REFLECTIONS ON HOW TO IMPROVE THE CONTRIBUTION OF SOCIAL SCIENCE RESEARCH TO AVALANCHE SAFETY PRACTICES

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ABSTRACT: The influence of human perception, judgment, and behavior on avalanche safety is well known and has been described in the literature for a long time. One of the most influential works on human factors in the avalanche safety community was the introduction of the concept of heuristics traps by Ian McCammon (2002). More than 20 years later, McCammon's FACETS remains the main reference for how our community conceptualizes human factors and the tool of choice for introducing the topic to recreationists. However, there is much more to the human dimension of avalanche safety.

Even though the number of social science studies in our field has grown considerably in recent years, we believe that the current perspective is rather limited, many key questions remain unanswered, and as a result, the contribution of social science research to avalanche safety seems far from reaching its potential. To help tackle this issue, we present our perspective of the current high-level challenges that prevent our community from fully benefiting from social science efforts. This includes reflecting on the quality of the existing research but also how social science research is valued and employed in the avalanche safety community. Our reflections are supported with constructive calls-to-action for academic and practitioner researchers conducting social science projects, research users implementing the results of such studies, and managers setting strategic directions and allocating resources.

KEYWORDS: Social science, human factors, product development, product evaluation.

1. INTRODUCTION

Avalanche safety is ultimately a human problem. It is people assessing conditions and making decisions about when, where, and how to expose themselves or their assets to avalanche hazard. Therefore, an in-depth understanding of the human dimension of this challenge is critical for improving avalanche safety.

The influence of human perception, judgment, and behavior on avalanche safety is well known in the avalanche community and has been described in the applied literature for a long time. Early examples include LaChapelle's (1980) description of the psychological context of conventional avalanche forecasting, Fredston and Fesler's (1994) listing of human factors contributing to accidents, and Munter's (1992) chapter on "Dreizehn fatale Irrtümer des gesunden Menschenverstandes" (Thirteen fatal errors of common sense). One of the most influential works on human factors in the avalanche safety community has been the introduction of the concept of heuristics traps by McCammon (2002), which illustrates how the subconscious use of well-known mental shortcuts identified by cognitive psychologists can potentially lead to unsafe decisions and accidents in the backcountry.

Social science is the branch of academic study that examines human behavior within its social and cultural context (Nisbet and Greenfeld, 2023), which typically includes the disciplines of anthropology, sociology, psychology, political science, and economics. Various research paradigms exist within the social sciences, which describe the beliefs, assumptions, practices, and values that guide how researchers approach and conduct their studies (Blaikie and Priest, 2017). Together, these paradigms have developed a powerful range of complementary qualitative and quantitative methodologies to identify patterns in human behavior and systematically study the factors and mechanisms that influence them.

Since the introduction of heuristic traps more than 20 years ago, the number of academic social science contributions on the human dimension of avalanche safety have increased dramatically (Hetland et al., 2023). While this is an encouraging trend, this body of research also has several challenges that currently limit our community's ability to benefit from these efforts. While rigorous social science combined with thoughtful implementations has great potential to improve avalanche safety, poorly designed stud-

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ies and/or misguided applications of research results can have detrimental consequences.

Some of the most powerful examples that illustrate the destructive impacts of ignoring or misusing social science insights outside of the avalanche community include the devastating consequences of the "war on drugs" without evidence on its effectiveness (Global Commission on Drug Policy, 2011), as well as the unnecessary incarceration of millions of people under "tough on crime" policies despite the scientific consensus that tougher penalties do not reduce crime (Shelden and Brown, 2003). If we want to avoid these types of traps in the avalanche safety community, it is important to better understand social sciences and create an environment that allows us to take full advantage of their capabilities.

The objective of this paper is to reflect on the quality of the existing social science research and the high-level challenges that currently prevent our community from fully benefiting from these efforts. The reflections are complemented with constructive and encouraging calls-to-action for academic and practitioner researchers conducting social science projects, research users aiming to implement results of such studies, as well as program developers and managers setting strategic directions and allocating resources for the development of new avalanche safety products and services.

