Exploring the Effectiveness of Avalanche Risk Communication: A Qualitative Study of Avalanche Bulletin Use Among Backcountry Recreationists

by

Anne St. Clair

B.A. (Anthropology and Sociology), University of Notre Dame, 2006

Research Project Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Resource Management

in the
School of Resource and Environmental Management
Faculty of Environment

Report No. 738

© Anne St. Clair 2019
SIMON FRASER UNIVERSITY
Fall 2019

Copyright in this work rests with the author. Please ensure that any reproduction or re-use is done in accordance with the relevant national copyright legislation.

Approval

Name:	**Anne St. Clair**
Degree:	**Master of Resource Management**
Title:	**Exploring the Effectiveness of Avalanche Risk Communication: A Qualitative Study of Avalanche Bulletin Use Among Backcountry Recreationists**
Examining Committee:	**Chair:** Henry Finn Master of Resource Management Candidate

Pascal Haegeli
Senior Supervisor
Assistant Professor
School of Resource and Environmental Management
Simon Fraser University

Robin Gregory
Supervisor
Adjunct Professor
School of Resource and Environmental Management
Simon Fraser University

Date Defended/Approved: September 26, 2019

Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University

or has conducted the research

c. as a co-investigator, collaborator, or research assistant in a research project approved in advance.

A copy of the approval letter has been filed with the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Simon Fraser University Library
Burnaby, British Columbia, Canada

Update Spring 2016

Abstract

Warning backcountry recreationists about the risks from snow avalanches is a particularly challenging communication task due to the complexity of the phenomenon, the voluntary and repeated nature of the exposure, the diversity of recreational activities, the range in individual's risk management skills, and the need for self-determined risk management decision-making in an environment with rare corrective feedback. To better understand the effectiveness of daily avalanche bulletins for improving recreationists' safety in the backcountry, a research team conducted 46 semi-structured interviews with an inclusive sample of recreationists to shed light onto how travel decisions are made and how avalanche information is incorporated. The present study combines a qualitative applied thematic analysis with quantitative statistical techniques (topic models, simple correspondence analysis, and multinomial logistic regression) to detect, examine, and classify patterns in recreationists' bulletin use into an Avalanche Bulletin User Typology. The resulting classification system establishes an evidence-based foundation for improving avalanche risk communication that offers actionable recommendations to enhance recreationists' ability to conceptualize and manage avalanche risk with bulletin products.

Keywords: Avalanche risk; risk communication; backcountry recreation; risk information seeking and processing; decision-making; mixed analysis; applied thematic analysis; topic models

Acknowledgements

I would like to offer my sincere gratitude to all who contributed to this study, especially those who supported our recruitment efforts, who volunteered for our interview practice, and who participated as interviewees. This project reflects the genuine commitment of the backcountry community to improving public avalanche safety.

I would like to thank the team at Avalanche Canada for their engagement with this study and for their important insights from a forecasting perspective. A special thanks to Karl Klassen for bringing valuable expertise to the brainstorming table and for championing this study in the avalanche industry. A sincere thank you to Robin Gregory for contributing to the theoretical direction of this research and to Patrick Mair for making the statistical components of this project accessible and possible for me. I would also like to acknowledge the Simon Fraser University Teaching and Learning Center for fostering opportunities for interdisciplinary engagement that played an instrumental role in this research.

I owe an enormous debt of gratitude to my colleague, Henry Finn. Thank you for your tireless dedication to this work and for the countless hours you spent transcribing this dataset. Working together on this project has been a privilege, and I learned my most valuable lessons through your example of collaboration.

A tremendous thank you to Pascal Haegeli for your devotion to the quality of this project and to the quality of the experience for all involved. I am honored to take part in this research and grateful for your dedicated supervision. Your support and encouragement are deeply appreciated.

I gratefully acknowledge the support of Avalanche Canada and Mitacs for funding this research with the Simon Fraser University Avalanche Research Program (SARP). SARP is also financially supported by Canadian Pacific Railway, HeliCat Canada, Mike Wiegele Helicopter Skiing, and the Canadian Avalanche Association.

Table of Contents

Approval ii
Ethics Statement iii
Abstract iv
Acknowledgements v
Table of Contents vi
List of Tables viii
List of Figures ix

Chapter 1. Introduction 1

Chapter 2. Background 5
2.1. Trends in Backcountry Recreation 5
2.2. Avalanche Canada's Bulletin Design and Public Safety Initiatives 7
2.3. Research in Risk Communication 11

Chapter 3. Methodology 14
3.1. Data Collection 16
3.1.1. Study Recruitment 16
3.1.2. Interview Script Design 17
3.1.3. Sample Overview 18
3.2. Phase 1: Applied Thematic Analysis 19
3.2.1. Identification of the Avalanche Bulletin User Typology 19
3.2.2. Respondent Validation 20
3.3. Phase 2: Quantitative Data Analysis 20
3.3.1. Text Preprocessing and Data Transformation 20
3.3.2. Topic Modeling 21
3.3.3. Correspondence Analysis 23
3.3.4. Multinomial Logistic Regression Model 24

Chapter 4. Results 26
4.1. Phase 1: Applied Thematic Analysis 26
4.1.1. Avalanche Bulletin User Typology 26
Type A: Absent 26
Type B: Base a Go or No-Go Decision on the Danger Rating 28
Type C: Combine the Danger Rating with Avalanche Terrain Severity to Decide if Exposure is Appropriate 31
Type D: Distinguish and Integrate Avalanche Problem Conditions into a Complete Risk Management Framework 34
Type E: Extend Evaluation of Bulletin Information to a Localized Assessment of Avalanche Hazard 36
4.1.2. Respondent Validation 38
4.2. Phase 2: Quantitative Data Analysis 38
4.2.1. Topic Modeling 38

4.2.2. Correspondence Analysis 51
4.2.3. Multinomial Logistic Regression Model 58

Chapter 5. Discussion 62
5.1. The Avalanche Bulletin User Typology as a Stage Theory 62
5.2. Recommendations for Avalanche Bulletin Improvements 65
5.3. Limitations 69

Chapter 6. Conclusion 71

References 74

Appendix A. Recruitment Sign-up Survey Questions 87

Appendix B. Qualitative Interview Script 89
Introduction 0-4 mins 89
Part 1: General Motivation 4-8 mins 89
Part 2: Planning Process 8-18 mins 89
Part 3: Sources of Information 18-28 mins 90
Part 4: ThinkAloud exercise 28-36 mins 91
Part 5: Application activities 36-55 mins 92
Part 6: Evaluation of interview 55 – 58 mins 94
Part 7: Conclusion 58 – 60 mins 94

Appendix C. Elevation Band Photo Sorting Exercise 95

Appendix D. Bulletin Information Application Exercise Using the Ortovox Safety Academy Mountain (SAM) Model 97

Appendix E. Respondent Validation Survey Question 101

List of Tables

Table 1 Comparision of patterns of participant classification between the multinomial logistic regression model and the Avalanche Bulletin User Typology for the Planning Process corpus 58

Table 2 Comparision of patterns of participant classification between the multinomial logistic regression model and the Avalanche Bulletin User Typology for the Information Influence corpus 59

Table 3 Comparision of patterns of participant classification between the multinomial logistic regression model and the Avalanche Bulletin User Typology for the Bulletin Use corpus 59

Table 4 Comparision of patterns of participant classification between the multinomial logistic regression model and the Avalanche Bulletin User Typology for the Group Dynamics corpus 59

