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## LEISURE & TOURISM | RESEARCH ARTICLE

# Rethinking the heuristic traps paradigm in avalanche education: Past, present and future

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**Abstract:** This paper will review the emergence and adoption of decision heuristics as a conceptual framework within the avalanche research and education community and demonstrate how this emphasis on the heuristic decision framework has anchored and was critical in redefining the discussion around avalanche accidents. This paradigm has been a critical and meaningful step in recognizing the importance of decision making in avalanche accidents. However, in an attempt to reduce the incidence of fatal accidents, the adoption of these ideas within the wider avalanche community has overlooked some clearly stated limitations within the foundational work of the heuristic decision frame. With respect to the concept of heuristic traps in conventional avalanche education, the concepts are poorly operationalized to the extent that they are vague about what exactly they describe. The result is that as presently framed, they are of negligible value to avalanche education that seeks its basis on the best available information. We end with a discussion, and a call to action to the avalanche research community, of how we could move towards resolution of these weaknesses and add value to prior work on human factor research. Our aim is not to disparage the seminal, paradigm shifting work by McCammon, but rather draw attention to how it has been operationalized and how the industry needs to move beyond this paradigm to see further gains in our understanding of avalanche fatalities.

**Subjects:** Sport and Leisure Studies; Outdoor Recreation; Quantitative methods in sport; Adventure and Lifestyle Sports; Sport Psychology; Thinking, Reasoning & Problem Solving

**Keywords:** risk and decision making; heuristics; backcountry skiing; avalanche accidents

### ABOUT THE AUTHOR

The authors are members of an international research consortium from the United States (Montana State University) and Norway (UiT The Arctic University of Norway). The broad focus of the group is to better understand the role of social dimensions and cognitive processes in high-risk decision making in avalanche terrain. Our approach is multi-disciplinary and encompasses snow science, psychology, behavioral economics, and policy studies. A key mission of the group is to provide new knowledge about the human factor in avalanche terrain and improve education to prevent loss of lives internationally.

### PUBLIC INTEREST STATEMENT

We make important decisions every day. Many are complex and filled with uncertainty. Sometimes we cannot know with certainty that our decisions are correct and will not result in harm to ourselves or our family, especially in settings that provide inadequate feedback on incorrect choices. Our paper reflects on prior research and expands our understanding of decision making using the lessons of backcountry skiing in avalanche terrain to help us think about how decisions are made, how we study them, and how we can improve our understanding of complex decision making.

## 1. Introduction

In the world's alpine countries approximately 250 people die in avalanches every year (Schweizer et al., 2009); most occur in North America and Europe (Statham et al., 2018). Most of these are “accidents of choice” where victims willingly place themselves at risk during recreational or professional activities such as backcountry skiing, snowmobiling, mountaineering, or professional avalanche mitigation (Greene et al., 2006).<sup>1</sup> The actual accident rate is likely to be decreasing over recent decades (e.g., Birkeland et al., 2017; Jekich et al., 2016).

Accidents are unfortunate incidents that happen unexpectedly and unintentionally. They are however, not random or unexplainable. The ultimate cause of an avalanche accident is failure of the snowpack and subsequent burial and/or injury or death. The precipitating factor that led to the failure, is that a person or group was in a position of risk with respect to avalanche hazard. Indeed, most avalanche accidents are “victim-triggered” (Avalanche Canada, 2018; Klassen et al., 2013) suggesting that some miscalculation preceded the event. Thus, the miscalculation is often due to a failure of decision processes that do not make full use of the victim's informational assets (Arnott, 1998).

Up to 53 factors have been identified for decision making in avalanche terrain making it a complicated matter even for experts (Landrø, Hetland et al., 2019; Landrø, Pfuhl et al., 2019). Additionally, avalanche related decisions are influenced by a range of external factors such as; environmental, organizational, and demographic. The examination of (failed) decision heuristics has dominated the inquiry into decision processes that result in avalanche accidents for the past two decades (Adams, 2005; Atkins, 2000; Fredston et al., 1994; Furman et al., 2010; Grímsdóttir & McClung, 2006; Haegeli et al., 2010; Haegeli & Strong-Cvetich, 2018; Hendrikx et al., 2016, 2014; Johnson et al., 2016; Mannberg et al., 2018a; Marengo et al., 2017; McCammon, 2000, 2002, 2004, 2009; McClung, 2002; Silverton et al., 2009; Statham et al., 2018; Tremper, 2008; Zweifel et al., 2012). In North America, the findings from these studies have been adopted in a wide range of avalanche education courses, awareness programs, magazine articles and online feature articles (Page, 2014, 2015). The avalanche education community has used the term “human factors” to include errors in judgement and social dynamics to explain the decision processes of why people die in avalanches (Atkins, 2000; Furman et al., 2010; Maguire, 2014; McCammon, 2002, 2004, 2009; McClung, 2002). However, it is a mistake to assume that only factors within the heuristic traps framework account for the full complexity of human factors in avalanche decision making.

This paper will review the emergence and adoption of decision heuristics within the avalanche research and education community and demonstrate how it has framed the discussion around avalanche accident causes. We then revisit the heuristics paradigm, highlighting some of the methodological deficiencies and how they could be addressed in order to enhance their explanatory power with respect to avalanche accidents. Finally, we present the research and education community with a proposal for future research to address these misunderstandings.

## 2. Background

### 2.1. Decision heuristics

Decision heuristics, mental processes used in decision making, are a fundamental way for people to reduce the effort of making a decision to arrive at satisfactory outcomes/solutions (Simon, 1956). There are two major streams of research within the field of heuristics (Bobadilla-Suarez & Love, 2018; Grüne-Yanoff & Hertwig, 2016; Raue & Scholl, 2018; Simon, 1990; Zajchowski et al., 2016). One is the “heuristic and biases” program—the study of systematic biases in decisions and, the “fast and frugal” program where heuristics are demonstrated to be a very effective and precise decision-making tool (Kahneman, 2003, p. 1449). Both recognize that people employ limited information, time, and/or processing power/cognitive resources to seek a satisfactory rather than optimal decision. (Gigerenzer & Todd, 1999; Grüne-Yanoff & Hertwig, 2016). Fast and frugal heuristics have been demonstrated to be as accurate or better than rational decision making

under some conditions. However, the heuristics and bias program also demonstrates circumstances under which heuristics trade off some accuracy for less effort (Tversky & Kahneman, 1974).

Both schools of heuristic thought share the constraint of bounded rationality: that people must make decisions within the limits of both their cognitive resources (knowledge, skills and abilities) and their environment (time and information). These natural limits to our decision-making powers and the available evidence about the objective state of the world are most important for decision making in avalanche terrain that is, there is a good deal of inherent uncertainty and the probabilities of snowpack failure are seldom absolutely known. Outcomes can only be subjectively, or at best probabilistically determined.

Heuristics simplify the amount of information individuals process by relying on memories based on past experience and simple algorithms to look for decision clues. They rely on less information, and they examine fewer alternatives (Shah & Oppenheimer, 2008). Heuristic decision making is not, in itself, a flawed decision process (Klein, 2015). However, we sometimes employ heuristics at the risk of making an even better decision (Frame, 2012; Gardner & Steinberg, 2005; Kahneman, 2011; De Martino et al., 2006; Slovic et al., 2005; Tversky & Kahneman, 1974, 1978). This may happen when there is a perception that time or cognitive load is constrained (Zhao et al., 1987), the consequence of a mistake is low (Sherman & Corty, 1984), or emotion overrides logic (Tiedens & Linton, 2001).

