving recreationists with (a) awareness, (b) basic training, and (c) advanced training. All values are relative to those in figure 1.

indicated by the D'Agostino-Pearson test), I chose a non-parametric test (the Mann-Whitney tied rank, normal approximation) to assess differences in the distributions (Zarr, 1999). For each hazard score median, I computed the probability that its variation from the median score of the untrained group was due to chance (**table 1**). Surprisingly, hazard scores show no significant reduction with increased training, and for victims with basic formal training, hazard scores actually *increased*. Apparently, avalanche training had little influence on where these people chose to ski, snowmobile, etc., except in the case of those with basic formal

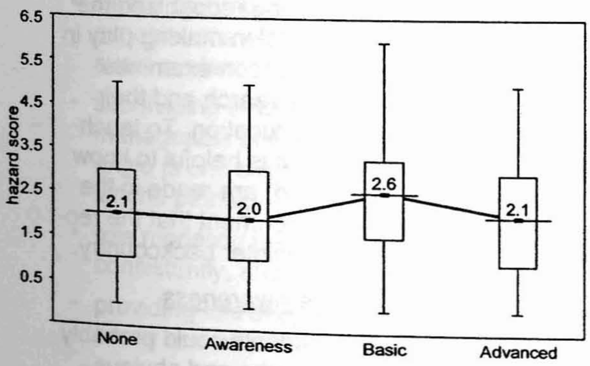

Figure 3. Hazard scores for avalanche victims by level of training. Boxes indicate the inter-quartile range and whiskers indicate maximum and minimum values.

Training	P_n	Q_{dev}	median	$P_{M\text{-}W(0)}$
none	0.359	1.0	2.1	-
awareness	0.269	1.0	2.0	0.958
basic	0.125	0.9	2.6	0.009
advanced	0.542	1.0	2.1	0.958

Table 1. Hazard score distributions in figure 3. P_n is the probability that the distribution is normal, Q_{dev} is the quartile deviation and $P_{M\text{-}W(0)}$ is the Mann-Whitney probability that the difference relative to the "no training" median is due to chance. Sample sizes are the same as in figures 1 and 2.

training, who exposed their group to more hazards than any other training category.

The frequencies of the six mitigation parameters for victims with no training appear in **figure 4**. Understandably, these recreationists failed to take any significant precautions other than not travelling alone, since they probably did not recognize the hazard. Other training categories (**figure 5**) show a uniform increase in almost all of the mitigation measures. Note that the improvement is not simply due to carrying more rescue gear; victims with more training were actually engaged in a higher incidence of behavioral mitigation (having a plan, minimizing exposure, maintaining contact) than victims with less training. Remarkably, the tendency to expose more than one person at time to the hazard remained significant at all levels, as has been noted in previous studies (Smutek, 1980).

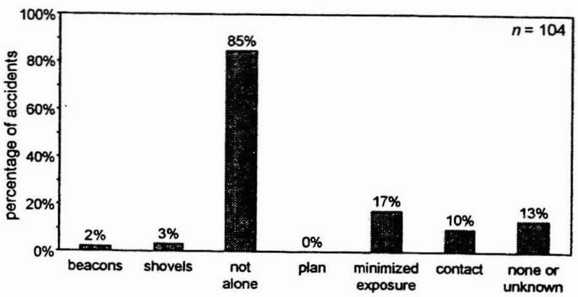

Figure 4. Reported frequency of mitigation measures for accidents involving recreationists with no avalanche training.

The correlation of improved mitigation measures with avalanche training appears more clearly in **figure 6**. Again, due to non-normality of the mitigation score distributions, I used a non-parametric method to asses differences between median scores. **Table 2** shows a very strong correlation between avalanche training and increased mitigation, particularly among recreationists with formal training.

