Human factors in avalanche accidents: Evolution and interventions

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ABSTRACT: Errors in judgement have long been identified as key contributors to backcountry avalanche accidents. Our understanding of human error in avalanche terrain is improving, but our practical knowledge of how to combat its negative influences remains in its infancy. This article explores how the concept of human factors has evolved in the context of avalanche risk and examines the role of this concept in attempts to reduce avalanche accidents. We'll look at the implicit assumptions behind five intervention strategies and show how their strengths and limitations point the way to improved decision tools for avalanche terrain.

KEYWORDS: Avalanche accidents, human factor, human error, education, decision making

1 INTRODUCTION

The author of a best-selling mountaineering guide writes:

> *Avalanches constitute a source of danger which cannot be wholly guarded against. Yet, for the most part, the risk is extremely small if the mountaineer will take the trouble to use his intelligence and see where and under what conditions they are likely to occur. (p. 197)*

This advice – to be alert to signs of avalanche danger and to make intelligent choices – would be at home in any modern avalanche classroom. And it seems just as reasonable today as it probably did when it first appeared in Dent's classic text *Mountaineering* in 1892.

The difference is that today, most avalanche instructors would add the uncomfortable footnote that despite our best intentions, our decisions can be lead astray by emotions, beliefs, motivations and biases. Such factors work in the twilight world beneath our awareness and are subtle, insidious, and difficult to defend against. And like the Sirens of Greek myth, simply knowing about them is no guarantee against being lured into disaster.

In this short article, I hope to shed some light on the concept of the human factor and its role in avalanche accidents. I'll explore how our understanding of the concept has evolved, and how several assumptions have shaped our attempts to minimize its negative effects. I also hope to show how, by understanding the strengths and shortcomings of these assumptions, we can gain a deeper understanding of our own decisions in avalanche terrain and improve the ways we perceive and manage avalanche risk.

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2 HUMAN FACTORS AND AVALANCHES

In the same spirit as the advice of Dent (1892) in the opening quote, Rickmers (1905) described the value of simple decision strategies for maintaining humility in the face of avalanche risk. Richardson (1909) further developed the concept and gives simple guidelines that are not substantively different than those used by backcountry recreationists today. Lunn (1921) provided somewhat more detailed guidelines and Bilgeri (1929, as cited in Seligman, 1936) established the Six Points, perhaps the first practical decision framework for avalanche terrain.

In the post-war era, Atwater's (1954) Ten Contributory Factors established the foundation for avalanche forecasting based on quantitative rather than subjective factors. Perla (1970) cited the benefits of Atwater's perspective in combating subjective errors. McClung and Schaerer (2006) provide an excellent overview of the practical difficulties of balancing inductive and deductive factors in avalanche risk assessment.

In the 1970s and 1980s a broader awareness of human factors in avalanche accidents began to emerge. Contemporaneous with a rising awareness in other fields (Drury, 2008; Reason, 1990), LaChapelle (1975) famously discussed some of the psychological aspects of forecasting, and Smutek (1981) and Daffern (1981) discussed some of the psychological pitfalls of travel in avalanche terrain. Also during this period, discussions of judgement errors were becoming commonplace in accounts of avalanche accidents (e.g. Williams, 1975).

In the late 1970s, Doug Fesler and Jill Fredston were among the first to use the term "human factor" in their avalanche courses to differentiate subjective influences from more objective hazards in the snowpack, terrain, and weather – creating the so-called "avalanche triangle" (Fesler, 1981; Fredston, personal communication). The term appears to have gained wide acceptance following the publication of their book *Snow Sense* in 1984, which in later editions went on to become perhaps the most widely read book on avalanche safety. In subsequent years, human factors concepts became integral to most avalanche education, and contemporary instructional texts now routinely warn of human factors in avalanche terain (see, for example, Tremper, 2008 or McClung and Schaerer, 2006).

As is often the case in avalanche science, empirical studies appeared rather late in the evolution of field wisdom. Atkins (2000) presented categorical evidence of human factors in historical avalanche accidents in the United States, and McCammon (2000) examined correlations between avalanche training, hazard exposure, and precautionary behaviour in US historical accidents. McCammon's follow-up retrospective study of US accidents (2004) explored correlations between voluntary hazard exposure of victims and the presence of cues (so-called heuristic traps) known to trigger automatic behaviour. Adams (2004) reported compelling evidence from qualitative studies of avalanche professionals that identified human factors as a critical ingredient in many avalanche accidents.

Research on human factors in avalanche accidents, although admittedly quite preliminary, reflects a growing awareness that simply knowing about avalanche phenomena and rescue methods is not sufficient for preventing accidents. Some knowledge of human factors - their nature, mechanics and pitfalls - seems necessary to capture a more complete picture of avalanche accident prevention.

3 WHAT EXACTLY *ARE* HUMAN FACTORS?

Most avalanche people agree that human factors pose real dangers in avalanche terrain, but precise definitions of human factors are surprisingly difficult to find. More commonly, authors list specific attitudes, assumptions, motivations and biases that might cloud judgement in avalanche terrain.