Avalanche terrain is a “wicked learning environment”, i.e., one in which feedback from decisions in the form of outcomes (i.e. avalanche incidents) are misleading or missing and asymmetric; poor decisions do not always result in avalanche incidents. Because so few avalanche accidents occur, feedback from our decision processes is not robust and so conclusions based on the analysis of failure must be considered circumspect. This is in contrast to a “kind” learning environment (Hogarth et al., 2015) that foster improved analytical decision making because feedback is valid and robust. Both environments foster experience-based heuristic decision strategies. However, while the heuristics produced by kind learning environments are formed by highly informational experiences, those derived from a wicked learning environment rely on non-informative or false experiences (i.e. false stability). Heuristic decision strategies may be highly productive and efficient in-kind learning environments but may be useless or even detrimental in avalanche terrain where rather than asking “what are the chances for this specific slope to avalanche” (Hogarth et al.), we substitute the question for an easier one: “how readily does an experience of an avalanche incident come to mind” (Hogarth et al.). This ease of retrieval guides our decision but critical corrective feedback is missing (Schwartz, 2010).

## **2.2. Avalanche accident analysis**

Avalanche accident reports have historically been examined along two lines—snowpack failure and human failure. The first approach looks to the physical structure of the snowpack to determine why an avalanche occurred. The second looks to the characteristics of victims and the decision process that placed them at risk. In this paper, we are mainly interested in the latter.

The factors analyzed in research on avalanche accidents can be divided into two broad groups: individual characteristics, e.g., gender, training, experience (Fredston et al., 1994; Grímsdóttir & McClung, 2006; Haegeli et al., 2010; Kobe & Jenkins, 1991; Sole et al., 2010) and behavioral factors, planning, avalanche forecast information-seeking behavior, communication, and decision making as skiers consider terrain constraints, changing weather, and snowpack conditions and express a range of adaptive behaviors in order to return home safely (Atkins, 2000; Jamieson et al., 2010; Johnson et al., 2016; McCammon, 2002, 2004; McCammon & Hägeli, 2004).

The two threads share a common finding that is; accidents are seldom caused by a lack of basic information regarding terrain, weather, and snowpack. Rather, accidents are a function of how

information about terrain, weather, and snowpack uncertainty is processed within the context of social or personal bias. The avalanche education community uses the term borrowed from industrial risk management “human factors” to mean errors in human judgement and the social dynamics that result in avalanche accidents.

Fredston and Fesler introduced the concept of human factors associated with avalanche accidents as early as 1994 (Fredston et al., 1994). Atkins followed with analysis of fatal accidents in North America during the 1990s and pointed to accidents being the result of human errors, with the great majority being considered as judgment errors rather than errors in skill or knowledge and identified a set of elements that he thought had contributed to the accidents (over-confidence, anti-authority, impulsivity, and invulnerability, group management, complacency, and poor communication) (Atkins, 2000).

McCammon analyzed 622 recreational accidents involving 1180 individuals that occurred in the US between 1972 and 2001 (McCammon, 2002).<sup>2</sup> Data were derived primarily from the Colorado Avalanche Information Center accident database (McCammon, 2002). He pointed to several heuristics skiers misapply while making decisions in avalanche terrain. He termed these “heuristic traps”. He was the first to apply these concepts as an effort to understand avalanche accidents (Furman et al., 2010).

Accident data can provide valuable information about the causes of an accident but it is a mistake to use it to develop any theory about decision-making processes exclusively. Many industries collect accident data as an effort to model accident causes but such data are the source of several inherent biases that can distort conclusions. Among these are: sampling bias, base rate bias, analysis bias, the group-wise comparison bias and the hindsight bias. McCammon acknowledged many of these issues in his exploratory work. Below, we define and discuss the implications of these limitations for avalanche accident analysis.

### 2.2.1. *Sampling bias*

Accident reports are a form of convenience sampling. They represent a biased sample based on available data rather than a representative sample that reflects the true range and frequency of behavior among all backcountry travelers. With respect to avalanche accidents, they describe only reported accidents—typically where rescue or medical treatment was involved. Caution should be exercised when generalizing those conclusions to a population outside the mainstream study population. For example, one should not draw generalizations to the whole of the backcountry skiing population from accident data; those involved in avalanche accidents represent a narrow and rare part of the spectrum of the skiing experience. Undoubtedly, avalanche accidents occur and go unreported because the outcome did not result in a fatality and so fall outside the sample/analysis. Furthermore, there are untold incidents of incorrect risk judgements that do not result in an avalanche being triggered and therefore provide no feedback. Luck rather than correct judgement prevails, but we do not obtain any data on what decision errors were made or how, so analysis is problematic if not impossible.

### 2.2.2. *Base rate fallacy/neglect*

Base rate fallacy/neglect is the strong tendency to favor specific diagnostic information while disregarding or underweighting general base rate probabilities (Kahneman & Tversky, 1973; Tversky & Kahneman, 1974). In the case of explaining decision failures that result in avalanche accidents we do not know the overall population frequencies for skiers and riders and the subgroups (i.e., how many men vs. women, trained vs. untrained, or the skill level of groups of skiers) that are touring in avalanche terrain. Without that data we cannot draw conclusions about groups as represented in the accident data. Suppose that 75 percent of all backcountry riders are males. This means that all things being equal such as education levels, experience, etc., we should expect to see more avalanche accidents among males because they are over-represented in the backcountry population. If many males show up in the accident data, it is not necessarily

evidenced that males take more risk than women or that they engage in more flawed decision making. Similarly, if individuals who seek avalanche training have a greater interest in backcountry touring, and therefore spend more days in the backcountry than do individuals who do not seek avalanche training, then unless the education gains can fully off-set the increased temporal exposure, we should expect to see more victims with avalanche training than without. A relatively higher rate of accidents among those with avalanche education should not lead us to the conclusion that those with education make worse decisions. The base rate problem is overcome by knowing the distribution for each category in the group—i.e. gender, training, number of days skiing, time in potentially hazardous terrain, etc., and calculating the probability of each group being in an accident.

Likewise, in order to assess the role and failure/success of heuristic-based decisions, we also need to know the true frequency (base rate) of the use of heuristics in the population. Just because certain heuristics appear to have been used in decision processes that led to accidents, it does not follow that the heuristic failure necessarily caused the accident. It could be that 99% of all skiers used the same heuristic decision processes so the heuristics will obviously appear in accident analysis.

### 2.2.3. Analysis bias

Accident report data is historical and often consolidated longitudinally. If some variable changes over time with respect to accident causes, we may miss the effects of that change if models either do not take into account these changes or they are not designed to adjust temporally.

In the McCammon data some of the cases happened 30 years before the analysis yet the analysis treats all accidents temporally the same. These shifts in the accident rate and causes are the source of some discussion in the literature (K. Birkeland, 2016; K. W. Birkeland et al., 2017; Jekich et al., 2016). Most important, the number of backcountry skiers and snowmobilers increased over the past two decades and so increased the pool available for accident victims. Snowmobile technology improved providing easier access to extreme terrain both for skiers and snowmobilers. Conversely, avalanche education became more widespread and available and more forecast centers meant there was more and higher quality information for the public. Greater media attention provided social rewards for skiing hazardous terrain (i.e. social cues). Safety equipment (beacons, airbag packs) meant recovery from an accidents increased survival/injury rates and so the accident may not appear in accident data (Haegeli et al., 2014; Ng et al., 2015).

Accidents are analyzed as ensembles rather than temporally (Wilde, 1988). The difference is that for phenomena that exhibit a varying trajectory over time, as with avalanche accidents (K. W. Birkeland et al., 2017), ensemble analysis frameworks are not satisfactory and discrete periods need to be identified and defined to explain how casual relationships may change over time.

### 2.2.4. Group-wise comparison bias

The nature of accident data is that one cannot always distinguish individual decisions within the group from collective decisions made by the group. Nor can it identify the role of specific individual traits of the decision maker (Adams, 2005). This is referred to as the level of analysis problem (Bartholomew et al., 2008). Behaviors are attributed to the group when in fact, one individual may have been instrumental in the decision that resulted in a group accident. Analysis and conclusions from accidents reports often confuse the level of analysis by conflating both individual and group behaviors within the same accident.