Table 5 Distinguishing terms and word importance scores from the logistic regression model for the Planning Process corpus according to bulletin user type 61

Table 6 Distinguishing terms and word importance scores from the logistic regression model for the Bulletin Use corpus according to bulletin user type 61

List of Figures

Figure 2.1 Danger rating product view on Avalanche Canada's bulletin webage (Avalanche Canada, 2018) 8

Figure 2.2 North American Public Avalanche Danger Scale (Stathem et al., 2010) ... 9

Figure 2.3 Wind slab avalanche problem product view on Avalanche Canada's bulletin webpage (Avalanche Canada, 2018) 10

Figure 3.1 Mixed analysis study design 16

Figure 3.2. Ortovox Safety Academy Mountain (SAM) model with route options for the bulletin information application exercise 18

Figure 4.1 Word clouds produced by the topic model for the Planning Process corpus 40

Figure 4.2 The balance of topics across bulletin user types in the Planning Process corpus 41

Figure 4.3 Word clouds produced by the topic model for the Information Influence corpus 43

Figure 4.4 The balance of topics across bulletin user types in the Information Influence corpus 44

Figure 4.5 Word clouds produced by the topic model for the Bulletin Use corpus ... 46

Figure 4.6 The balance of topics across the bulletin user types in the Bulletin Use corpus 47

Figure 4.7 Word clouds produced by the topic model for the Group Dynamics corpus 49

Figure 4.8 The balance of topics across the bulletin user types in the Group Dynamics corpus 50

Figure 4.9 Associations between word frequencies and bulletin user types in the Planning Process corpus 52

Figure 4.10 Associations between word frequencies and bulletin user types in the Information Influence corpus 54

Figure 4.11 Associations between word frequencies and bulletin user types in the Bulletin Use corpus 56

Figure 4.12 Associations between word frequencies and bulletin user types in the Group Dynamics corpus 57

Figure 5.1 Link between the Avalanche Bulletin User Typology and the SOLO Taxonomy (Biggs & Collis, 1982) 64

Chapter 1. Introduction

As the deadliest natural hazard in Canada, snow avalanches pose a risk to public safety (Avalanche Canada, 2018b). While most avalanches leading to fatalities traditionally occurred in the transportation or resource extraction industries, the vast majority of fatal avalanches now involve self-directed backcountry recreationists (Jamieson & Stethem, 2007; Haegeli, 2018). Over the last decade, avalanches in Canada have claimed the lives of an average 11 people per year (Avalanche Canada, 2019), and self-directed backcountry recreationists comprise 92% of these fatalities (Haegeli, 2018). Popular winter backcountry activities include mountain snowmobiling, snowshoe hiking, ice climbing, and backcountry skiing and snowboarding. The mountainous regions of British Columbia, Alberta, Quebec, Newfoundland, and the Yukon have reported growing trends in participation in these activities (Campbell, Bakermans, Jamieson, & Stethem, 2007).

Risk management is critical when traveling in avalanche terrain. In industrial safety contexts (e.g., transportation corridors, infrastructure, resource industries, work sites) and commercial backcountry guiding, the risk from avalanches is typically managed through safety planning and operational programs (Haegeli, 2018). Operational risk management strategies generally involve an ongoing, iterative process of monitoring conditions including weather, snowpack, and recent avalanches and forecasting the severity of avalanche hazard conditions in terms of expected likelihood of avalanches, avalanche size, and runout extent (Statham et al., 2018). Avalanche professionals synthesize this information into an overall picture about the hazard conditions with the goal of minimizing uncertainty as to the spatial and temporal variability of avalanche release, from which they make informed decisions about risk mitigation strategies (Statham et al., 2018).

Unlike the clients on commercially guided backcountry trips where professionally trained guides conduct this process and manage the risk, self-directed backcountry recreationists are responsible for their own risk management (Statham et al., 2018). To mitigate the risks involved in winter backcountry travel, recreationists traveling in snow-covered mountains must independently gather information to plan for travel in appropriate terrain given the conditions and to anticipate the hazard. The availability of

accurate avalanche information as well as the ability to interpret it are both of primary importance to recreationists planning safe backcountry travel.

In western Canada, the not-for-profit organization, Avalanche Canada, and the government agencies, Parks Canada and Alberta Parks, publish daily avalanche bulletins to provide recreationists with the necessary information to enable them to make informed decisions about when and where to travel in the backcountry. Together, these organizations compose avalanche bulletins for 19 different forecast regions covering more than 250,000 square kilometers in western Canada during the main winter months (approximately mid-November to the end of April) (Avalanche Canada, 2018b). The avalanche bulletin offers up-to-date avalanche danger ratings, details about avalanche conditions, travel advice, and weather information. It represents the primary source of information for recreationists assessing avalanche hazard.

The aim of the avalanche bulletin is to consistently communicate sophisticated and accurate avalanche information in a comprehensible format. To be effective, avalanche bulletins must excel in two distinct capacities: (1) providing a consistent, accurate, and unbiased technical hazard assessment by professional forecasters; and (2) communicating the forecasted conditions in a coherent way (Lanzanasto et al., 2018). However, the recreational audience varies widely when it comes to their knowledge, skills, and experience managing avalanche risk. This variation produces differences in information comprehension across the audience and makes communicating coherently a challenge. Responding to differences in recreationists' levels of comprehension, avalanche bulletin designs across North America and Europe have incorporated a tiered format, ordering public safety messages by information complexity (Statham & Jones, 2006; Winkler & Techel, 2014). The tiers of the bulletin's information pyramid prescribe the following design recommendations to maximize comprehension among various audiences: (1) icons, colors, and signal words for entry-level audiences; (2) bulletin information and terrain considerations for users with basic familiarity; and (3) snowpack observations and raw data for advanced users (Statham & Jones, 2006; Statham et al., 2010).

While the bulletin's information pyramid is designed to accommodate differences in recreationists' avalanche risk management knowledge and expertise, existing studies have yet to examine how effectively bulletin information resonates across these

differences. Much of the research on avalanche bulletins has concentrated on establishing formal products (Statham, Campbell, & Klassen, 2012; Statham et al., 2010; Statham et al., 2018; Statham & Jones, 2006; Tremper & Conway, 2006), and founding forecasting programs (Azusa & Yusuke, 2013; Landrø, Kosber, & Müller, 2013; Wikberg & Palmgren, 2016; Winkler, Kuhn, & Volk, 2014). To date, studies specifically evaluating bulletin effectiveness have largely focused on identifying sources of bias or inconsistency in technical assessments (Lanzanasto et al., 2018; Lazar, Trautman, Cooperstein, Greene, & Birkland, 2016; Moner, Orgué, Gavaldà, & Bacardit, 2013; Statham, Holeczi, & Shandro, 2018; Techel et al., 2018). Research with an explicit focus on examining the bulletin's comprehensibility is just beginning to emerge (Burkeljca, 2013; Engeset, Pfuhl, Landrø, Mannberg & Hetland, 2018; Ipsos Reid, 2009; Winkler & Techel, 2014) but has yet to comprehensively analyze these user differences.