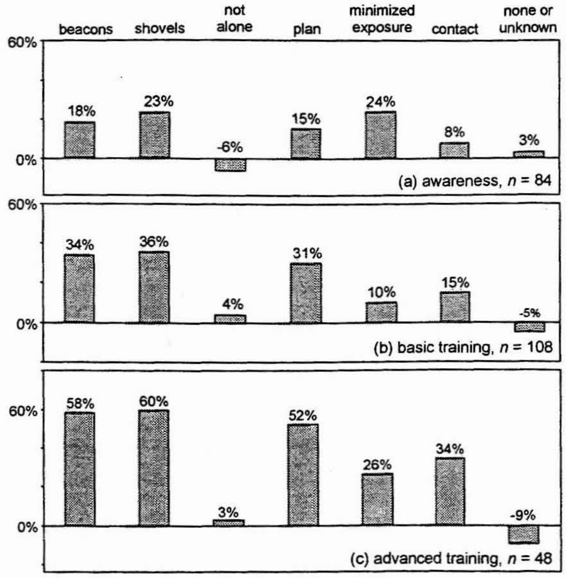

Figure 5. Reported frequency of mitigation measures for accidents involving recreationists with (a) awareness, (b) basic training, and (c) advanced training. All values are relative to those in figure 4.

By combining the median hazard scores and the median mitigation scores for each group in equation 3, we can calculate the median relative risk for each category of victim training. As shown in **Figure 7**, the overall risks taken by recreational victims does in fact decrease with training, suggesting that avalanche education correlates with a decrease in the accident rate among recreationists. It is interesting to note that the decrease is not linear; victims with basic training appear to have taken more risks than all other groups with training or awareness, but they still took fewer risks than victims with no training.

It's important to note that the decrease in relative risk among trained recreationists does not necessarily mean that avalanche education is the sole cause of the decrease. Factors not examined by this study include: (1) the relative risk attitudes between recreationists who seek out different levels of training, and (2) field experience among the different groups. Clearly, further study is needed in this area.

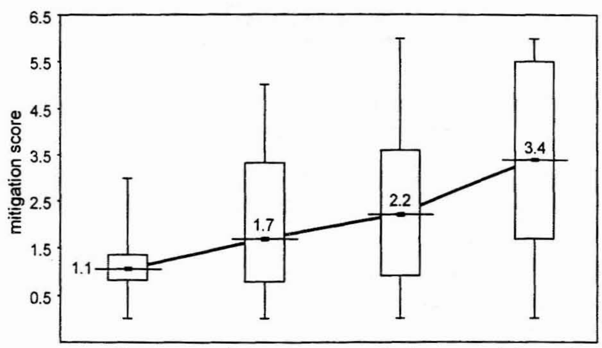

Figure 6. Mitigation scores for avalanche victims by level of training. Box-whisker parameters are the same as in figure 3.

Training	P_n	Q_{dev}	median	$P_{M\text{-}W(0)}$
none	0.001	0.3	1.1	-
awareness	0.083	1.3	1.7	0.0001
basic	0.038	1.3	2.2	0.0000
advanced	0.219	1.9	3.4	0.0000

Table 2. Mitigation score distributions for figure 6. Variables and sample sizes are the same as in table 1.

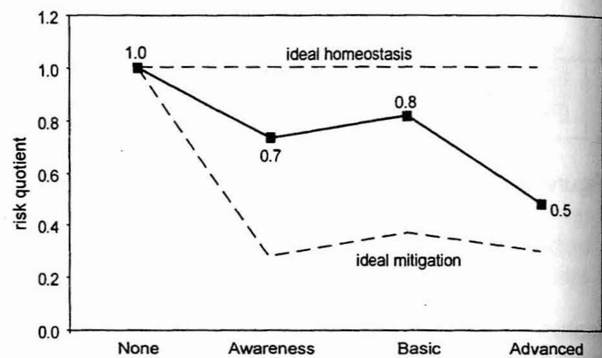

Figure 7. Risk quotients for avalanche victims by level of training. If education had no effect, the data would follow an ideal homeostasis model. If education was maximally effective at teaching precautions, the data would follow an ideal mitigation model.

4. DECISION MAKING AND AVALANCHE EDUCATION

Because the majority of avalanche accidents are caused by the victims (90% in this study), avalanche educators have long recognized the roles that education and decision making play in preventing accidents. This section examines recent findings in decision research and their implications for avalanche education. To teach decision making effectively, it is helpful to know how decisions (good and bad) are made in the complex and uncertain environment that the recreationist encounters in the winter backcountry.

4.1. Victims with Avalanche Awareness

By definition, these individuals could probably recognize most avalanche paths and obvious signs of instability, but they had little experience in making decisions in avalanche terrain.