### 2.2.5. Hindsight bias

Hindsight Bias is the inclination to declare an event as predictable when it is analyzed after the fact. This occurs because during the debriefing, information becomes available to those involved in the accident and/or those involved in its analysis. Decisions that made sense at the time may look different in hindsight. For example, avalanches are notoriously difficult to predict with precision at a spatial and temporal scale relevant for back country users, but no responsible forecast would

pinpoint the slope and time of a future avalanche event. However, after an accident, the incidence of the slide is known with certainty, thereby triggering the response of flawed decision-making i.e. the group chose to ski an unstable slope. Backcasting the avalanche hazard or the weather data, there is a tendency to place blame of the accident on the existence of information that may not have existed at the time of the accident. It is therefore easy to mistakenly conclude certain causal relations in the decision process when in fact each step in that decision process may not have been knowable at the time of the decision.

### 3. Avalanche accidents and decision bias

#### 3.1. Heuristics and heuristic traps in avalanche accidents review

McCammon first identified four potential factors he suggested have influenced the decisions of avalanche victims: familiarity, social proof, commitment and scarcity (McCammon, 2002). He later developed the acronym “FACETS” that included two additional factors (i.e. Expert Halo and Acceptance). Although McCammon identified them as heuristic traps most of them are not heuristics by definition, but rather represent a bundle of decision biases or habits that may lead to decision errors. Briefly, McCammon’s description for each are:

**F= Familiarity**—our past actions to guide our behavior in a familiar setting. You’ve skied this slope a dozen times and it’s never slid, so despite obvious avalanche warning signs, you ski it again this time.

**A=Acceptance**—tendency to engage in activities that we think will get us noticed or accepted by people we like or respect. You want to impress others in the group, and this causes you to overlook warning signs.

**C=Consistency**—an initial decision about something, subsequent decisions are much easier if we maintain consistency with previous decisions. i.e. .... we’re determined to ski this slope no matter what ...

**E=Expert Halo**—trusting an informal leader, who ends up making critical decisions for the ski group that may not make the most prudent one.

**T= First tracks.** This refers to scarcity, the tendency to value resources or opportunities in proportion to the chance that you may lose them. For backcountry skiers, wanting to ski untouched powder adds to the excitement and so skiers may ignore avalanche warning signs.

**S= Social Facilitation** presence of other people enhances risk-taking by a subject. Fresh tracks on the slope encourage one toward safe conditions even through avalanche danger is high.

McCammon provided only cursory discussion of the derivation of FACETS in the footnotes (McCammon, 2004) depending primarily on the work of Tversky and Kahneman and their work on decision bias (Kahneman, 2011; Kahneman et al., 1982; Kahneman & Tversky, 1973; Tversky & Kahneman, 1978). FACETS is important to understand because it aids in the future operationalization and investigation of variables associated with each decision bias and provides in-depth explanation of the behavioral and psychological underpinnings of each. Table 1 summarizes the definitions of each FACET and provides an example of how it manifests in the backcountry skiing setting.

McCammon made a seminal contribution to the understanding of avalanche accidents by placing failure in the context of human factors, although he mislabeled several of them as decision heuristics and potential heuristic traps. For the most part he is describing biases, habits, behaviors, and group dynamics rather than computation-saving decision short cuts. His analysis is appropriate to the nature of the data available at the time and he is explicit about its limitations. However, like any emergent scientific idea there is room for improvement.



**Table 1. FACETS Definitions and Relevance**

<b>Decision bias</b>	<b>Definition</b>	<b>Backcountry Skiing Relevance</b>
Familiarity	Based on the <i>availability heuristic</i> (Kahneman & Tversky, 1973; Tversky & Kahneman, 1974) (see McCammon, 2004 footnote #4). Because of our limited cognitive abilities, we are better at remembering things that we have seen often, or recently, and we have a problem imagining things that we have not seen. Our ability to evaluate the frequency or probability of events is biased toward those we have experienced in the past.	In avalanche terrain we may fail to realize that even though we have never experienced an avalanche on a particular slope, we cannot assume it must be safe.
Acceptance	Inspired by research in psychology on social norms (Cialdini & Trost, 1998; Sherif, 1936), stereotypes e.g., (Brewer et al., 1972) and self-presentation (Baumeister, 1982). Humans are social beings, with both a physical and psychological need to belong to and be an accepted member of a social group. Group membership increases our chances for survival and success. Our dependency on the acceptance by others makes us prone to conform to social norms and adapt our behavior to what we think is expected from us.	While skiing, we may have reservations about a particular slope but may “give in” to peer or group pressure (gender or peer acceptance). Further, McCammon suggested that when females are present males may engage in riskier behavior in order to impress them.
Consistency <sup>1</sup>	Cognitive dissonance may evoke a negative emotional state we seek to avoid (Aronson, 1969, Aronson, 1992). Individuals have a need to maintain a reliable and positive self-image. If we do things that do not match our self-image, we tend to rationalize our behavior so that our perception of the situation changes in favor of our behavior and our self-image is left intact.	We may think of ourselves as a careful expert skier and make a decision to descend a risky slope. The decision may be ill-informed, but we maintain our self-defined expert status and later rationalize as being not as dangerous as initially thought if the slope did not fail. McCammon sought to apply this concept to groups as well as individuals.
Commitment	Behavior is sunk costs that cannot be recovered once spent. (Arkes & Blumer, 1985; Slesman et al., 2012; Thaler, 1980, Thaler, 1985, Thaler, 1999). If we make an investment of money or time in something (a plan, a relationship, an asset), we tend to continue investing in the face of failure because we would otherwise perceive the initial investment as a loss.	In avalanche terrain we may proceed with a plan to ascend a peak even though we agree that the plan is bad, because we made an initial investment of time and effort to start the ascent. In the process we may ignore weather, time, or hazard.
Expert halo	Related to the need to belong and gain acceptance in a valued group (the acceptance bias) and do so in such a way as to conform to and not destabilize the group (Cialdini & Goldstein, 2004). Also identified as “groupthink” in 1972 (Janis, 1972) where cohesive groups try to reach a common goal and maintain social cohesion. The desire to maintain membership in the group, the respect for authority, and the desire reach unanimity, may override the motivation to realistically appraise alternative courses of action.	The expert halo effect allows us to rationalize our group decision given the presence of an “expert” in the group. Some members (novices, women in mixed groups) may express self-doubt and lack of confidence and so tend to defer to a perceived expert. Fatigue, cold, fear may also cause deferment.

(Continued)

**Table 1. (Continued)**

<b>Decision bias</b>	<b>Definition</b>	<b>Backcountry Skiing Relevance</b>
Scarcity motivation (later known as the tracks heuristic in FACETS)	The increased value of potential loss of scarce resources that occurs due to competition (Cialdini, 2009 in McCammon, 2004, p. 6) (Lancaster, 1966; Mittone & Savadori, 2009). We overvalue and	Skiers refer to “powder fever” “first tracks” or “first descents” as rival goods and as they compete, they may engage in illogical behavior and miss or ignore avalanche warning signs.
Social facilitation	compete for rival goods and aggressively bid to consume them (Massey & Thaler, 2013). The presence of others improves and deteriorates humans’ performance (Uziel, 2007). Those who are confident in their skills may be emboldened when they are not alone and may take more risk when they have an audience (Zajonc, 1965). Results in an invalid selection and understanding of the available evidence	The presence of encountering others on a slope may act as a false demonstration of slope stability.

1Consistency and Commitment are not necessarily the same notions although McCammon conflates them in his findings and FACETS. See: I. McCammon (2004) (footnote #5).



Given the ubiquity of his work in avalanche education and the media, it is easily forgotten that McCammon (2002, 2004) is speaking of the narrow sample of fatal avalanche accidents using data available to him at the time. His work never suggested that these factors were predictive of accidents for all groups, and he is clear that he is not generalizing to the whole of the ski population suggesting their decision processes are not effective. Neither is he assuming to propose a definitive answer to the causes of avalanche accidents. He explicitly recognizes that there may be variables as yet unidentified that contribute to accidents. Below we propose to focus on the specification and measurement of FACETS in order to provide a well-understood foundation upon which researchers can build. Our suggestions are intended to begin to overcome the above-mentioned limitations of the existing FACTS paradigm.