2. OUR APPROACH

The information shared in this paper represents personal reflections from social science and interdisciplinary researchers who have worked in the avalanche safety community for the last decade. Our academic backgrounds are diverse (atmospheric science, social science, public health, economics, psychology), and we have had a variety of academic and practitioner roles (recreationist, educator, avalanche forecaster, researcher, academic supervisor, proposal reviewer, academic journal editor).

It is <u>not</u> our intent to promote our own research programs but rather to offer a self-critical high-level perspective based on our own experience working in this space. However, it is unavoidable that some of our personal research directions are based on these observations and ideas. We purposely chose not to illustrate the challenges by highlighting individual studies to avoid destructive finger-pointing. Instead, we include tangible calls-to-action to create a more productive and encouraging pathway.

3. CURRENT SITUATION

The avalanche safety community is a very applied, natural science dominated research and development field. Our scientific approach is heavily rooted in western traditions of understanding and generally follows the positivist research paradigm that focuses on objective and empirically testable truth. Many of the current avalanche risk management practices have originated in central Europe, and we have generally employed a paternalistic approach to avalanche safety where hazard experts develop products and services for laypeople with only limited input from other experts and their target audiences.

The term "human factors" is used as a general umbrella term to describe any type of human influence on the avalanche risk assessment and decision-making process. While the existing research covers a wide range of topics including population characteristics, accident analyses, risk perception, willingness to take risk, decision-making strategies, avalanche education and risk communication (see Hetland et al. (2023) for details), there is a strong focus on studying individuals and the flaws in their risk management process. The social and cultural aspects of avalanche safety and the effectiveness of products and services have so far received much less attention. Of all the people exposed to avalanche hazard, recreational backcountry skiers are by far the most studied target audience.

Research is conducted by academic and practitioner researchers, both in collaboration and independently. Within the avalanche community, most research funding is directed towards improving hazard assessments, the development of related infrastructure, and technical products and services, while the support for social science is more limited.

Most of the influential literature is published in ISSW proceedings, community journals or books and is therefore not peer-reviewed. This is not necessarily an issue, but it requires a more cautious approach to the literature since the processes of peer-review provides quality assurance. While some social science insights have been adopted quickly and have shaped how the community conceptualizes human factors (e.g., heuristic traps), the use of social science principles and insights is generally limited.

4. REFLECTIONS & CALLS-TO-ACTION

Our reflections are organized around three main themes: a) identifying good research questions, b) upholding scientific rigor, and c) strengthening the link to practice. In an applied research field, all three components are critical for producing insightful and actionable results that can help improve avalanche safety in a practical way. Table 1 presents calls-to-action for program developers and managers (PD), academic researchers (AR), practitioner researchers (PR), and research users (RU), which are referenced at the end of each section.

4.1 <u>Identifying good research questions</u>

The foundation of impactful research is good research questions. Existing social science studies

can roughly be divided into two main areas based on their primary focus of inquiry: a) people-focused research, and b) product/service-focused research.

The vast majority of the existing research in our field has been people-focused with the aim of improving our fundamental understanding of how hazard is assessed and risk management decisions are made. Much of this research has focused on highlighting flaws and challenges in these processes. While the resulting body of research on heuristics and biases has been instrumental for increasing people's awareness of the influence of human factors on avalanche safety and identifying some of the potential underlying causes, its practical contribution to improving avalanche safety so far has been limited. This is partially because our influence on the cognitive processes of backcountry users is actually very limited. Simply raising the awareness about potential cognitive traps does not make people less susceptible to them because heuristics operate at the subconscious level (e.g., Kahneman, 2011). Furthermore, the heuristics themselves are not the problem. People use heuristics all the time, and they can be very effective when matched well to the decision environment at hand (Gigerenzer and Selten, 2001). Familiarity, for example, can be a great asset under the right circumstances and does not need to be a trap. Hence, as pointed out by Zajchowski et al. (2016), our focus on heuristic traps over the last two decades might have blinded our community to other potentially more constructive inquiries on decision-making approaches. Research examining what works and why can be equally insightful as research examining what is challenging.