Recognizing the need to better understand the risk communication audience, several descriptive studies have aimed to provide more details about the characteristics of recreationists and their specific attitudes toward avalanche risk (Haegeli, Gunn, & Haider, 2012; Mannberg, Hendrikx, Landrø, & Stefan, 2018; Marengo, Monaci, & Miceli, 2017). While offering informative insights, these characterizations have used a person-centered approach that identifies individual qualities rather than a product-centered approach that evaluates the comprehensibility of the information. To better inform targeted improvements to public safety initiatives, McCammon (2009) categorized out-of-bounds skiers/riders according to meaningful differences in the various stages of their precautionary behavior. This marked a transition from describing the characteristics of a risk communication audience to differentiating their behavioral processes, which allowed for more prescriptive design recommendations for effective risk communication interventions. The present study mirrors this process-focused approach by examining differences in the process by which bulletin information is incorporated into recreationists' travel decisions to deepen understanding of the bulletin's comprehensibility and to offer prescriptive suggestions for improvement.

Understanding backcountry recreationists' in terms of their bulletin use and comprehension is particularly useful given the unique challenges in the avalanche risk communication context. In contrast to natural hazards such as tornadoes or hurricanes, the exposure to avalanche hazard in backcountry recreation is voluntary and requires a self-directed process of risk management (Statham et al., 2018). Compared to natural

hazards to which exposure is rare (i.e., volcanic eruptions and earthquakes), for many backcountry recreationists, exposure to avalanche hazard is routine. Despite this repeated exposure, recreationists seldom receive corrective feedback in response to their avalanche risk management decisions, which Hogarth (2001) described as a "wicked" learning environment. In contrast to a "kind" learning environment in which feedback is immediate, accurate, and plentiful, feedback in the snow-covered mountains in response to avalanche risk management decisions is commonly poor, missing, or misleading (Hogarth, Lejarraga, & Soyer, 2015). Adding to the wickedness in the name, when feedback occurs as avalanches, mistakes can be fatal (Mannberg et al., 2018). Within this context of voluntary and repeated exposure to a hazard with high stakes consequences and in a wicked learning environment, the bulletin's capacity to effectively guide recreationists' risk management decision-making carries greater weight.

The currently limited understanding of recreationists' avalanche bulletin use poses a considerable hurdle for evaluating and improving the effectiveness of avalanche risk communication products. The present study aims to address this knowledge gap by explicitly examining the process by which recreationists find, interpret, and incorporate Avalanche Canada's public bulletin information into their travel decisions. The objective of this research is to develop a bulletin user typology by identifying patterns in how recreationists use, understand, and apply the information. By classifying patterns in recreationists' bulletin information seeking and processing behavior, risk communication interventions can more effectively target specific user processes with design improvements.

Chapter 2. Background

2.1. Trends in Backcountry Recreation

Increased participation in winter backcountry activities heightens the need for effective avalanche risk communication interventions. While explicit participation numbers are difficult to pinpoint, industries in North America report rapid growth in equipment expenditures and tourism revenues for winter backcountry activities, signifying that participation is increasing (Winter Wildlands Alliance, 2018). Winter backcountry recreation falls within the broader outdoor recreation industry, which represents a growing sector of the American economy generating $125 billion in tax revenue in 2017 (Winter Wildlands Alliance, 2018). In 2016, sales in winter backcountry equipment increased by over 50% in the U.S. (Winter Wildlands Alliance, 2018). In Canada, Campbell et al. (2007) projected that growing participation in winter backcountry activities will continue.

As the lure of winter backcountry travel captures greater mainstream media attention and gains more widespread popularity (Burkeljca, 2013), the increased numbers of backcountry recreationists constitute a broadening audience. To signify growing mainstream popularity, Gunn (2010) pointed to the emergence of popular media coverage of winter backcountry pursuits as an indicator of a widening public interest, and Strong-Cvetich (2014) cited a rise in snowmobile-related entertainment media, such as videos, publications, and high-profile events. In efforts to increase visitation, ski areas also prominently advertise backcountry-like images and messages, which likely contribute to a growing interest in a backcountry recreation experience (McCammon, 2009).

Continued advancements in technology are expanding backcountry accessibility to a more diverse usership and to newfound modes of travel, contributing to this broadening effect. Research in recreation and leisure emphasizes the important influence of technology on both the amount and type of backcountry recreation participation (Ewert & Shultis, 1999). Recent improvements in equipment quality, availability, and capability, demonstrated by light-weight gear, high-powered snowmobiles, the advent of avalanche airbags, and the convenience of satellite communication devices, have played a role in facilitating backcountry travel by

increasing comfort, access, and safety (Ewert & Shultis, 1999; Haegeli et al., 2014; Ng, Smith, Wheeler & Macintosh, 2015, Martin & Pope, 2012; Strong-Cvetich, 2014). Additionally, the emergence of new recreational activities, such as snow kiting, speed flying, and snow biking, exposes more recreationists to avalanche hazard and introduces unforeseen modes of travel into previously inaccessible areas (Carter, Milton, & Hanke, 2014). The issue that arises with the advent and growth of each new activity is that recreationists often gain access to avalanche terrain before they develop an awareness of avalanche hazard or the skills to manage it (Carter et al., 2014). This continual evolution in participation and technology presents a challenge to maintaining effective risk communication strategies.

With growing participation in backcountry recreation, public engagement with Avalanche Canada's public safety initiatives has exhibited a marked increase. Avalanche Canada reported an 81% increase in bulletin website page views between the 2016-2017 and 2017-2018 winter seasons, and enrollment in their recreational avalanche education courses in 2017-2018 has more than doubled over the last ten years (Avalanche Canada 2018a; Canadian Avalanche Centre, 2013). Despite the surge in webpage activity, studies that have intercepted recreationists in the backcountry reveal that their use and recollection of avalanche bulletin information still has room for improvement. In a popular lift-accessed backcountry area, Sykes, Hendrikx, Johnson, and Birkland (2018) calculated that the proportion of participants who could correctly recite the forecasted avalanche danger rating was 64%, which is similar to the 67% found by Fitzgerald, Kay, Hendrikx, and Johnson (2016). Interestingly, previous work by Procter et al. (2014) in the European Alps identified that more skiers than snowshoers could recall the danger level (53% versus 28% of groups). Understanding these differences in information use and recollection across the range of backcountry users is necessary to improve the effectiveness of public avalanche safety initiatives.

Given the expansive trends in winter backcountry recreation, the fact that the average number of avalanche fatalities in Canada over the past decade has gradually declined offers a promising trend (Avalanche Canada, 2019). Since the winter of 2004-2005, the ten-year moving average has steadily decreased from 16 avalanche fatalities to 11 in 2018-2019 (Avalanche Canada, 2019). While fatality averages, page views, and enrollment numbers may offer encouraging metrics, they may not reveal the data most needed to improve public avalanche safety. For example, corresponding with the rise in

snowmobiling popularity, snowmobilers accounted for a significant proportional increase in recreational avalanche fatalities in Canada over the last decade, with the 2008-2009 season resulting in a record number of snowmobiler deaths and 78% of avalanche fatalities that year (Strong-Cvetich, 2014). Jekich et al. (2016) noted a similar shift in recreational avalanche accidents in the U.S., with snowmobilers replacing backcountry skiers/riders as the largest cohort killed by avalanches. These shifts signal important opportunities to examine how risk information resonates across recreational activity types and to target meaningful improvements.

As trends in participation growth, audience diversification, and technological advancement are expected to continue, it is important that avalanche safety initiatives identify and address barriers to effective risk communication as they evolve. Backcountry recreationists constitute the primary group at risk in Canada and remain at the forefront where public safety initiatives can make improvements. Understanding the recreational audience in terms of how they use bulletin information is a critical first step.