### 3.2. Operationalization of heuristics in the avalanche community

Central to any research is the ability to operationalize variables—the process of strictly defining concepts with measurable factors. The process defines ambiguous concepts and allows them to be measured, empirically and quantitatively. Unless we are specific about how we measure our observations they cannot be replicated by others, in other settings, and under different conditions. Many of the terms used in FACETS can be more effectively operationalized and more easily understood for use in future research. We present two specific examples to illustrate:

(i) Familiarity—our past actions guide our behavior in a familiar setting. Relevant measures must include agreement on the definition of “familiar”. How many times must one visit a slope in order for it to be considered familiar; what is familiar about it—terrain, snowpack conditions; for whom was the slope familiar—all the group, one of the group? What is the scale of familiarity—is it run contingent, locality, or regional? Some of these terms can be placed on a scale that could indicate the degree of familiarity. Table 2 delineates variables for operationalizing “Familiarity”. Finally, familiar may be a synonym for habit—the process of automaticity and reduced deliberation, analysis, and volition. An example would be the use of the “normal” skin track approach to a slope regardless of snowpack conditions. These terms, if they are to be used in formal statistical analysis, need to be specified to the extent that the work can be replicated.

(ii) Social Facilitation—describes how the presence of other individuals encountered during the tour can both improve and deteriorate humans’ performance on different tasks. This can begin with the nature of the encounter—was it used to encourage competition and risk taking or was it used as an opportunity for information gathering or friendly social interaction. Was the interaction in person or observed? Where the people encountered known to the other group, if so, how? Social interaction effects are understood to be important in language learning, addiction treatment, and media viewing and can be measured using in-person field surveys.

Each of the decision biases discussed above are thought by their user to be rational in terms of making efficient and effective choices; rational people tend to frame their decisions in logical

**Table 2. Operationalization of Familiarity Heuristic**

Variable	Dimensions	Metric
Familiarity of slope	Number of times skied by a member of the group/individual	Frequency, scale (i.e. trail, slope, drainage basin).
	Experience	Real or virtual information (e.g., detailed guide, Goggle earth, maps and photos). In person or verbal report/web page. Time of year.
	Attributes of destination	Local trail head, clearly demarked trail, ease of access, recognizable place name.
	Temporal dimensions	Last visited, change in snowpack conditions.

terms (Tversky & Kahneman, 1986). They also appear to have face validity that is; they appear to explain reality in terms of how people arrive at decisions (Gigerenzer & Brighton, 2009; Gilovich et al., 2002; Kahneman et al., 1982; De Martino et al., 2006).

Even considering the caveats of sampling and population bias inherent in post hoc accident analysis, the importance of McCammon's (2002, 2004) work for raising awareness of the human in avalanche accidents cannot be overstated. His analysis contributed to an important discussion of the causes of avalanche accidents. As we discuss in detail below, however, despite the shortcomings identified above, FACETS is widely used in avalanche courses, awareness courses and cited in the popular media. While some information is generally better than no information, incorrect or conflated results may reduce future advancement in avalanche education and, lead to confusion and misunderstanding. Below, we suggest a course of action that would address these shortcomings.

### **3.3. The future: refining the heuristic paradigm**

The concepts contained in the FACETS framework are poorly operationalized to the extent that they are overly vague about what exactly they describe. This is largely a function of inadequate response by the research and education community to scrutinize and expand the research agenda rather than inherent weaknesses in McCammon's original exploratory research. The avalanche education community appears to misunderstand the structural issues associated with the findings. They fail to understand the base rate problem and so tend to overstate the occurrence of decision errors in every day backcountry touring. By focusing on the occurrence of errors (i.e. accidents) they fail to understand their true rate for the skiing population as a whole and apply heuristics unreservedly.

Few studies have attempted to explicitly test the role of FACETS in non-accident settings. Two studies (Furman et al., 2010; Marengo et al., 2017) that have sought to do so rely on hypothetical scenarios to analyze decision-making in avalanche terrain. We chose to examine these studies in order to illustrate both the difficulty of FACETS evaluation due to the lack of operationalized variables and the lack of agreement on how to evaluate FACETS. Both studies use discrete choice experiments to identify the effects of the heuristic traps and incorporate avalanche education as variables in the analysis.

Furman et al. (2010) recruited 266 participants from AIARE level 1 avalanche courses in the United States and asked them to state the likelihood that they would ski a set of runs with a slope of 33°. Each participant read six descriptive vignettes that varied systematically in terms of avalanche hazard (low, moderate, considerable, high), and the presence of various FACETS. Below is an example question:

You are part of a group that is out for a day of backcountry skiing. The avalanche forecast states that the avalanche hazard is HIGH. You have chosen to ski terrain that YOU HAVE SKIED MANY TIMES BEFORE. You have a HIGH commitment to skiing the line you intend to ski. You are in a MIXED-gender group. There IS a clearly defined leader in your group suggesting you ski the slope. During your approach you saw NO other parties. You plan to ski an UNTRACKED slope. (Furman et al., 2010, p. 459)

They employed hierarchical linear regression to test for the effects of FACETS. The first level model tested for effects of avalanche forecast and FACETS, while the second level model controlled for differences in individual risk propensity using the stimulating-instrumental risk inventory (Zaleskiewicz, 2001). Their results show that the most important factor for a high stated probability to ski the slope is the avalanche danger rating. However, they also find that if the participant was told that they had skied in the area many times before (i.e. Familiarity), was committed to the line (i.e. Consistency), were touring in a group with a clear leader who wanted to ski the line (i.e. Expert Halo), had planned to ski an untracked slope (i.e. First Tracks), and met others on the approach (i.e. Social Facilitation) they stated a higher probability of skiing the slope. They found no effect of

touring in a mixed gender group (i.e. Acceptance). All participants in this study were currently enrolled in a level one avalanche class so the explicit role of education was not tested.

A second study conducted in Northern Italy tested the effects of two heuristic traps (familiarity and tracks) (Marengo et al., 2017). Participants were recruited online (N = 376) and were presented with four vignettes describing ski runs that differed systematically in terms of avalanche hazard, slope, familiarity with the area, presence of tracks, and availability of avalanche equipment. An example scenario appears below:

You are out for a day of backcountry skiing and you have just reached the slope you intended to ski. Please rate the likelihood you would actually decide to ski the slope given the following characteristics:

The forecasted avalanche danger for the area is HIGH.

Your familiarity with the slope is LOW, YOU HAVE NEVER SKIED IT BEFORE.

The slope is already TRACKED.

The slope is QUITE STEEP (INCLINATION BETWEEN 35 AND 40 DEGREES).

You HAVE an avalanche beacon, a probe and a shovel as part of your equipment. (Marengo et al., 2017, p. 80)

The results of their regression analysis indicate the most important factor for participants' choice to ski or not ski a slope is the forecasted avalanche hazard. Participants also stated a lower likelihood to ski a slope at steeper angles or if no avalanche equipment was available. They find that familiarity with the skiing area and pre-existing tracks on the slope increased the stated likelihood to ski the run (Marengo et al., 2017).

The goal of both research efforts was to test for the presence and relative importance of FACETS as operationalized separately by the two research groups. The results indicate that a set of well-articulated variables may play some role in the decision process. However there was a set of multiple variables contained in each scenario such that it is difficult to know what if any stand out as important drivers of the decision outcome.

Both projects sought to lend greater specificity to the FACETS variables. The fact that they both identified the forecasted avalanche hazard as being of primary importance in the go/no go decisions suggests that knowledge of a forecast plays an important role in the ski decision. This is a fundamental skill that is taught at the introductory classes. Both research efforts found evidence for the familiarity heuristic but, both studies left it undefined. Future surveys would benefit from exploring the concept of familiar terrain as discussed above.