Research centered around products and services has the potential to produce more actionable insights because we have much more control over the product development and delivery. This type of solutions-focused research is currently emerging but is somewhat dispersed and not yet sufficiently organized to produce an effective body of research that can meaningfully inform development. Luckily, fields like public health and risk communication are well experienced in harnessing social sciences for developing effective interventions in a structured way. We will explain their approaches in more detail in Section 4.3, when discussing how to strengthen the link between research and application.

While both person- and product/service-focused research can produce valuable insights to improve avalanche safety directly or indirectly, we believe that the community would benefit from a stronger focus on practical research questions that produce tangible recommendations for the development of products and services. Identifying these types of research questions meaningfully require researchers to collaborate closely with practitioners. Furthermore, instead of looking at individual processes or single products, we believe that research employing a higher-level systems perspective for looking at the entire avalanche safety system with all its parts has great potential (St. Clair and Haegeli, 2023).

Calls-to-action: PD-3, AC-1

4.2 Upholding scientific rigor

Research can only provide meaningful insight if it is conducted in a rigorous way (Hofseth, 2018). While the approaches for achieving scientific rigor differ between research areas and methods, it refers to the foundational practice of "taking great care in establishing and articulating research objectives, selecting and implementing appropriate research methods and interpreting research results while at the same time acknowledging omissions and limitations" (Sovacool et al., 2018).

We have observed challenges with scientific rigor in many studies in our field conducted by both academic and practitioner researchers. While it is beyond the scope of this paper to comprehensively discuss common challenges in social science projects and how to avoid them, there are countless textbooks providing detailed introductions into different research methods (e.g., Dillman et al., 2014; Walliman, 2022; Denzin and Lincoln, 2005), and papers have been written to promote domain-specific best practices (e.g., Sovacool et al., 2018) or present tool kits for practice-based research (e.g., Winterstein and Vermeulen, 2008). Instead of getting into the specifics, we present a few high-level challenges related to scientific rigor that everybody should be aware of.

Importance of social science theory

The importance of theory for social science research cannot be overstated. Good research is either grounded in existing theory or contributes to new theory. Theories encapsulate the existing understanding of a topic and give directions for how to tackle a research question, interpret results, and synthesize insights from multiple studies (Chijioke et al., 2021). Hence, tying research questions to relevant theories is critical for thoughtful study design. Simply making observations without relating it to the bigger context is only of limited value.

The dual process theory of reasoning (i.e., System 1 vs. System 2; heuristic vs. systematic) and particularly the heuristics and biases perspective on judgment and decision-making (Kahneman, 2011) are well established in our community, but there are many other theories that can provide valuable guidance for research projects. Examples include the theories of naturalistic decision-making (Klein, 2008) and ecological rationality (Todd et al., 2012) for a more positive perspective on heuristic decision-making, the RISK (Liu et al., 2022) and PADM (Lindell and Perry, 2012) models to better understand how people seek and process risk infor-

Table 1: Calls-to-action for different audiences

Audience	Calls-to-action
Program developers and managers (PD) e.g., warning service managers, curriculum developers	1. Consider established planning models from public health for creating systematic plans for the development, implementation and evaluation of new products and services. 2. Include social science research in product development projects, engage researchers early in project development, and allocate sufficient time and resources. 3. Communicate research needs with social science research community. 4. Purposefully invest in establishing long-term relationships with relevant social scientists. 5. Systematically engage with the full range of current and potential product users when developing new or modifying existing products and services.
Academic researchers (AR)	1. Collaborate with practitioners and more explicitly align research questions with community needs for solution-oriented and actionable insight. 2. Choose methods appropriate for the research question and follow established methods-specific best practices to ensure scientific rigor. 3. Solidly ground research in relevant theory and/or describe how it contributes to theory. 4. Ensure participant sample is appropriate for research question and method. 5. When possible and appropriate, use established and validated research instruments (e.g., survey and interview questions). 6. Contribute towards standardized and validated research instruments, especially for difficult to measure concepts (e.g., willingness to take risk; forecast literacy). 7. Use analysis methods that can account for diversity in study sample. 8. Ensure research implications and recommendations are evidence based, aligned with research question, and within the capabilities of the chosen research methods and study sample. Explicitly discuss limitations and their effect on the practical use of the research results. 9. Publish in open-access journals known to the community to avoid unproductive dispersion of research field. 10. View the peer-review process as an opportunity to get constructive feedback from relevant researchers and strengthen the contribution of your research project. 11. Publish accessible companion papers in community journals that highlight management implications. 12. Support and train practitioner researchers on social science techniques and best practices.
Practitioner researchers (PR)	1. Reach out to social scientists early and often to get advice on research design and analysis plan. 2. Choose research questions that are within your research expertise and the capability of the chosen research method and available study sample. 3. Whenever possible and appropriate, use established and validated research instruments (e.g., survey and interview questions). 4. Ensure research implications and recommendations are aligned with research question, analytical methods, study sample and provided evidence. Explicitly discuss limitations and their effect on the practical use of the research results. 5. Consider having a social scientist review your article before submitting it to a community journal.
Research users (RU) e.g., practitioners, educators	1. Review conclusions and recommendations of studies carefully with respect to the methods used, study sample, provided evidence, and stated limitations. 2. Base confidence in study results more on scientific rigor than their intuitiveness. 3. If possible, reach out to researchers before integrating their research results into safety practices and teachings to ensure appropriateness.
All	1. Do not believe everything you read. Be critical! 2. Collaborate!