2.2. Avalanche Canada's Bulletin Design and Public Safety Initiatives

Responding to differences in audience comprehension, Avalanche Canada's daily bulletin organizes regional hazard information into an information pyramid comprised of three tiers. Introduced in North America in 1994 and re-designed in 2010, the North American Public Avalanche Danger Scale (NAPADS) comprises the first tier designed to alert the public to the general avalanche conditions (Statham & Jones, 2006; Statham et al., 2010). It provides a relative measure of avalanche danger with a basic ranking for a mountain region over a given period of time (Statham et al., 2010). Avalanche Canada's bulletin provides danger ratings for each forecast region and for alpine, tree-line, and below tree-line elevations, as well as a two-day forecasted danger rating outlook (Figure 2.1). The danger rating is communicated with a color-coded, five-level, ordinal scale, labeled with the corresponding signal words: *low*, *moderate*, *considerable*, *high*, and *extreme* (Statham et al., 2010) (Figure 2.2). Green, yellow, and red colors are applied to the danger ratings *low*, *moderate*, and *high* to establish universally understood associations with the actions go, caution, and stop (Conger, 2004). However, as evident in initial efforts to evaluate the design of this scale, the *considerable* danger rating and corresponding orange color-coding are subject to wide

variation in comprehension among backcountry recreationists (Conger, 2004; Ipsos Reid, 2009). To more explicitly define recommended actions beyond color correlations, the NAPADS defines what the avalanche conditions are in terms of likelihood and size and offers advice on how to travel (Statham et al., 2010) (Figure 2.2). Given the generic nature of this product, one of the principal objectives is to establish awareness in users that safe and informed backcountry travel decisions must be supported with additional information and to motivate recreationists to learn more (Statham & Jones, 2006).

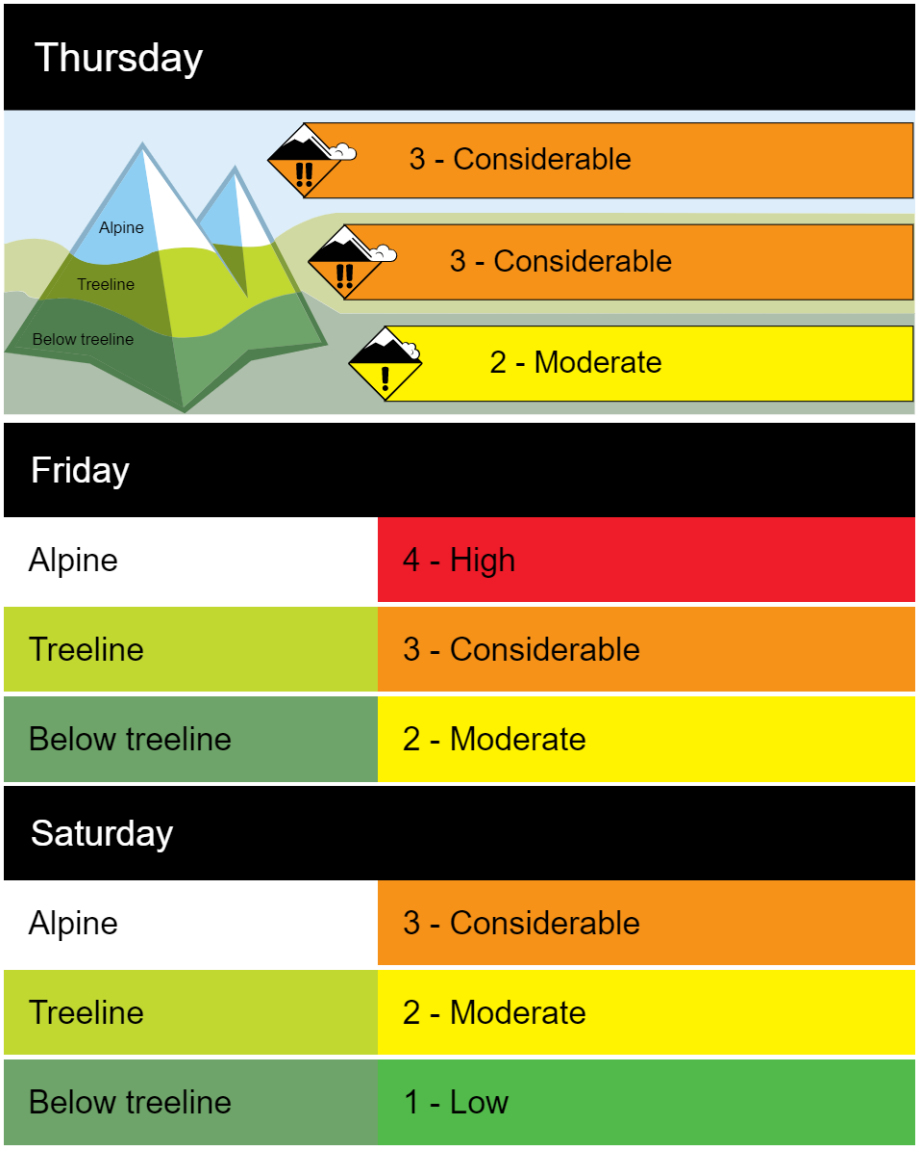


Figure 2.1 Danger rating product view on Avalanche Canada's bulletin webage (Avalanche Canada, 2018)

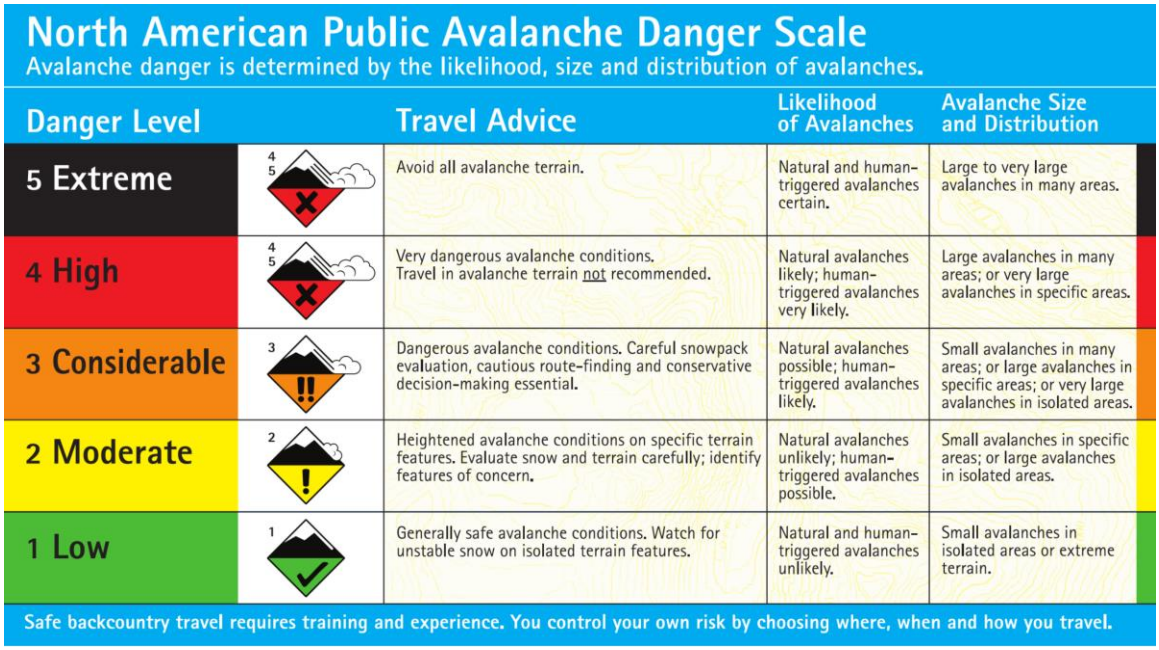


Figure 2.2 North American Public Avalanche Danger Scale (Stathem et al., 2010)