Both also found evidence for the scarcity heuristic although each appear to have defined it differently. The first defined it (in the negative) as *During your approach you saw NO other parties. You plan to ski an UNTRACKED slope* (Furman et al., 2010). The other as: *The slope is already TRACKED* (Marengo et al., 2017) but makes no mention of meeting other parties—leaving out part of the definition of the variable as defined by McCammon. This points to the difficulty of having no generally accepted definition of the FACETS. Scarcity-related behavior could be initiated when one ski party meets another, it could be when they see tracks on the intended slope, it could be when both or neither occur. Does the number of tracks relative to the area of the slope matter? Does the ski quality for the day matter to feelings of scarcity?

Both studies demonstrate how progress toward operationalization of FACETS can proceed and how surveys of the general skiing population can elucidate behaviors and decisions when properly designed. Certainly there are differences between in-person surveys of daily tours and machine-based surveys but both can be used effectively to expand our knowledge of the decision processes of the skiing population (Chamarro et al., 2013; Dohmen et al., 2011; Fitzgerald et al., 2016; Furman

et al., 2010; Grímsdóttir & McClung, 2006; Haegeli et al., 2014, 2012; Haegeli & Strong-Cvetich, 2018; Harvey et al., 2002; Hendrikx & Johnson, 2014, 2016; Hendrikx et al., 2016, 2013; Hendrikx et al., 2014; Johnson et al., 2016; Mannberg et al., 2018b; Marengo et al., 2017; Saly et al., 2020; Stamberger et al., 2018). Beyond the various survey designs, the experimental methods of psychology offer a valuable methodological approach to empirically test hypotheses about human factors in decision making in avalanche terrain. They permit the study of causal relations between two variables while controlling for extraneous factors in order to clarify the principle drivers of the decision process.

We suggest a next step in skier survey design, analysis, and implementation could be for the research community to build a depository of questionnaire items to be used in surveys aimed at refining FACETS and other human factor frameworks. This is a common practice among social scientists in multiple subject areas (i.e. crime reports, health and dietary practices, learning outcomes, political surveys and polls) where dimensions of a variable that could be measured in numerous ways are standardized across research questions.

For example, demographics, the statistical data relating to the population and particular groups within it, can include age, gender, employment status, group size, participation in outdoor activities, and skills (i.e. years skiing; experience in backcountry skiing; skill level with terrain management, avalanche transceiver, and snowpack assessment; avalanche education level) (Atkins, 2000; Bergeron et al., 2016; Harvey et al., 2002; Jamieson et al., 2010; Jekich et al., 2016; Johnson et al., 2016; McCammon, 2002, 2004, 2009; McCammon & Hägeli, 2004; Simenhois & Savage, 2010). Likewise, a set of standardized decision framework questions could be formulated for use in decision analysis research aimed at skiers and riders. Such a coordinated effort would help us better understand the role of heuristics/human factors in decision making in avalanche terrain.

Standardized questionnaires produce some advantages that include (Kelley et al., 2003):

- (1) **Reliability**—refers to consistency in how a question is asked and answered. Reliable questions measure a variable the same each time. A simple example is measuring body weight using the same metric (i.e. kilograms).
- (2) **Validity** refers to how well a questionnaire can measure what it is intended to measure. Using the example above, all scales used to measure weights are accurate relative to each other. That is, a weight registered on one scale will be the same ( $\pm$ ) on another scale.
- (3) **Sensitivity** is how well the questionnaire can discriminate between differences in respondents. When measuring body weight one kilo may be sensitive enough.
- (4) **Objectivity** is the concept that all researchers can independently verify the measurement statements of others.
- (5) **Quantification** is the manner in which a variable is measured. Quantification may be at the nominal, ordinal, interval, or ratio level.

Other features of a question bank aimed to measure standardized concepts include efficiency for researchers when searching for methods to measure a variable. Finally, multiple findings can be compared spatially and temporally if methods and measures are standard.

In order to address the move toward a standard question bank for investigation of the multiple aspects of the social side of snow science we have designed and will launch a research-specific website for citizen scientists. The site, housed in the Montana State University Snow and Avalanche Laboratory (<http://www.montana.edu/snowscience/researchaid.html>), will lead those not trained in social science research through the process. One feature of the site will be a battery of standardized questions for investigating questions related to human dimensions of decision making in avalanche terrain.

### 3.4. Need for this work

A credible question(s) from the education community could be: What are the costs of not refining the FACETS paradigm? If the goal is to avoid avalanche accidents what is the harm in potentially misunderstanding the causes?

First, it potentially skews the perception and curriculum of avalanche education by misplacing emphasis on behaviors that may not play an important role in accidents while other aspects may be deemphasized. At the same time, refinement could yield greater insights into the role of human factors in accidents and lead to more highly focused lessons for backcountry travelers. One specific example of this, is the recent work that points towards the increased age of avalanche fatalities in the USA in recent decades, which suggest a change in the critical target audience of avalanche educators (Peitzsch et al., 2020).

Second, it could weaken the role of education in the reduction of accidents. Clearly education is efficacious for teaching various skills and knowledge of avalanche terrain and there is no logical reason it should not do so for human factors (Gosbee & Anderson, 2003). DiGiacomo suggests that “letting the results of conditional statistical analysis (i.e. wrong results) morph into habits and rules of thumb is potentially ... dangerous ... Once these take hold, they become embedded in avalanche education programs and materials, and ultimately in the decision-making process of individual users” (DiGiacomo, 2006). As they do, they may be very difficult to change due to organizational inertia and culture.

Finally, drawing the wrong lessons from avalanche accidents may occlude important underlying emergent patterns in accidents and skier behavior in general. It may be that the FACETS framework is not the most effective one to use for analysis. An alternative framework could yield more effective insights. Framing around FACETS encourages us to use language and interpretations centered around decision failure when in fact, it could be that many of the decisions that resulted in accidents were attributable to a very different set of circumstances.

### 4. Summary and future directions

Over the last four decades, the avalanche accident investigation literature has evolved from a relatively one-dimensional snowpack assessment perspective to a comprehensive approach based on snowpack stability assessment and terrain features as well as an improved understanding of decision processes, communication skills, and other behavioral dynamics of skiers and riders. Quality avalanche education courses reflect those developments.

Methods have evolved from descriptive surveys to incorporate user-friendly GPS tracking technology and innovative social science theory (Furman et al., 2010; Haegeli & Strong-Cvetich, 2018; Hendrikx & Johnson, 2014; Hendrikx, Shelly, Johnson, 2016). However, even the most sophisticated methods suffer from shortcomings; primary among them is convenience or non-probability sampling that constrains generalization to the whole of the ski population. This is particularly acute when highly biased samples, such as accident data, are used to educate the overall ski population about avalanche accidents. While the heuristics paradigm was timely and seminal for this community it has been adopted with little critical review and analysis for more than 15 years.

The next phase of research could follow Maguire’s (2020) framework of formulating an integrative approach for avalanche education where multiple dimensions of complex decisions in avalanche terrain are better understood as a set of parallel and sometimes competing processes. Table 3 identifies and briefly defines her concepts.

The general acceptance of the heuristic traps frame in avalanche education is problematic given the lack of peer review in scientific journals, the lack of clear operationalization of its key variables, and so risks being misunderstood and misapplied in avalanche education. Backcountry skier behaviors are a cause for some accidents, but they cannot effectively be understood treating them as a homogeneous group across time and space. Rather, skiers, like

**Table 3. Integrative Cognitive Processes for Decision Making**

Perception	Sorting out the important data from “noise”
Attention	Directed focus on the problem at hand
Memory	Ability to store and activate knowledge from past experience
Reasoning	Employing logic in the face of ambiguity
Decision Making	Use all available data to make a decision
Goal Conflicts	Recognizing and satisfying multiple sometimes competing goals
Tradeoffs	Recognizing and weighing that all decisions entail tradeoffs

the accidents they are involved in, can be segmented using demographic and psychographic attributes. Behavioral concepts such as positionality may prove useful (Mannberg et al., 2018a)

The study of accidents as the central consequence of backcountry skiing is problematic. The fact is most skiers never experience an avalanche incident and the accident rate seems to be decreasing for all types of users. More attention should be placed on the successful implementation of best practices and researchers would be wise to move from emphasis on failure to emphasis on success and look beyond the heuristics traps paradigm.