Tversky and Kahneman (1974) have demonstrated that people in difficult and unfamiliar situations base their responses on simple rules, or "heuristics." In certain well-defined circumstances (such as estimating probabilities or drawing inferences from hypothetical data), heuristics can lead to systematic biases (Plous, 1993; Slovic, Fischoff and Lichtenstein, 1982). Since most heuristics research has focused on understanding these biases (Cohen, 1993), it has encouraged a view of human beings as marginally effective decision makers (Lopes, 1991; Kleinmuntz, 1985). But in ill-defined, real-world situations, heuristic decision strategies generally perform very well. For the recreationist, a heuristic might as simple as: "avoid slopes over 30° on high hazard days."

Where do heuristics come from? In unfamiliar situations, people readily adopt simple guidelines and recipes for action, and will typically not abandon them until they clearly fail. In the absence of clear rules, people are adept at searching a situation and their experience for patterns that suggest approximate rules, which they modify as required by the circumstances (Baron, 1988).

Given people's preference for heuristic reasoning in unfamiliar situations, it's no surprise that successful efforts aimed at increasing avalanche awareness favor simple messages (see, for example, Fredston, Fesler and Tremper, 1994; or Tremper, 1990). Munter (1997) has even proposed a numerical heuristic set for decision making in avalanche terrain.

If inexperienced recreationists prefer to use heuristics in avalanche terrain, are there ways to teach heuristics more effectively? Studies of how people learn show that effective instruction of motor and cognitive skills tends to follow a behavioral model (Davis and Davis, 1998). For the avalanche educator, this means:

- clearly communicating the specific skills and expectations of the course (e.g. recognize and avoid avalanche paths),
- subdividing skills and expectations into manageable tasks (e.g. measuring slope angle is one sub task in recognizing avalanche paths),
- role modeling the skill competently and consistently, and
- providing lots of opportunities for practice, with timely and effective feedback.

Behavioral approaches underscore the importance of field time in introductory avalanche education. According to the behavioral model, theoretical instruction beyond basic concepts will have little impact on the beginner's ability to execute heuristic-based skills (such as recognizing avalanche slopes). Perhaps most valuable is practice involving real examples of the problem, preferably in the environment where the skills will be applied. Current guidelines for avalanche education emphasize the importance of a field component (AAAP, 1999). Further arguments for an emphasis on field-based activities can be found in brain-based educational theory, which maintains that, under stress, people do what they have physically practiced rather than what they've been told (Jensen, 1998).

Avalanche educators can significantly reduce risky behavior among recreationists by simply building better mitigation skills among their students. The lower curve of **figure 7** indicates how the accident data would appear if victims had taken all six mitigation measures (MS=6) while keeping their hazard exposure the same. Clearly, a small improvement in mitigation habits yields a large gain in overall risk reduction.

<u>4.2. Victims with Advanced Avalanche Training</u>

At the other end of the training spectrum are recreationists with extensive training and field experience. Studies of experts in complex real-world situations suggest that these people do not, as a whole, use heuristic strategies (Dreyfus and Dreyfus, 1986). Instead, experts seem to recognize a situation as typical of a class of situations, mentally test a response, then act (Klein, 1998). The process of recognizing key features of a situation and recalling the appropriate response happens quickly and unconsciously, commonly being experienced by the expert as "intuition." This recognition-primed decision (RPD) model implies two important messages for non-experts: (1) its accuracy depends on the size of the experience base, and (2) the skill to recognize a situation as typical cannot be taught; it can only be learned.

For avalanche educators wanting to build expertise in their students, at least three teaching methods will be effective (Means et al., 1998):

- focused field exercises and well-designed scenarios covering a wide variety of situations (with quality feedback),
- diligent documentation by the students of their observations and decisions, and
- applying new theoretical concepts to show different ways to recognize familiar patterns.

A useful tool for providing feedback to advanced students is the *pre-mortem* exercise (Klein, 1998). Once a student has outlined the specifics of a plan (route, rescue, or other result of a decision), ask them to imagine their plan being executed perfectly, but failing. Having them examine possible sources of failure in a future context breaks their attachment to the plan's success in the present, allowing them to creatively explore new ways of perceiving situations they thought were familiar.