Avalanche problem information comprises the second tier of the bulletin information pyramid. Widely adopted by North American avalanche warning services over the last decade, the avalanche problems integrate the Conceptual Model of Avalanche Hazard (CMAH) (Statham et al., 2018) into a graphical representation of the hazard conditions. The CMAH establishes a step-by-step process founded in risk-based systems theory to standardize a forecasting workflow, to direct how hazardous conditions are characterized, and to establish a meaningful link to mitigation practices (Statham et al, 2018). To integrate the CMAH into the bulletin's design, the information icons organize avalanche hazard into the following four key considerations to guide recreationists with their travel decisions: (1) what kind of avalanche is expected (i.e., avalanche problem type); (2) where the problem exists in the terrain (i.e., elevation and aspect); (3) the likelihood that an avalanche will occur (i.e., *unlikely*, *possible*, *likely*, *very likely*, *certain*); and (4) how large an avalanche is expected to be (i.e., *small*, *large*, *very large*) (Statham et al., 2018) (Figure 2.3). This information is then translated into explicit terrain and travel advice to guide appropriate mitigation strategies (Klassen, Haegeli, & Statham, 2013; Wagner & Hardesty, 2014). Avalanche Canada's daily bulletin discusses up to three out of a possible eight avalanche problems in decreasing order of concern.

While there is agreement across the industry that avalanche problem information may not be fully grasped or practiced by the recreational community (Haegeli & Strong-Cvetich, 2018; Klassen et al., 2013; Wagner & Hardesty, 2014), the product is designed to help recreationists determine appropriate terrain choices and mitigation strategies given the nature and distribution of the avalanche conditions.

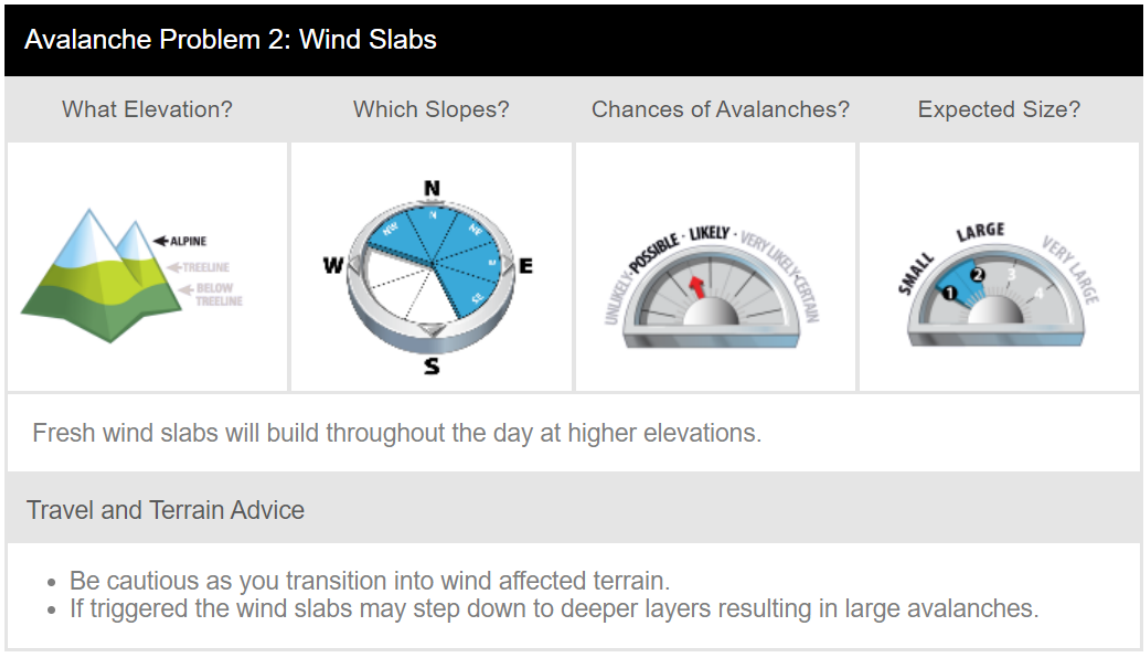


Figure 2.3 Wind slab avalanche problem product view on Avalanche Canada's bulletin webpage (Avalanche Canada, 2018)

The third tier of Avalanche Canada's bulletin compiles relevant snowpack observations and recent avalanche activity into detailed summaries for advanced users. These text-based descriptions offer supporting evidence for the assigned danger ratings and avalanche problem icons. They also provide links to specific observations on the Mountain Information Network (MIN), Avalanche Canada's web-based platform for information sharing, as well as to an in-depth weather analysis. These products serve bulletin users looking to conduct an individual assessment of raw data and to identify sources of uncertainty.

Recognizing the limitations of avalanche bulletin products, Avalanche Canada has developed an integrated suite of products and programs to augment and

complement the information from the daily bulletin to further support recreationists' risk management decision-making (Avalanche Canada, 2018b). For example, recreational avalanche education courses teach a foundational risk framework for deconstructing scenarios, fostering a fundamental risk fluency to ease communication (Statham & Gould, 2016). Additionally, local-level decision support tools have been developed to address the shortcomings of regional forecasts for making slope-scale assessments (Haegeli, 2010), and an online trip planner with avalanche terrain severity ratings (i.e., *simple*, *challenging*, *complex*) has been included on the bulletin website to help recreationists to more directly link the avalanche hazard to terrain selection (Klassen, 2012; Statham, McMahon, & Tomm, 2006). Recent developments in awareness campaigns have also incorporated social media outreach to explicitly model appropriate decision-making behavior in the field (Avalanche Canada, 2019; Coulter & Hegelson, 2018). The present study offers foundational insight into the effectiveness of this integrated approach.

2.3. Research in Risk Communication

Effective risk communication has been the focus of extensive research in the risk domain with strong connections to decision theory. Early constructs emphasized information transferral through message content (Shannon, 1948) and fit with normative theories in decision science in which audiences were believed to be rational actors optimizing their decisions in a calculated way (Simon, 1947). However, the limited success of this content-driven approach gave rise to descriptive approaches demanding a deeper understanding of the communication and decision-making contexts (Fischhoff, 1995; Morgan, Fischhoff, Bostrom, & Atman, 2002; Tversky & Kahneman, 1974). Current best practices in risk communication embrace a broader perspective than information transferal and analyze factors such as risk perception, trust, affect, and efficacy (Bandura, 1977, Maddux & Rogers, 1983; Slovic, 1987; Wachinger, Renn, Begg, & Kuhlicke, 2013).

A systematic methodological approach that emerged from this descriptive movement is the Mental Models Approach to Risk Communication (MMARC) (Morgan et al., 2002). Organized to identify and evaluate risk communication effectiveness, the MMARC establishes the following five-step process: (1) create an expert model to describe best practices and establish a reference for comparison, (2) conduct qualitative

interviews to construct public mental models, (3) design and distribute a structured survey to assess a broader population, (4) draft alternate risk communications, and (5) evaluate the new communication formats (Morgan et al., 2002). Since its development in the 1990s, researchers have applied the MMARC to a wide range of areas including the communication of health, technological, and environmental risks (Boase, White, Gaze, & Redshaw, 2017). Recent studies in risk communication for natural hazards such as flash floods, hurricanes, and wildfires have utilized the MMARC to contrast public perceptions of the hazards with expert knowledge to identify opportunities for improvement (e.g., Bostrom, Morss, Lazo, Demuth, & Lazrus, 2016, 2018; Lazrus, Morss, Demuth, Lazo, & Bostrom, 2016; Morss, Demuth, Bostrom, Lazo, & Lazrus, 2015; Morss et al. 2016; Steelman & McCaffrey, 2013).