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#### Notes

1. Winter backcountry travelers may include skiers, snowboard riders, snowmobilers, and those traveling on snowshoes. In the interest of brevity, we use backcountry skiers as a catch all phrase to represent all potential backcountry winter recreationists.
2. McCammon later increased his number of cases to 715 and included years up through 2003.
3. Most avalanches occur on slopes between 35 and 45 degrees with the “bulls eye” being 38 degrees ((Tremper, 2008).

#### References

- Adams, L. (2005). *A systems approach to human factors and expert decision-making within Canadian Avalanche Phenomena* [MALT Thesis]. Royal Roads University, Victoria, BC, 284.
- Arkes, H. R., & Blumer, C. (1985). The psychology of sunk cost. *Organizational Behavior and Human Decision Processes*, 35(1), 124–140. [https://doi.org/10.1016/0749-5978\(85\)90049-4](https://doi.org/10.1016/0749-5978(85)90049-4)
- Arnott, D. (1998). *A taxonomy of decision biases*. Monash University, School of Information Management and Systems, Caulfield.
- Aronson, E. (1969). The theory of cognitive dissonance: A current perspective. In *Advances in experimental social psychology*. Leonard Berkowitz, ed. (Vol. 4, pp. 1–34). Elsevier.
- Aronson, E. (1992). The return of the repressed: Dissonance theory makes a comeback. *Psychological Inquiry*, 3(4), 303–311. [https://doi.org/10.1207/s15327965pli0304\\_1](https://doi.org/10.1207/s15327965pli0304_1)
- Atkins, D. (2000). *Human factors in avalanche accidents* [Paper presentation]. The International snow science workshop, Big Sky, MT.
- Avalanche Canada, A. (2018). *General analysis of trends and factors causing avalanches*. Canadian Avalanche Association <http://old.avalanche.ca/cac/library/avalanche-accidents>



- Bartholomew, D. J., Steele, F., & Moustaki, I. (2008). *Analysis of multivariate social science data*. Chapman and Hall/CRC.
- Baumeister, R. F. (1982). A self-presentational view of social phenomena. *Psychological Bulletin*, 91(1), 3. <https://doi.org/10.1037/0033-2909.91.1.3>
- Bergeron, A., Johnson, J., & Hendriks, J. (2016). *An analysis of avalanche accident causes: Ski area professional patrol* [Paper presentation]. The International Snow Science Workshop, Breckenridge, CO.
- Birkeland, K. (2016). *U.S. avalanche fatality trend is flat for the past 22 seasons*. U.S. Forest Service. <https://avalanche.org/2016/06/27/2016627us-avalanche-fatality-trend-is-flat-for-the-past-22-seasons/>
- Birkeland, K. W., Greene, E. M., & Logan, S. (2017). In response to avalanche fatalities in the United States by Jekich et al. *Wilderness & Environmental Medicine*, 28(4), 380–382. <https://doi.org/10.1016/j.wem.2017.06.009>
- Bobadilla-Suarez, S., & Love, B. C. (2018). Fast or frugal, but not both: Decision heuristics under time pressure. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 44(1), 24.
- Broverman, I. K., Vogel, S. R., Broverman, D. M., Clarkson, F. E., & Rosenkrantz, P. S. (1972). Sex-role stereotypes: A current appraisal. *Journal of Social Issues*, 28(2), 59–78. <https://doi.org/10.1111/j.1540-4560.1972.tb00018.x>
- Chamarro, A., Marti, G., Rovira, T., Carola, F., & Fernández-Castro, J. (2013). *Risk appraisal and decision making in front of avalanche risk: A pilot study with backcountry skiers* [Paper presentation]. Proceedings of the international snow science workshop, Grenoble-Chamonix Mont-blanc, France.
- Cialdini, R. B. (2009). *Influence: Science and practice* (Vol. 4). Pearson education Boston.
- Cialdini, R. B., & Goldstein, N. J. (2004). Social influence: Compliance and conformity. *Annual Review of Psychology*, 55(1), 591–621. <https://doi.org/10.1146/annurev.psych.55.090902.142015>
- Cialdini, R. B., & Trost, M. R. (1998). Social influence: Social norms, conformity and compliance.
- De Martino, B., Kumaran, D., Seymour, B., & Dolan, R. J. (2006). Frames, biases, and rational decision-making in the human brain. *Science*, 313(5787), 684–687. <https://doi.org/10.1126/science.1128356>
- DiGiacomo, N. (2006). *Toward better decision-making: Recognizing the effect of selection bias in the analysis of recreational avalanche data* [Paper presentation]. International Snow Science Workshop, Telluride, CO.
- Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., & Wagner, G. G. (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association*, 9(3), 522–550. <https://doi.org/10.1111/j.1542-4774.2011.01015.x>
- Fitzgerald, K. R., Kay, J. M., Hendriks, J., & Johnson, J. (2016). *Backcountry and sidcountry users: An intercept survey approach* [Paper presentation]. International Snow Science Workshop, Breckenridge, CO.
- Frame, J. D. (2012). *Framing decisions: Decision-making that accounts for irrationality, people and constraints*. John Wiley & Sons.
- Fredston, J. A., Fesler, D., & Fesler, D. (1994). *Snow sense: A guide to evaluating snow avalanche hazard*. Alaska Mountain Safety Center, Incorporated.
- Furman, N., Shooter, W., & Schumann, S. (2010). The roles of heuristics, avalanche forecast, and risk propensity in the decision making of backcountry skiers. *Leisure Sciences*, 32(5), 453–469. <https://doi.org/10.1080/01490400.2010.510967>
- Gardner, M., & Steinberg, L. (2005). Peer influence on risk taking, risk preference, and risky decision making in adolescence and adulthood: An experimental study. *Developmental Psychology*, 41(4), 625. <https://doi.org/10.1037/0012-1649.41.4.625>
- Gigerenzer, G., & Brighton, H. (2009). Homo heuristicus: Why biased minds make better inferences. *Topics in Cognitive Science*, 1(1), 107–143. <https://doi.org/10.1111/j.1756-8765.2008.01006.x>
- Gigerenzer, G., & Todd, P. M. (1999). Fast and frugal heuristics: The adaptive toolbox. In *Simple heuristics that make us smart* (pp. 3–34). ABC Research Group. Oxford University Press.
- Gilovich, T., Griffin, D., & Kahneman, D. (2002). *Heuristics and biases: The psychology of intuitive judgment*. Cambridge university press.
- Gosbee, J., & Anderson, T. (2003). Human factors engineering design demonstrations can enlighten your RCA team. *BMJ Quality & Safety*, 12(2), 119–121. <https://doi.org/10.1136/qhc.12.2.119>
- Greene, E., Wiesinger, T., Birkeland, K., Coléou, C., Jones, A., & Statham, G. (2006). *Fatal avalanche accidents and forecasted danger levels: Patterns in the United States, Canada, Switzerland and France* [Paper presentation]. Proceedings of the International Snow Science Workshop, Telluride, CO.
- Grímsdóttir, H., & McClung, D. (2006). Avalanche risk during backcountry skiing—An analysis of risk factors. *Natural Hazards*, 39(1), 127–153. <https://doi.org/10.1007/s11069-005-5227-x>
- Grüne-Yanoff, T., & Hertwig, R. (2016). Nudge versus boost: How coherent are policy and theory? *Minds and Machines*, 26(1–2), 149–183. <https://doi.org/10.1007/s11023-015-9367-9>
- Haegeli, P., Falk, M., Procter, E., Zweifel, B., Jarry, F., Logan, S., Kronholm, K., Biskupič, M., & Brugger, H. (2014). The effectiveness of avalanche airbags. *Resuscitation*, 85(9), 1197–1203. <https://doi.org/10.1016/j.resuscitation.2014.05.025>
- Haegeli, P., Gunn, M., & Haider, W. (2012). Identifying a high-risk cohort in a complex and dynamic risk environment: Out-of-bounds skiing—an example from avalanche safety. *Prevention Science*, 13(6), 562–573. <https://doi.org/10.1007/s11121-012-0282-5>
- Haegeli, P., Haider, W., Longland, M., & Beardmore, B. (2010). Amateur decision-making in avalanche terrain with and without a decision aid: A stated choice survey. *Natural Hazards*, 52(1), 185. <https://doi.org/10.1007/s11069-009-9365-4>
- Haegeli, P., & Strong-Cvetich, L. R. (2018). Using discrete choice experiments to examine the stepwise nature of avalanche risk management decisions—An example from mountain snowmobiling. *Journal of Outdoor Recreation and Tourism*. March 9. <https://doi.org/10.1016/j.jort.2018.01.007>
- Harvey, S., Signorell, C., & Genswein, M. (2002). *Avalanche accidents in back country terrain of the Swiss alps: New investigations of a 30 year database* [Paper presentation]. Proceedings of the International Snow and Science Workshop. Penticto, British Columbia, CA.
- Hendriks, J., & Johnson, J. (2014). *Using global crowd-sourced data to understand travel behavior in avalanche terrain* [Paper presentation]. Proceedings of the International Snow Science Workshop, Banff, Alberta, Canada.
- Hendriks, J., & Johnson, J. (2016). *Tracking Snowmobilers To Understand Travel Behavior In Avalanche Terrain*