mation, and various intervention and behavior change theories in public health (Glanz and Bishop, 2010). In addition to making our research more insightful and effective, tying studies to established theories also allows us to meaningfully contribute to these larger research fields.

Calls-to-action: AR-3, PR-1

Validity of research instruments

A central challenge in research is linking complex and sometimes not directly observable concepts (e.g., risk perception) to measurable factors. How survey or interview questions are worded, delivered, and interpreted by participants is critical for whether we measure the intended concept. In the academic literature, the effectiveness of research instruments is described in terms of validity (whether it captures the targeted concept) and reliability (whether it does it consistently) (Kimberlin and Winterstein, 2008).

There are several factors that make the design of survey and interview questions particularly challenging for us. First, the concepts we try to measure (e.g., willingness to take risk, forecast literacy, application of information) are multifaceted, nuanced and context-dependent, which prevents us from using simple and easy to understand questions. For example, users' preference for a new information presentation format is not a good measure of whether it actually improves decision-making. Second, the resulting complexity of our questions makes them more susceptible to being misinterpreted by participants. Finally, the answers participants provide in interviews or surveys only offer limited insight into what people actually do when they plan a trip with friends for their upcoming holidays or stand at the top of an untracked slope.

To overcome these challenges, social science research instruments need to be carefully designed and tested extensively to ensure they capture what we want them to measure. Specialized researchers have developed and extensively tested standardized instruments for some more general concepts, such as sensation seeking (Zuckerman, 2006), motivations (Manfredo et al., 1996), or risk literacy (Cokely et al., 2012). However, the generic nature of these scales limits their uses for avalanche safety research. While some more specialized scales exist (e.g., Thomson et al., 2012; Frühauf et al., 2018), they are also not always meaningful or appropriate.

There are critical lessons to be learned about the design of effective survey and interview questions from existing studies. Instead of reinventing the wheel in every project, working together towards more standardized and validated approaches for measuring key concepts will allow the research to avoid known pitfalls, progress more quickly, and ultimately be more insightful. Furthermore, standardized questions for characterizing study participants will make it easier to compare results across studies and synthesize them into a bigger picture. We support Johnson et al.'s (2020) call for the creation of repositories of validated research instruments, but caution that such libraries should not be used as shortcuts for thoughtful study design.

Calls-to-action: AC-6, PR-3

The limits of convenient samples

The people who participate in our research projects fundamentally limit the conclusions we can draw and how transferable our results are to the broader population of backcountry users. Much of the social science research conducted in our community relies on convenience sampling, a non-probability sampling approach that takes advantage of easily accessible participants (e.g., trailheads, clubs, product users, social media users). The reason for this is that our study population is not well organized, transient, and no registration is required, which prevents us from using sampling approaches that produce more representative samples (e.g., random sampling). While this is not necessarily a problem, it is important to remember the limitations of these samples when interpreting results. Our convenient samples are often dominated by backcountry skiers and typically skewed towards more avalanche aware users who are using our products and services more regularly. Hence, our results only provide insight about this particular segment of our community. This bias is particularly problematic when trying to identify challenges in existing products or evaluating the overall effectiveness of new developments. For these types of studies to be useful, it is important to include novice and infrequent users, who might struggle with aspects of our products and services that more committed users do not. Hence, matching the sample to the research question and method is critical for producing insight.