While applying the MMARC to avalanche risk communication invites an opportunity to gain valuable insight for how to improve the presentation of avalanche safety information, this systematic approach has yet to be applied. However, existing descriptive studies of decision-making in the avalanche domain have examined differences between experts and novices and have concluded that they use different decision-making strategies (Adams, 2004, 2005; Atkins & McCammon, 2004; Engeset et al., 2018; Furman, Shooter, & Schumann, 2010; Haegeli, Haider, Longland, & Beardmore, 2010; Hallandvik, Andresen, & Aadland, 2017). Haegeli et al. (2010) found that user groups apply different decision-making strategies depending on their training, experience, and recreation preferences. Hallandvik et al. (2017) concluded that novices and experts consider different information in the avalanche forecast important and use different strategies to gather information about avalanche risk on a trip. These dualistic comparisons between experts and novices offer limited insight into meaningful distinctions across the community of backcountry recreationists, the primary audience of public avalanche bulletins.

More recently, research into the ways people seek and process information has emerged to enhance understanding of decision-making behavior and risk communication effectiveness. In the field of decision science, dual-process theories in human reasoning have established two systems of thinking: System 1 is fast, intuitive, and emotional; System 2 is slower, more deliberative, and more logical (Kahneman, 2003, 2011; Kahneman & Frederick, 2002). In the field of risk communication, the emphasis on information processing has taken form in behavioral models that capture

structural relationships between the constructs identified in descriptive studies with a more process-driven perspective, such as the Risk Information Seeking and Processing Model (RISP) (Griffin, Neuwirth, Dunwoody, & Giese, 2004; Yang, Aloe, & Feeley, 2014), the Protective Action Decision Model (PADM) (Lindell & Perry, 2011), and the Planned Risk Information Seeking Model (PRISM) (Kahlor, 2010). These models target the role of information in behaviors on the assumption that much can be gained from deepening our understanding of how people reason with information. However, for many of these models, the constructs are represented as a linear continuum despite concern that the processes that produce these behaviors are not (Weinstein, Rothman, & Sutton, 1998). In response to this limitation, a number of stage theories have been developed that identify discontinuous relationships between moderators and resulting behavior, such as the Health Adoption Process Model (Schwartzer, 2001; 2008) and the Precaution Adoption Process Model (PAPM) (Weinstein & Sandman, 2002), which have experienced growing empirical support (Glanz, Rimer, & Lewis, 2002). McCammon (2009) demonstrated these gains for public avalanche safety by outlining the stages in out-of-bounds skiers/riders' precautionary behavior using the Precaution Adoption Process Model and by offering a more constructive understanding of the audience for designing effective interventions. By classifying bulletin use processes into a user typology, our approach can identify discontinuities in the relationship between bulletin information use and planning behavior, establishing a foundation of knowledge for evaluating effectiveness.

The present study integrates three theoretical elements from the risk domain into an exploratory approach and foundational first step for identifying and evaluating improvements to the avalanche bulletin: (1) the MMARC framework to establish a foundational understanding of the audience using qualitative interviews, (2) a process-centered focus on finding patterns in how recreationists' incorporate bulletin information into travel decisions, and (3) a capacity to identify discontinuous differences in bulletin use processes across the audience. Rather than a descriptive study of the knowledge deficit between experts and audiences, the present study integrates a focus on a behavioral process into an established theoretical framework for evaluating effectiveness. The proposed approach targets differences in recreationists' bulletin use that offer constructive insight into how to improve risk messages to affect behavioral change.

Chapter 3. Methodology

To date, studies of avalanche risk communication have employed solely quantitative approaches using primarily survey instruments (e.g., Burkeljca, 2013; Duncan & Stewart-Patterson, 2016; Engeset et al., 2018; Haegeli et al., 2012; Haegeli & Strong-Cvetich, 2018; Hallandvik et al., 2017; Proctor et al., 2014; Wikberg, Palmgren, Hallberg, Maartensson, & Nordlund, 2018; Winkler et al., 2014; Winkler & Techel, 2014) and accident analyses (Eyland, 2018). While these studies offer valuable insight, their perspective is limited as it is difficult to capture the complex interplay of perceptions, interpretations, and decision-making inherent to recreationists' avalanche risk information seeking and processing behavior in a survey format.

Social science research has established qualitative inquiry as an effective approach for identifying patterns, making thematic connections, and offering insight into human behavior (Arksey & Knight, 1999; Denzin & Lincoln, 2007; Flicke, Kardoff & Steinke, 2004; Saldana, 2009). Specifically, qualitative interviews offer an instrument for uncovering meanings that underpin individual perceptions and behaviors, allowing researchers to explicitly explore relationships that are often implicit (Arksey & Knight, 1999). The Mental Models Approach to Risk Communication (MMARC) (Morgan et al., 2002) supports the value of this design instrument, prescribing qualitative interviews to examine what people know and need to know for managing a risk as the basis for effective risk communication. Despite the strength of the qualitative inquiry approach and its broad application in the risk communication field, there are few qualitative studies in public avalanche safety research. For example, McCammon (2009) employed focus groups and expert interviews to examine the out-of-bounds avalanche risk environment, Zweifel and Haegeli (2014) employed semi-structured group interviews to examine group decision-making behavior, Maguire (2014) used narrative inquiry to explore recreationists' experiences with in-depth interviews, and Michaelsen and Rolland (2016) employed ethnographic participant observation of backcountry recreationists' travel behavior. The effectiveness of avalanche bulletins has yet to be examined qualitatively.

To create a robust and rich foundation for improving avalanche risk communication, the present study combines both qualitative and quantitative elements to identify and classify recreationists' patterns of bulletin use into a user typology (Figure

3.1). A team of two researchers conducted 46 one-hour-long, individual, semi-structured interviews, which were designed to collect detailed information on how backcountry recreationists use, understand, and apply avalanche bulletin information. The subsequent mixed analysis involved two ordered phases: (1) a qualitative applied thematic analysis of the interview data as a whole to identify patterns of bulletin use and to establish a classification system; and (2) a quantitative analysis of specific interview sections generated by the initial analysis to further explore, visualize, and characterize the bulletin user typology (Figure 3.1). The qualitative applied thematic analysis directed an interpretive process, applying structural and content coding to identify, order, and match implicit and explicit ideas present in the data to establish the bulletin user typology. The quantitative analysis approaches included: (a) a topic model to deepen the thematic exploration with a statistical algorithm that identifies probabilistic clusters of words as themes, (b) a correspondence analysis to illustrate associations between words and among bulletin user types with a graphical representation of a frequency table, and (c) a multinomial logistic regression model to provide an additional perspective on the classification system by explicitly highlighting words that distinguish classes. To further substantiate the typology, I incorporated respondent validation by contacting interview participants via email and asking them to self-identify with a bulletin user type using a single survey question design (Appendix E). The combination of qualitative and quantitative components included in the analysis—Onwuegbuzie and Combs (2011) describe it as a qualitative-dominant, sequential mixed analysis with the subsequent quantitative phase offering complementary insights—aims to yield stronger inferences and cultivate a more coherent and meaningful understanding of the avalanche bulletin user types than individual analyses could provide on their own (Figure 3.1). Readers interested in a more in-depth discussion of the mixed analysis research approach are referred to Creswell and Clark (2007), Onwuegbuzie and Combs (2011), and Onwuegbuzie and Teddlie (2003).