- [Paper presentation]. International Snow Science Workshop, Breckenridge, CO.
- Hendrikk, J., Johnson, J., & Shelly, C. (2016). Using GPS tracking to explore terrain preferences of heli-ski guides. *Journal of Outdoor Recreation and Tourism*, April, 13, 34–43. <https://doi.org/10.1016/j.jort.2015.11.004>
- Hendrikk, J., Johnson, J., & Southworth, E. (2013). *Understanding travel behaviour in avalanche terrain: A new approach* [Paper presentation]. Proceedings of the international snow science workshop. Bamff, Alberta, Canada.
- Hendrikk, J., Shelly, C., & Johnson, J. (2014). *Tracking heli-ski guides to understand decision making in avalanche terrain* [Paper presentation]. ISSW. Bamff, Alberta, Canada.
- Hogarth, R. M., Lejarraga, T., & Soyer, E. (2015). The two settings of kind and wicked learning environments. *Current Directions in Psychological Science*, 24(5), 379–385. <https://doi.org/10.1177/0963721415591878>
- Jamieson, B., Haegeli, P., & Gauthier, D. (2010). *Avalanche Accidents in Canada: Volume 5, 1996–2007*. Canadian Avalanche Association.
- Janis, I. L. (1972). Victims of groupthink: A psychological study of foreign-policy decisions and fiascoes.
- Jekich, B. M., Drake, B. D., Nacht, J. Y., Nichols, A., Ginde, A. A., & Davis, C. B. (2016). Avalanche fatalities in the United States: A change in demographics. *Wilderness & Environmental Medicine*, 27(1), 46–52. <https://doi.org/10.1016/j.wem.2015.11.004>
- Johnson, J., Haegeli, P., Hendrikk, J., & Savage, S. (2016). Accident causes and organizational culture among avalanche professionals. *Journal of Outdoor Recreation and Tourism*, April, 13, 49–56. <https://doi.org/10.1016/j.jort.2015.11.003>
- Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review*, 93(5), 1449–1475. <https://doi.org/10.1257/00028280322655392>
- Kahneman, D. (2011). *Thinking, fast and slow*. Macmillan.
- Kahneman, D., Slovic, S. P., Slovic, P., & Tversky, A. (1982). *Judgment under uncertainty: Heuristics and biases*. Cambridge university press.
- Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review*, 80(4), 237. <https://doi.org/10.1037/h0034747>
- Kelley, K., Clark, B., Brown, V., & Sitzia, J. (2003). Good practice in the conduct and reporting of survey research. *International Journal for Quality in Health Care*, 15(3), 261–266. <https://doi.org/10.1093/intqhc/mzg031>
- Klassen, K., Haegeli, P., & Statham, G. (2013). *The role of avalanche character in public avalanche safety products* [Paper presentation]. Proceedings of the International Snow Science Workshop, Grenoble, France.
- Klein, G. (2015). A naturalistic decision making perspective on studying intuitive decision making. *Journal of Applied Research in Memory and Cognition*, 4(3), 164–168. <https://doi.org/10.1016/j.jarmac.2015.07.001>
- Kobe, K. J., & Jenkins, M. (1991). *Hazard perception and preparation by cross-country skiers in Utah*. Utah State University. Dept. of Forest Resources.
- Lancaster, K. J. (1966). A new approach to consumer theory. *Journal of Political Economy*, 74(2), 132–157. <https://doi.org/10.1086/259131>
- Landrø, M., Hetland, A., Engeset, R., & Pfuhl, G. (2019). Avalanche decision-making frameworks: Factors and methods used by experts. *Cold Regions Science and Technology*, 102897. February Vol. 170.
- Landrø, M., Pfuhl, G., Engeset, R., Jackson, M., & Hetland, A. (2019). Avalanche decision-making frameworks: Classification and description of underlying factors. *Cold Regions Science and Technology*, 102903. February Vol. 170.
- Maguire, L. (2014). *The human behind the factor: A brief look at how context informs practice in recreational backcountry users* [Paper presentation]. Proceedings of the international snow science workshop, Anchorage, Alaska.
- Maguire, L. (2020). *Cognition in the wild: Supporting avalanche professionals through cognitive systems engineering*. Canadian Avalanche Association Spring Conference. [https://www.youtube.com/watch?v=M3HR\\_Uuvqf4&feature=youtu.be](https://www.youtube.com/watch?v=M3HR_Uuvqf4&feature=youtu.be)
- Mannberg, A., Hendrikk, J., & Johnson, J. (2018a). Keeping up with jeremy jones: Positional preferences and risky terrain choices.
- Mannberg, A., Hendrikk, J., & Johnson, J. (2018b). *Are they experts? Self-assessed backcountry skills among backcountry skiers in Norway And North America* [Paper presentation] International Snow Science Workshop, Innsbruck Austria.
- Marengo, D., Monaci, M. G., & Miceli, R. (2017). Winter recreationists' self-reported likelihood of skiing backcountry slopes: Investigating the role of situational factors, personal experiences with avalanches and sensation-seeking. *Journal of Environmental Psychology*, April 49, 78–85. <https://doi.org/10.1016/j.jenvp.2016.12.005>
- Massey, C., & Thaler, R. H. (2013). The loser's curse: Decision making and market efficiency in the National Football League draft. *Management Science*, 59(7), 1479–1495. <https://doi.org/10.1287/mnsc.1120.1657>
- McCammon, I. (2000). *The role of training in recreational avalanche accidents in the United States* [Paper presentation]. Proceedings of the International Snow Science Workshop. Big Sky, Montana.
- McCammon, I. (2002). Evidence of heuristic traps in recreational avalanche accidents [Paper presentation]. Proceedings ISSW. Penticton, British Columbia, Canada.
- McCammon, I. (2004). Heuristic traps in recreational avalanche accidents: Evidence and implications. *Avalanche News*, 68(1), 42–50. <https://snowpit.com>.
- McCammon, I. (2009). *Human factors in avalanche accidents: Evolution and interventions* [Paper presentation]. International Snow Science Workshop. Davos, Switzerland.
- McCammon, I., & Hägeli, P. (2004). *Comparing avalanche decision frameworks using accident data from the United States* [Paper presentation]. International Snow Science Workshop, Jackson, WY.
- McClung, D. (2002). The elements of applied avalanche forecasting, Part I: The human issues. *Natural Hazards*, 26(2), 111–129. <https://doi.org/10.1023/A:1015665432221>
- Mittone, L., & Savadori, L. (2009). The scarcity bias. *Applied Psychology*, 58(3), 453–468. <https://doi.org/10.1111/j.1464-0597.2009.00401.x>
- Ng, P., Smith, W. R., Wheeler, A., & McIntosh, S. E. (2015). Advanced avalanche safety equipment of backcountry users: Current trends and perceptions. *Wilderness & Environmental Medicine*, 26(3), 417–421. <https://doi.org/10.1016/j.wem.2015.03.029>
- Page, D. (2014). *The human factor*. The Human Factor. <https://www.powder.com/the-human-factor-1-0/>