Calls-to-action: PD-5, AC-5, PR-2

Analysis and interpretation

There are many methods-specific rules and practices that need to be considered when analyzing data, and many resources are available to support researchers at various levels. See, for example, Zuur et al. (2010) for how to avoid common issues in statistical analyses, or Ravitch and Carl (2016) for guidance on ensuring rigor in qualitative research.

Here, we only comment on a few key aspects that should be considered when analyzing data. First, correlations do not imply causation. For example, a positive relationship between the degree of avalanche education and avalanche involvements does not necessarily indicate that avalanche education is dangerous. This spurious effect is likely caused by how much time people spend in the backcountry, which has a positive relationship to both training and the chance of being involved in an accident.

Hence, it is important that the interpretation is supported by theory and realistic causal effects between the variables. Similarly, the lack of a correlation between two variables does not necessarily mean that there is no relationship at all. The effect might simply be moderated by covariates and require more sophisticated analyses to be isolated properly. In both situations, relating the analysis to an established theory is critical.

Statistical analyses should be focused on the research question at hand and consistent with supporting theory. Hunting for results by testing many possible relations among variables should be avoided as it increases the chance of identifying non-existing results. Experiments need to be designed carefully to ensure variables of interest are as independent as possible.

It is established in the social sciences that populations (and samples) are diverse and that general analyses that lump everybody together might only provide limited insight (e.g., Lubke and Muthén, 2005). Hence, it is common practice to divide samples into meaningful segments based on their responses. This can be done a priory based on the research question at hand or in a data-driven manner based on response patterns using methods like latent class analysis (Collins and Lanza, 2010).

Finally, when synthesizing the results into a comprehensive response to the research question and discussing its practical implications, it is critical that conclusions presented are directly derived from the information presented and within the capabilities of the chosen method. Discussing incidental observations, personal opinions that go beyond the research questions and/or evidence provided, or making unrealistic claims is distracting, inappropriate and lowers the overall value of a study.

Calls-to-action: AR-2, AR-7, AR-8, PR-2, PR-4, RU-1

Strengthening expertise with collaborations

Meaningful research cannot be done in isolation, and we strongly believe that broad collaborations are critical for insightful and effective social science contributions to avalanche safety. Researchers benefit from the operational insight that practitioners can contribute to the research, and practitioner researchers can profit from the specialized expertise of academic researchers. It is the combination of the two skill sets that produce the best results. Hence, we recommend reaching out early so that issues can be addressed before data is collected.

In addition to collaborations within our community, researchers from other neighboring fields can have valuable specialized skills. In this spirit, Gale et al. (2016) proposed a pathway for linking the needs of the avalanche safety community with the behavioral science community. While we support the idea of establishing these connections, our personal experience has shown that creating meaningful relationships with other researchers requires considerable time, effort, and personal interest from both sides. The nature of avalanche hazard and how people interact with it often prevents the direct transfer of theories and concepts, and expecting “magic solutions” from external experts is unrealistic.

Calls-to-action: PD-4, AR12, PR-1

Role and limitations of the peer review process

Academic peer-review prior to publication plays an important role in ensuring scientific rigor. Getting constructive feedback from relevant experts (formally or informally) is critical for avoiding blind spots and optimizing the presentation of insight. However, the process is not without challenges (see, e.g., Proctor et al., 2023), and some of them are exacerbated by the nature of our community. The number of avalanche safety researchers qualified to review social science projects is small, and it is not uncommon for manuscripts to be either reviewed by experts with natural science backgrounds or social scientists with limited or no understanding of the avalanche safety context. Both situations can produce uninformative reviews and have led to the publication of studies with limited value. Hence, do not believe everything you read. Every study should be reviewed critically and assessed on its rigor.