4.3. Victims with Basic Avalanche Training

In the middle of the training spectrum are recreationists who have taken one or two formal classes but who have limited experience in applying their avalanche knowledge. These recreationists are at something of a decision making crossroads: they may feel that heuristics are too restrictive but they lack the experience to employ expert decision making strategies. If they attempt to employ one anyway, their experience base may contain little more than "I high marked this slope last week-end and nothing happened." Such statements of "rationalized expedience" are common in avalanche accident accounts, even among trained victims (Fesler, 1980).

A perceptive instructor can mitigate the negative effects of an inappropriate expertise strategy by being alert to its use. Simply asking a student "What experience did you base that decision on?" can be an effective way of emphasizing the importance of having a broad experience base for critical decisions.

Inappropriate use of the RPD strategy is not the only obstacle faced by this class of recreationists. Recent developments in decision science suggest at least four others.

failure of stage models

Stage models lead a decision maker through logical steps to arrive at the best course of action. A simple example is: (1) define objectives, (2) collect relevant data, (3) evaluate alternatives, and (4) pick the best alternative. Stage models are attractive because they appear systematic and portable, and have proven themselves to be very powerful tools for solving problems when objectives are known (Lewis, 1997).

Unfortunately, experiments with people facing ill-defined problems (such as those found in avalanche terrain) suggest that stage models can be ineffective and even misleading. Klein (1998) and Beach and Lipschitz (1993) and others have found that in ill-defined problems, subjects will avoid using stage models even when they have had extensive training in stage-based decision methods. Furthermore, the heuristic or intuitive strategies they end up using often yield better results (Means at al., 1993).

A qualified exception to the ineffectiveness of stage models occurs in occupational situations or on guided trips where objectives are simple and clear within the group, or in cases where judgements must be justified to others. In these situations, stage-based decisions can be useful, but they are time-consuming and remain highly vulnerable to biases introduced by unstated personal objectives (Simon, 1990).

The serious limitations of stage models suggest that they be used sparingly, if at all, in most avalanche education aimed at recreationists. While stage models are temptingly easy to teach and highly appropriate for well-defined problems (Nickerson, 1994), there is little evidence to recommend them for use by recreationists in avalanche terrain.

recalibration

Recalibration occurs when an individual seeks out experiential feedback to re-adjust their expectations (Plous, 1993). Recreationists who have been conditioned by avalanche classes or the media to see avalanches as the "white death" that sweeps away the ignorant and imprudent are naturally drawn to recalibration activities when they see their friends take chances on dangerous slopes and nothing happens. By taking risks in avalanche terrain, these people are simply attempting to recalibrate their estimate of the avalanche risk to a more realistic standard. Accidents are a natural consequence of this strategy. The responsibility of avalanche educators here is clear: avoid "scare tactics" and present realistic estimates of accident probabilities.

ballistic reasoning

Dörner (1996) has demonstrated that people tend to protect their perception of their own competence, and will actively avoid evidence to the contrary, particularly in complex situations. This results in "ballistic behavior" where people appear to ignore obvious clues that they are making a mistake. In the accident described in the Introduction, the victims were warned of the hazard, they saw recent avalanches and experienced collapsing, and yet they chose to ski a wind loaded avalanche path ending in a terrain trap. Although it is tempting to view this behavior as "irrational," ballistic reasoning has an important function within the individual: it reduces confusion and builds confidence, allowing the person to move on to more challenging problems. Most people reserve ballistic behavior for non-critical situations where the benefits are great and the risks minimal. But when a situation is incorrectly perceived as low-risk, ballistic behavior is clearly self-destructive.

One solution to ballistic behavior is "external attribution;" basically, examining how circumstances or previous events lead to understandable errors. When students understand how they made their errors, they are less likely to make the same mistake again. An obvious message for the avalanche educator is to stress the limitations of heuristic reasoning at the outset, and be compassionate yet realistic about student mistakes and their consequences.

risk homeostasis

This theory maintains that education aimed at reducing accidents will be ineffective because individuals maintain an approximately continuous level of risk (Wilde, 1994). As people learn how to mitigate a hazard, they compensate by taking more chances while keeping their overall level of risk (their "target risk") the same. Research results supporting this theory can be found in driver safety training, drug education, AIDS awareness, and natural hazards education. In the risk homeostasis model, recreationists who have completed an introductory avalanche course may perceive their new knowledge as inherently decreasing their chances of being involved in an avalanche, and thus choose riskier slopes in an effort to maintain their target level of risk.