For example, Fredston and Fesler (1999) list 14 human factors found to be major contributors to avalanche accidents. Similarly, Tremper (2008) lists 11 factors, McClung and Schaerer (2006) list 15, and Volken, Schell and Wheeler (2007) list 25 factors. Such lists are valuable from an educational perspective because most of these factors can be vividly illustrated by tragic case studies.

But as real-time diagnostic guides for making decisions in avalanche terrain, simple taxonomies have not proven particularly practical. As Tremper points out in the first (2001) edition of *Staying Alive in Avalanche Terrain*, human factors are not really distinct influences that are either present or absent in any particular situation. Rather, they are latent byproducts of how we make sense of the world, woven inextricably into our perceptions and judgements. The problem is not merely a philosophical one (Godfrey-Smith, 2003; McClung and Shaerer, 2006), but one that actively affects our perceptions of risk. Dekker (2006) explores this taxonomy problem relative to hindsight bias, confirmation bias, and cognitive dissonance, and compellingly argues that human error taxonomies are at least as much of a *post hoc* construct as a practical tool for improving decisions in real time.

This is not to say that human factors are not a useful concept. Compelling natural warnings of avalanche hazard do exist, and people are at times aware that their decisions are influenced by emotion. But from the perspective of pre-accident diagnosis, it appears that a concise definition of human factors will be elusive. And, as it is with avalanche hazard, simply knowing about human factors will not alone be sufficient to prevent future accidents.

4 COMBATING HUMAN FACTORS

We may not always be aware of it, but how we understand problems generally shapes our attempts to solve them. Contemporary avalanche culture seemingly embraces various assumptions of how accidents happen, with each philosophy engendering its unique solutions.

I present the models below without value judgement as I believe that each contains some element of truth. Due to space limitations only the most common models and solutions are presented here. Many other approaches are emerging in other fields that show promise but have yet to be implemented in the avalanche world.

4.1 The bad apple model

The Bad Apple Model (after Dekker, 2006) is based on the premise that most accidents involve individuals that, for some reason, have a personal disregard for safety. This model appeals to the folk wisdom that bad things happen to bad people, a principle more formally known as the fundamental attribution error (Ross, 1977), or the well-documented tendency for people to over-attribute outcomes to personality traits (Plous, 1993).

Supporting evidence for the Bad Apple Model derives mostly from the variance of risk tolerance in the population (Zuckerman, 2007; Lying, 2008; McCrea and Costa, 1997). Some people do seem to take certain risks more frequently, and trait psychology has enjoyed some success in message design for specific audiences (e.g. Stephenson and Southwell, 2006).

Nevertheless, the relationship between risk perception, social context, self-efficacy and true mitigation ability remains unclear.

Although this model is satisfying on a visceral level it has at least three difficulties: 1) accidents do not happen exclusively to individuals who fit the profile of risk takers, 2) the model neglects the profound influence of context (e.g. Lowenstein, 2001), and 3) the model offers little promise for accident reduction, since personality traits are unlikely to be altered by awareness campaigns, skills clinics, or avalanche classes.

4.2 The informed deliberator model

This model assumes that most accidents are the result of deliberate choices by victims that lacked sufficient knowledge or information about the hazard. This model has great appeal due to its optimism regarding human rationality and its congruence with long-standing normative decision models.

While there is little doubt that basic knowledge and practical skills are necessary for travelling safely in avalanche terrain, they are by no means sufficient to ensure sound decisions (Tremper, 2008; McCammon, 2004). Deviations from the ideal of rational deliberation are substantial, widespread, and well documented (see Bazerman, 2005 and Gigerenzer et al., 1999 for reviews) but nevertheless the paradigm of the informed deliberator remains common in many avalanche courses. An unfortunate consequence of this model is the knowledge gap that develops in at-risk communities as educational resources increasingly flow towards groups who already have a solid grasp of the hazard (Viswanath and Finnegan, 1996).

4.3 The introspection model

Given the limitations of rational deliberation for reducing avalanche accidents and the role of human foibles in causing them, it is tempting to embark on an introspective journey to identify personal weaknesses that may derail decisions. Tremper (2008) discusses the benefits of a reflective approach, and helicopter ski guide Roger Atkins emphasizes the value of personal knowledge and mastery in avalanche terrain (Tremper, 2008). In my own courses, students report an introspective exercise to identify personal heuristic trap sensitivity to be very helpful in their post-course risk management.

There is some evidence that this approach might be successful in preventing avalanche accidents. Cognitive behavioural interventions prescribe a systematic procedure for mitigating potentially dangerous emotional and behavioural patterns, and have demonstrated considerable success in a range of settings involving personal risk (Sue and Sue, 2008; Mennuti, Freeman and Christner, 2006). This approach to mitigating human factors has so far seen little application in avalanche education and appears worthy of further exploration.