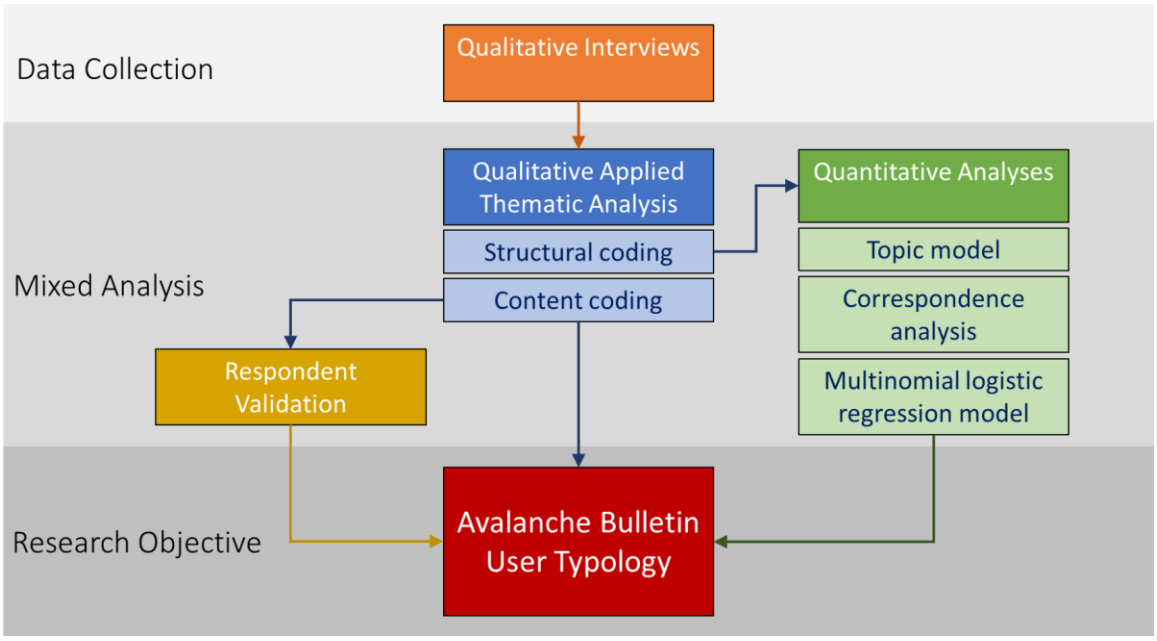


Figure 3.1 Mixed analysis study design

3.1. Data Collection

3.1.1. Study Recruitment

The research team recruited participants for the study in the Lower Mainland and Sea-to-Sky Corridor regions of southwestern British Columbia in the spring of 2018. We promoted our study through popular communication channels of backcountry users, including a banner on Avalanche Canada's website, social media outreach, direct contact with local clubs and outdoor organizations, and support from local avalanche education course providers. However, existing studies (e.g., Furman et al., 2010; Haegeli et al., 2012; Winkler & Techel, 2014) have highlighted that these recruitment channels tend to result in participant groups that are biased towards committed recreationists with an established interest in avalanche safety. To round out the sample, we spent considerable effort connecting with users who might not be reached through the traditional communication channels. This involved getting in contact with local outdoor clubs with broader connections to winter recreation in avalanche terrain (e.g., hiking clubs) and in-person recruitment at two popular snowshoe and snowmobiling trailheads.

All interested individuals were asked to complete a sign-up survey, which collected information on primary activity, years of experience traveling in the backcountry, level of formal avalanche awareness, and the frequency with which participants reference the avalanche bulletin (Appendix A). The resulting pool of 180 prospective participants and corresponding information enabled us to put together a sample of 46 interviewees that encompassed an inclusive range of recreationists. Even though the recruitment efforts were spatially limited, the larger population of more casual backcountry users in the metropolitan area of Vancouver allowed us to assemble a group of participants that accounted for the diversity in skills, activities, and levels of experience observed in the winter backcountry recreation community.

3.1.2. Interview Script Design

Through team-based development and pre-testing, the research team designed an hour-long, semi-structured interview script divided into seven ordered sections: (1) participant background information including activity type, trip frequency, and years of experience; (2) a discussion of participants' planning processes and considerations when preparing for backcountry travel; (3) an outline of participants' information sources and the role of the information in their travel decisions; (4) an in-depth review of avalanche bulletin product use and comprehension; (5) bulletin information application activities; (6) a discussion of how social factors may or may not influence information seeking and processing behavior; and (7) an opportunity for participants to provide feedback for bulletin products or for the research in general (Appendix B). The interview script followed best practices as outlined by Morgan et al. (2002). For example, to control for reactivity, the questions for the initial discussions about participants' planning process (Section 2) avoided hints about what topics should be addressed or what language should be used, and we purposely omitted mention of Avalanche Canada's bulletin products. To explore bulletin use and comprehension in Section 4, we incorporated a Think Aloud activity (Ericsson & Simon, 1998), in which participants detailed their thought processes as they utilized a mock Avalanche Canada bulletin website. We followed this activity with questions about specific products to uncover tacit understandings and to elicit feedback. To further stimulate the conversation, Section 5 included two application activities: (1) a photo sorting exercise of terrain images to explore participants' understanding of elevation bands (Appendix C), and (2) a bulletin

information application exercise to examine how participants apply the information to a three-dimensional application context (Appendix D). Using the Safety Academy Mountain (SAM) 3D model developed by Ortovox as a prop (Ortovox, 2019), we asked participants to locate the hazardous areas given the bulletin information, discuss the terrain they would choose to avoid under the given avalanche conditions in the context of four established route options, and detail the reasons for their terrain avoidance (Figure 3.2).

Figure 3.2. Ortovox Safety Academy Mountain (SAM) model with route options for the bulletin information application exercise

3.1.3. Sample Overview

Two researchers conducted 48 interviews in the municipalities of Vancouver, Squamish, and Whistler in the spring of 2018 and winter of 2019. All interviews were transcribed verbatim, except two, due to concerns with coherence and suitability to the study. The final sample of 46 backcountry recreationists included 20 backcountry skiers

or snowboarders, 12 snow-shoe hikers, 10 mountain snowmobilers, and four ice climbers. Participants encompassed a wide range of ages from 20-55+ and comprised two gender identities, including 27 participants (59%) identifying as men and 19 (41%) as women. In addition to frequently engaged or formally trained recreationists, the sample had representation from less engaged or more entry-level winter backcountry users, including 14 participants with no formal avalanche training, as well as four participants who reported never using the avalanche bulletin and five participants who reported rarely using it.