As shown in **figure 7**, he overall influence of education on relative risk among avalanche victims does not follow a purely homeostatic model. However, risk homeostasis probably plays some role in hazard exposure, particularly among recreationists with basic avalanche training. Methods for overcoming the effects of risk homeostasis are not clear; some educators have suggested that simply pointing out how people's target level of risk is set by social circumstances or advertising will be sufficient to reduce their risk level.

<u>4.4. The limits of education</u>

Can quality avalanche education, aimed at a motivated audience, completely eliminate avalanche accidents? Perrow (1984) has suggested that in highly complex systems, small events can combine in unforeseeable ways to create a baseline accident rate beyond which we cannot reduce our risk and still extract benefits from the experience. In this study, about 4% of the 344 accidents had a known hazard score of zero. Half of these resulted in fatalities. At the current fatality rate among recreationists, this corresponds to about 0.5 lives per year lost in the United States as an irreducible risk of recreation in avalanche terrain.

Because winter recreationists will always seek out steep and dangerous slopes, it's unlikely that fatality rates will ever approach the irredicible limit, regardless of improvements in avalanche education. But in 98% of fatalities, education has the potential to make a significant difference.

5. SUMMARY

In the 344 recreational avalanche accidents reviewed in this study, avalanche training correlated with:

- an overall decrease in the relative risk taken by victims at the time of the accident, and
- an increase in mitigation measures among victims.

Avalanche training did not appear to decrease the hazards that groups exposed themselves to, and in the case of victims with basic training, hazard exposure actually increased.

Recent findings in decision science suggest that victims use two strategies for decision making in avalanche terrain: heuristic (rule-based) and expertise. Heuristic skills can be developed by classical behavioral education methods and a strong emphasis on practical exercises. Expertise can be developed by demonstrating conceptual relationships with detailed scenarios and exercises combined with various feedback methods.

Ultimately, the real measure of avalanche education is the reduction of the accident rate. By carefully building on decision skills that students already have, educators can help recreationists reduce their risks without limiting their experience of the winter backcountry.

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7. DISCLAIMER

The views expressed are those of the author and do not necessarily reflect official positions of the National Outdoor Leadership School.

8. REFERENCES

AAAP. 1999. Recommendations and philosophy of the AAAP avalanche course guidelines. *Avalanche Review*, Vol. 18 no. 2, 4–5.

Bacharach, M. and Hurley, S. 1991. *Foundations of Decision Theory: Issues and Advances*. Basil Blackwell, Cambridge, MA, 1–38.

Baron, J. 1988. *Thinking and Deciding*. Cambridge University Press, Cambridge, UK, 16–28.

Beach, L. and Lipshitz, R. 1993. Why classical decision theory is an inappropriate standard for evaluating and aiding most human decision making, in *Decision Making in Action: Models and Methods*, G. Klein et al. eds. Ablex Publishing, Norwood, NJ, 21–35.

Cohen, M. 1993. Three paradigms for viewing decision biases, in *Decision Making in Action: Models and Methods*, G. Klein et al eds., Ablex Publishing, Norwood, NJ., 36–50.

Davis, J. and Davis, A. 1998. *Effective Training Strategies*. Berrett-Koehler Publishers, San Francisco, CA, 103–135.

Dörner, D. 1996. *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations*. Perseus, Cambridge, MA.

Dreyfus, H. and Dreyfus, S. 1986. *Mind Over Machine: The Power of Human Intuitive Expertise in the Era of the Computer.* Free Press, New York.

Fesler, D. 1980. Decision-making as a function of avalanche accident prevention, Assoc. Committee on Geotechnical Research, National Research Council, Canada, Technical Memorandum 133, Ottawa, Canada, 128–136.

Fredston, J. and Fesler, D. 1994. *Snow Sense, A Guide to Evaluating Snow Avalanche Hazard*, Alaska Mountain Safety Center, Anchorage, AK.