4.4 The bounded deliberator model

Simon (1947) has famously described the fundamental limitations of our capacity to gather and process information, and we have learned a great deal about how these limitations introduce systematic error into our decisions (Gilovich, Griffin and Kahneman, 2002). The bounded deliberator model proposes that these errors can be minimized by procedures or algorithms which exclude purely subjective factors.

The bounded deliberator model generally takes one of two approaches. The first approach emphasizes procedure over content. Examples can be found at least as far back as Bilgeri's Six Points Method (1926, see Section 2), with more contemporary methods such as the Avalanche Triangle and Munter's 3x3 Method gaining popularity in recent years. Other decision constructs focus on the cognitive skills of the team, such as the crew resource methods adopted from aviation by some avalanche programs (Kern, 2001).

A second variation of the bounded deliberator model emphasizes both content and procedure. This approach, sometimes referred to as decision automation, performs very well in certain applications and in some cases has proven superior to expert performance (Dawes, 1979; Slovic and Lichtenstein, 1971). Several decision support systems have been developed for avalanche terrain (see McCammon and Haegeli, 2007 for a review) and while all appear to have the potential to prevent accidents, rigorous field evaluations have not yet been conducted.

Pitfalls in automated decision aid design are well known and well documented (e.g. Endsley and Kaber, 1999; Parasuraman and Mouloua, 1996). At least four limitations are of particular relevance to decision support in avalanche terrain: 1) Derivation of reliable regression models (on which decision aids are based) requires that meaningful non-event data is available for analysis. Collecting data from avalanche accidents that did not happen poses various phenomenological, methodological, and operational problems. 2) The wide range of conditions across which avalanche hazards exist makes it likely that accurate regression models will be complex and operationally cumbersome. 3) Accuracy of decision aids appears very difficult to communicate to users. Experts are often underconfident in decision aids and novices overconfident. In either case, biases can develop during use that lead to greater errors than if the decision aid was not used (Endsley et al., 2003). 4)

There appears to be a non-linear inverse relationship between decision aid accuracy and situational awareness of the operator. Even when carefully implemented, decision aids use can lead to automation induced complacency (MacDonald et al, 1995). In summary, decision aids show great promise but must be carefully designed to avoid introducing error.

4.6 The bounded vigilance model

This model attempts to avoid the problems of predictive decision aid design while recognizing that recreationists in avalanche terrain 1) are unlikely to consciously attend to a large number of information sources, and 2) are likely to exhibit behaviours that have significant elements of cue-based automaticity (Bargh, 2006; Wegner, 2003). The bounded vigilance model assumes that engaged awareness of a relatively small number of carefully-chosen cues will guide users to higher levels of situational awareness and more consciously formulated decisions regarding avalanche risk.

The Obvious Clues Method (McCammon, 2006) is a proof-of-concept prototype that implements the bounded vigilance model as a field decision guide. Based on established cues to avalanche hazard (e.g. Fredston and Fesler, 1999), the method is intended to serve as an avalanche hazard status display (Crocoll and Coury, 1990; Sarter and Schroeder, 2001; Endsley et al, 2003) rather than a predictive model. Framed in terms of past accidents and intended to trigger pre-mortem reasoning (Klein, 2001) and an accountability frame (McDonald et al, 1995), the method is implemented as simple acronym that, with minimal training, can be easily recalled and applied in the field.

Although preliminary, the Obvious Clues Method has provided a number of insights into implementation difficulties of the bounded vigilance model: 1) Communication of the pre-mortem frame has proven problematic in light of the common expectation for a predictive tool, 2) although minimal, the knowledge-based content of the instrument has proven difficult for some users who appear to be seeking a purely prescriptive device, and 3) enthusiasm about and early adoption of the method has lead to confusion between situational awareness concepts and avalanche prediction.

5 CONCLUSIONS

Historical avalanche literature shows that mountain travellers have been aware of the subjective hazards of avalanche terrain for a century or more, and that methods to implicitly reduce human factor influences date back to at least the 1920s. But only recently have we begun to explicitly explore the nature of the human factor, and our understanding of its role in avalanche accidents continues to evolve.

In recent years, innovative methods have emerged that attempt to mitigate the effects of the human factor in avalanche terrain. While it is too early to categorically identify any approach as being the most effective, it appears that all of these methods are consistent with field wisdom regarding avalanche danger and all have the potential to reduce avalanche accidents.

In closing, it is worth a reminder that there is nothing inherently safe about recreating on steep, avalanche-prone slopes. Avalanches themselves remain a complex and poorly-understood phenomenon, and subjective risk assessment is likely to remain an inevitable element of travelling in avalanche terrain. As a result, it seems unlikely that we are close to achieving practical devices that will point us to slopes that are categorically safe. But as we learn to identify key features of the interface between avalanche knowledge and the human factor, we can reach toward solutions that actively create safety through our choices rather than waiting to passively discover it in nature.

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