Calls-to-action: AR-10, PR-5

4.3 Strengthening the link to practice

Connecting the dots and making them tangible for implementation

There are currently no established processes for how social science expertise and insights are integrated into avalanche safety practices, products, and services. On one side, some social science ideas and concepts just seem to resonate with the community and subsequently infiltrate practices in an unstructured way regardless of the quality of the work. On the other side, social science expertise currently only plays a minor role in development decisions for new products and services, which are mainly driven by expert opinion and technical developments.

The fields of public health and risk communication provide valuable insights for how to better guide and harness social science expertise for the design of effective products and services. Both fields have established frameworks and criteria for the development of evidence-based interventions that integrate social science expertise in various ways. In public health, for example, the PRECEDE-PROCEED planning model (Crosby and Noar, 2011) and the Intervention Mapping framework (Fernandez et al., 2019) provide adaptable blueprints for building effective intervention programs

supported by research. These types of frameworks help program developers and managers by highlighting times when social science perspectives are critical, identifying important knowledge gaps, articulating specific research questions and methods, and providing guidance on how to integrate research results in the intervention design and program implementation process (McNeil and Haegeli, 2023). The frameworks can also assist researchers with independently aligning their research programs with operational needs and articulating how their projects fits into the bigger picture.

Within these frameworks, social sciences' core contribution is to systematically and meaningfully capture the user perspective for needs assessments and product evaluations, where the complexity of avalanche hazard, the mostly voluntary exposure, and the nuance of the risk management process prevent us from adopting simple measures and solutions. For example, properly assessing people's ability to understand and meaningfully apply avalanche forecast information is a challenging task, and measuring the impact of a new avalanche safety curriculum is much more difficult than assessing whether a person stopped smoking or not.

However, it is important to recognize that the conceptualization and execution of high-quality and insightful research projects takes considerable time. While there are options for speeding up certain aspects of the research process (e.g., participant recruitment with research panels), it is important that social science projects are considered early when new development projects are conceptualized and are given sufficient time and resources to produce the needed insights.

Calls-to-action: PD-1, PD-2, AR-1, RU-3

Making research more accessible

There are several aspects that currently make it difficult for practitioners and researchers to access relevant social science research. First, academic studies are published across a wide range of social and natural science journals, which makes it difficult to keep track of the field. Second, most of these journals still require subscriptions to access articles, which puts them out of reach for practitioners and the public. In addition, academic publication fees and the peer-review process are intimidating for practitioner researchers and prevent them from publishing in academic journals. As a result, they are naturally drawn to publications in more accessible community journals (e.g., Avalanche Journal, The Avalanche Review, BergUndSteigen) and ISSW proceedings, which can be insightful but not peer-reviewed and often of lower scientific quality.

A long-term solution for consolidating the field would be to establish an explicit home for applied social science in avalanche risk management by creating a new open-access and peer-reviewed applied journal or partner with an existing journal. However, for such an initiative to be feasible, we need to significantly increase the volume and quality of our research efforts. More short-term solutions include publishing in existing open access journals, and writing companions papers in community journals.

Calls-to-action: AR-9, AR-11, PR-5

5. CONCLUSIONS

Existing avalanche safety programs and services represent great success stories that have saved countless lives. However, we believe that at this point, social science research can contribute substantially to further improving avalanche safety in meaningful ways. To properly harness its capabilities, our community needs to give it the necessary space and resources. In addition, researchers need to choose relevant research questions, ensure that their projects are of high quality, and make their results more accessible to the community.

In an ideal world, the natural and social sciences would be on more equal footings in our community, and research that examines how to best communicate the nature of the hazard and help users make better informed decisions from different perspectives would be equally valued as the research focused on improving hazard assessments. An example to aspire to is NOAA's latest report on priorities for weather research (NOAA Science Advisory Board, 2021), where one of the three main research priority themes is social science focused.

We encourage the avalanche safety community to examine and appropriately align itself with best practices developed in other fields focused on risk communication. The reflections and calls-to-action are intended to provide a starting point for the opinion leaders in our community to come together and sketch out a meaningful plan for strengthening the contribution of the social sciences. We welcome feedback and comments from all and encourage everybody to join the conversation. As a next step, we envision the collaborative development of a social science research strategy that articulates research priorities, creates funding opportunities, and offers targeted resources to help improve the quality of the research conducted as well as the social science literacy in our community in general.

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