- Page, D. (2015). *The human factor 2.0*. The Human Factor. <https://storied.storied.co/human-factor-2.0/chapter-1>
- Peitzsch, E., Boilen, S., Logan, S., Birkeland, K., & Greene, E. (2020). Research note: How old are the people who die in avalanches? A look into the ages of avalanche victims in the United States (1950–2018). *Journal of Outdoor Recreation and Tourism*, March 29, 100255. <https://doi.org/10.1016/j.jort.2019.100255>
- Raue, M., & Scholl, S. G. (2018). The use of heuristics in decision making under risk and uncertainty. In *Psychological perspectives on risk and risk analysis* (pp. 153–179). Raue M., Lerner E., Streicher B. (eds) Springer.
- Saly, D., Hendriks, J., Birkeland, K., Challender, S., & Johnson, J. (2020). Using time-lapse photography to document terrain preferences of backcountry skiers. *Cold Regions Science and Technology*, April 172, 102994. <https://doi.org/10.1016/j.coldregions.2020.102994>
- Schwartz, H. (2010). Heuristics or rules of thumb. In H. K. Baker & V. J. R. Nofsinger (Eds.), *Behavioral finance: investors, corporations and markets* (pp. 57–72). John Wiley & Sons.
- Schweizer, J., Mitterer, C., & Stoffel, L. (2009). On forecasting large and infrequent snow avalanches. *Cold Regions Science and Technology*, 59(2–3), 234–241. <https://doi.org/10.1016/j.coldregions.2009.01.006>
- Shah, A. K., & Oppenheimer, D. M. (2008). Heuristics made easy: An effort-reduction framework. *Psychological Bulletin*, 134(2), 207. <https://doi.org/10.1037/0033-2909.134.2.207>
- Sherif, M. (1936). The psychology of social norms.
- Sherman, S. J., & Cortsy, E. (1984). Cognitive heuristics.
- Silverton, N. A., McIntosh, S. E., & Kim, H. S. (2009). Risk assessment in winter backcountry travel. *Wilderness & Environmental Medicine*, 20(3), 269–274. <https://doi.org/10.1580/08-WEME-OR-209R1.1>
- Simenhois, R., & Savage, S. (2010). *Compiling and studying professional avalanche worker incident data to improve worker safety* [Paper presentation]. Proceedings: 2010 international snow science workshop. Squaw Valley, CA.
- Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review*, 63(2), 129. <https://doi.org/10.1037/h0042769>
- Simon, H. A. (1990). Invariants of human behavior. *Annual Review of Psychology*, 41(1), 1–20. <https://doi.org/10.1146/annurev.ps.41.020190.000245>
- Sleesman, D. J., Conlon, D. E., McNamara, G., & Miles, J. E. (2012). Cleaning up the big muddy: A meta-analytic review of the determinants of escalation of commitment. *Academy of Management Journal*, 55(3), 541–562. <https://doi.org/10.5465/amj.2010.0696>
- Slovic, P., Peters, E., Finucane, M. L., & MacGregor, D. G. (2005). Affect, risk, and decision making. *Health Psychology*, 24(4S), S35. <https://doi.org/10.1037/0278-6133.24.4.S35>
- Sole, A. E., Emery, C. A., Hagel, B. E., & Morrongiello, B. A. (2010). Risk taking in avalanche terrain: A study of the human factor contribution. *Clinical Journal of Sport Medicine*, 20(6), 445–451. <https://doi.org/10.1097/JSM.0b013e3181fc0a6d>
- Stamberger, L., van Riper, C. J., Keller, R., Brownlee, M., & Rose, J. (2018). A GPS tracking study of recreationists in an Alaskan protected area. *Applied Geography*, April 93, 92–102. <https://doi.org/10.1016/j.apgeog.2018.02.011>
- Statham, G., Haegeli, P., Greene, E., Birkeland, K., Israelson, C., Tremper, B., Stethem, C., McMahon, B., White, B., & Kelly, J. (2018). A conceptual model of avalanche hazard. *Natural Hazards*, 90(2), 663–691. <https://doi.org/10.1007/s11069-017-3070-5>
- Thaler, R. (1980). Toward a positive theory of consumer choice. *Journal of Economic Behavior & Organization*, 1(1), 39–60. [https://doi.org/10.1016/0167-2681\(80\)90051-7](https://doi.org/10.1016/0167-2681(80)90051-7)
- Thaler, R. (1985). Mental accounting and consumer choice. *Marketing Science*, 4(3), 199–214. <https://doi.org/10.1287/mksc.4.3.199>
- Thaler, R. H. (1999). Mental accounting matters. *Journal of Behavioral Decision Making*, 12(3), 183. [https://doi.org/10.1002/\(SICI\)1099-0771\(199909\)12:3<183::AID-BDM318>3.0.CO;2-F](https://doi.org/10.1002/(SICI)1099-0771(199909)12:3<183::AID-BDM318>3.0.CO;2-F)
- Tiedens, L. Z., & Linton, S. (2001). Judgment under emotional certainty and uncertainty: The effects of specific emotions on information processing. *Journal of Personality and Social Psychology*, 81(6), 973. <https://doi.org/10.1037/0022-3514.81.6.973>
- Tremper, B. (2008). *Staying alive in avalanche terrain*. The Mountaineers Books.
- Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185(4157), 1124–1131. <https://doi.org/10.1126/science.185.4157.1124>
- Tversky, A., & Kahneman, D. (1978). Judgment under Uncertainty: Heuristics and Biases: Biases in judgments reveal some heuristics of thinking under uncertainty. In *Uncertainty in economics* (pp. 17–34). Kahneman D., Slovic P., Tversky A. (eds). Elsevier.
- Tversky, A., & Kahneman, D. (1986). Rational choice and the framing of decisions. *The Journal of Business*, 59(S4), S251–S278. <https://doi.org/10.1086/296365>
- Uziel, L. (2007). Individual differences in the social facilitation effect: A review and meta-analysis. *Journal of Research in Personality*, 41(3), 579–601. <https://doi.org/10.1016/j.jrp.2006.06.008>
- Wilde, G. J. (1988). Risk homeostasis theory and traffic accidents: Propositions, deductions and discussion of dissonance in recent reactions. *Ergonomics*, 31(4), 441–468. <https://doi.org/10.1080/00140138808966691>
- Zajchowski, C. A., Brownlee, M. T., & Furman, N. N. (2016). The dialectical utility of heuristic processing in outdoor adventure education. *Journal of Outdoor Recreation, Education, and Leadership*, 8(2), 119–135. <https://doi.org/10.18666/JOREL-2016-V8-12-7697>
- Zajonc, R. B. (1965). Social facilitation. *Science*, 149(3681), 269–274. <https://doi.org/10.1126/science.149.3681.269>
- Zaleskiewicz, T. (2001). Beyond risk seeking and risk aversion: Personality and the dual nature of economic risk taking. *European Journal of Personality*, 15(S1), S105–S122. <https://doi.org/10.1002/per.426>
- Zhao, W., Ramamritham, K., & Stankovic, J. A. (1987). Preemptive scheduling under time and resource constraints. *IEEE Transactions on Computers*, 100(8), 949–960. <https://doi.org/10.1109/TC.1987.5009518>
- Zweifel, B., Techel, F., & Björk, C. (2012). *Who is involved in avalanche accidents* [Paper presentation]. Proceedings International Snow Science Workshop. Anchorage, Alaska.



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