Fredston, J., Fesler, D. and Tremper, B. 1994. The human factor–lessons for avalanche education, *Proc. 1994 International Snow Science Workshop*, Snowbird, UT, 473–487.

Jensen, E. 1998. *Teaching with the Brain in Mind.* Assoc. for Supervision and Curriculum Development, Alexandria, VA.

Klein, G. 1998. *Sources of Power: How People Make Decisions.* MIT Press, Cambridge, MA.

Kleinmuntz, D. 1985. Cognitive heuristics and feedback in a dynamic decision environment, *Management Science*, 32(6), 680–702.

Lewis, H. 1997. *Why Flip a Coin?: The Art and Science of Good Decisions.* John Wiley and Sons, New York

Logan, N. and Atkins, D. 1996. *The Snowy Torrents: Avalanche Accidents in the United States, 1980-86.* Colorado Geological Survey, Special Publication 39, Denver, CO.

Lopes, L. 1991. The rhetoric of irrationality. *Theory & Psychology*, 1, 65–82.

Means, B. at al. 1993. Training decision makers for the real world, in *Decision Making in Action: Models and Methods*, G. Klein et al. eds., Ablex Publishing, Norwood, NJ., 307–326.

Munter, W. 1997. *3 x 3 Lawinen: entscheiden in kritischen Situationen*, Agentur Pohl und Schellhammer, Garmisch-Partenkirchen, Germany.

Nickerson, R. 1994. The teaching of thinking and problem solving, in *Thinking and Problem Solving*, R. Sternberg ed., Academic Press, San Diego, CA, 409–449.

Perrow, C. 1984. *Normal Accidents: Living with High-Risk Technologies*. Basic Books, New York.

Plous, S. 1993. *The Psychology of Judgement and Decision Making*. McGraw-Hill, New York, 222–229.

Simon, H. Alternative visions of rationality, in *Rationality in Action*, P. Moser, ed., Cambridge University Press, Cambridge, UK, 189–204.

Slovic, P., Fischoff, B. and Lichtenstein, S. 1982. Facts versus fears: understanding perceived risk, in *Judgement Under Uncertainty, Heuristics and Biases*, D. Kahnenman, P. Slovic and A. Tversky, eds. Cambridge University Press, Cambridge, UK., 463–489.

Smutek, R. 1980. Experience and perception of avalanche hazard, Assoc. Committee on Geotechnical Research, National Research Council, Canada, Technical Memorandum 133, Ottawa, Canada, 145–50.

Tobin, G. and Montz, B. *Natural Hazards: Explanation and Integration*. Guilford Press, NY., 282.

Tremper, B. 1990. Alternatives to boredom and bewilderment–report from the avalanche classroom, *Avalanche Review* 8(4), 3–6.

Tversky, A. and Kahneman, D. 1974. Judgement under uncertainty: heuristics and biases, *Science*, 185, 1124–1131.

Wilde, G. 1994. *Target Risk.* PDE Publications, Toronto, Ontario, 83–107.

Williams, K. and Armstrong, B. 1984. *The Snowy Torrents: Avalanche Accidents in the United States 1972-79.* Teton Bookshop Publishing, Jackson, WY.

Zarr, J. 1999. *Biostatistical Analysis*. Prentice-Hall, Upper Saddle River, NJ. pp. 87–89, 146-153.

9. APPENDIX

Table A1. Hazard parameters

high forecast	high or extreme forecast posted for the region
terrain trap	terrain feature that increased severity of the slide's effects
obvious path	distinct start zone, track or runout, or known path
recent avalanches	within last 48 hrs and seen by victim(s)
collapsing	cracking, or hollow sounds
obvious wind loading	obvious wind pillow or fresh cornice
thaw instability	above-freezing air temperatures or rain

Table A2. Mitigation parameters

beacons	worn by party
shovels	and probes carried by party
not alone	group size > 1
plan	group communication regarding route and use of islands of safety
minimized exposure	minimum number of people exposed
contact	visual or verbal contact with the person being exposed

Table A3. Education parameters

none	no training or awareness
aware	rudimentary awareness of hazard
basic	1-2 day avalanche course minimum
advanced	multiple trainings over several years, plus several years or more of backcountry experience.