3.2. Phase 1: Applied Thematic Analysis

3.2.1. Identification of the Avalanche Bulletin User Typology

To systematically, inductively, and meaningfully reduce the volume of the interview transcripts and to organize the content into connecting threads to explore relationships and construct the bulletin user typology, I conducted an applied thematic analysis (Guest, MacQueen, & Namey, 2012). Guest et al. (2012) summarized the goal of this analytic approach as clearly mapping "the path between theory and the way data were collected, between data collection and the resulting evidence, and between the evidence and theories about what it all signifies" ("Linking Themes to Theoretical Models," para. 1). Applied thematic analysis directs an interpretive process in which the researcher identifies, orders, and matches implicit and explicit ideas through structural and thematic coding. Therefore, this method incorporates the qualitative research principle of grounded theory for improved research credibility, whereby researchers gather data and generate theories from within the research process that are grounded in the data (Glaser & Strauss, 1967). Thematic analysis is commonly used to analyze qualitative data in research in psychology, public health, and policy (Braun & Clarke, 2006, 2014; Herzog, Hanke, & Hitters, 2019). Of greater relevance to our study, researchers have employed applied thematic analysis to study risk communication in the context of health risks and natural hazards, such as cancer risk (Wilbur et al., 2018), disaster management (Sitas et al., 2016), and tsunami hazard (Paton et al., 2017).

To establish the link between the data collection and the generated evidence, I applied structural coding as the first cycle coding method. Structural coding segments the text based on the questions defined by the interview design as a way to facilitate the

exploration of thematic elements (Guest et al., 2012). I applied content coding as the second cycle coding method, which I used to identify and match references to bulletin use behavior present in the structural codes. Content coding finds connections between the evidence and their significance by linking data to an idea and then to all subsequent data that pertain to that idea (Guest et al., 2012; Saldana, 2009). Through multiple, iterative coding cycles, I synthesized themes across codes and classified them into distinguishable patterns of avalanche bulletin use. I then identified each interviewee in one of the classified bulletin use patterns. I performed the thematic analysis in NVivo 12 (QSR International, 2018) qualitative data analysis software.

3.2.2. Respondent Validation

To evaluate the participant classifications established by the applied thematic analysis, I utilized a method referred to as member checking or respondent validation (Guest et al., 2012; Saldana, 2009), in which interviewees review the summarized data for confirmation of the interpretations and meanings. To do this, I reconnected with the participants via email during the following winter season. I composed a list of statements distinguishing each pattern of bulletin use, which I organized into a single survey question. I prompted participants to select the statement best reflecting their approach (Appendix E). The responses allowed for a comparison between participants' self-identified bulletin user type and their assigned classification per the qualitative analysis.

3.3. Phase 2: Quantitative Data Analysis

3.3.1. Text Preprocessing and Data Transformation

The objective of the quantitative analyses was to examine how different sections of the interview script played a role in distinguishing the bulletin user typology that emerged from the applied thematic analysis. To prepare the text data for these analyses, I created separate text corpora (i.e., structured sets of text) for the following four structural sections of the interviews:

- *Planning Process*: participants' descriptions of their trip planning process;
- *Information Influence*: participants' discussions as to how information sources play a role in their decisions;

- *Bulletin Use*: participants' responses to the Think Aloud activity, detailed bulletin product questions, the bulletin information application exercises, and product feedback;
- *Group Dynamics*: participants' descriptions of their role in group decision-making and the role of information within those contexts

Each of these text corpora consisted of a selection of interview responses, organized by the qualitative structural coding and labeled with the associated avalanche bulletin user type.

I performed standard text mining pre-processing procedures to facilitate the efficiency of analysis and the clarity of interpretation (Franz, Nook, Mair, & Nock, 2019). I removed punctuation, numbers, capitalization, and highly common terms (i.e., *but*, *for*, *the*, *that*) known as stop words, and I separated contractions. Additionally, I customized the stop words list by removing words present in the text that offered minimal contextual contribution for distinguishing differences in bulletin use. I organized these words into the following categories: (a) fillers (i.e., *arghh*, *mmm*, *ooo*), (b) names of individuals, (c) references to specific locations (i.e., *Vancouver*, *Mount Harvey*, *British Columbia*), (d) words specifically relating to activity type (i.e., *snowmobile*, *hike*, *ski*), and (e) references to interview props (i.e., *PhotoA*, *RunB*). Finally, to retain meaning from relevant multi-word descriptors, I combined words into a representative term where necessary, such as *avalanchecanada* and *belowtreeline*.

The resulting text body allowed for the construction of a document term matrix (DTM) for each text corpus. DTMs are two-way contingency tables that present the frequency of words in columns and bulletin user types or individual participants in rows. Hence, they reflect how often each word was mentioned by the different avalanche bulletin user types or by the individual participants. I computed both the text preprocessing and all of the subsequent quantitative analysis using R statistical software (R Core Team, 2019).

3.3.2. Topic Modeling

Topic modeling is an emerging natural language processing technique to uncover hidden semantic structures in a collection of documents (Blei, 2012; Franz et al., 2019; Mair, 2018; Steyvers & Griffiths, 2007). Topic models originate in unsupervised

statistical clustering, and their central idea is that a topic is a probabilistic distribution over words occurring in a document (Steyvers & Griffiths, 2007). As Blei (2012) explains, “The central computational problem for topic modelling is to use the observed words in a text body to infer the hidden topic structure” (p. 79). Topic models perform this computation on a DTM with latent Dirichlet allocation (LDA), which applies statistics from the frequencies of the words spoken by participants to (a) characterize what the generated topics might be based on words that occur together and to (b) analyze the balance of topics spoken by each bulletin user type (Blei, Ng, & Jordan, 2003; Franz et al., 2019; Mair, 2018). Prior to the analysis, the number of topics is set by the researcher using one of several metrics to estimate the optimal number of topics and maximize interpretability (Mair, 2018). The results of topic models are often illustrated with word clouds, which assist in the interpretation of the identified topics by highlighting dominant words, and heat maps, which show the associations between topics and documents.

Topic models are commonly employed in the field of social media analytics (e.g., Myslin, Zhu, Chapman, & Conway, 2013; Paul & Dredze, 2011), and in meta analyses of research trends (e.g., Anupriya & Karpagavalli, 2015; Lee, Jung, & Song, 2015). Within risk research, topic models have been incorporated in studies of health risk education (Kandula, Curtis, Hill, & Zeng-Treitler, 2011), health risk behavior (Paul & Dredze, 2011), climate change risk perception (Cody, Stephens, Bagrow, Dodds, & Danforth, 2017; Tvinnereim & Fløttum, 2015; Tvinnereim, Fløttum, Gjerstad, Johannesson, & Nordø, 2017), organizational culture (Schmiedel, Müller, & Brocke, 2018), and cybersecurity (Kolini & Janczewski, 2017). Given the computational power for open-ended inquiries, topic models offer promising potential to the study of risk communication, though they have yet to be applied to the discipline. While closed-ended survey questions are limited to measuring predefined constructs (Schmeidel et al., 2018), topic models offer the possibility of inductively capturing what an audience deems most relevant about a risk context or communication product.

For the present study, I computed a topic model to identify general topics discussed in the four corpora and to quantify how the various bulletin user types discuss the identified topic. I conducted the analysis in R using the TopicModels package by Grün and Hornik (2011). I utilized the FindTopicsNumber function in the ldatuning package (Murzintcev, 2019), which creates a random process that iteratively generates and refines its own solution in order to find the best fit for the number of topics (Franz et

al., 2018). To make the computations more efficient, I only included the 50% most important (i.e., most frequently used) words from the DTM in the analysis. I identified these words by computing the tf-idf (term frequency-inverse document frequency), a numerical statistic that is calculated to reflect the importance of a word in a document and that is designed to meet this computational need for reduction (Mair 2018). To illustrate the results of the analysis, I produced word clouds of the emergent topics in each corpus and a heat map to visualize the extent to which the identified topics were present in the responses of each bulletin user type.

3.3.3. Correspondence Analysis

I conducted a correspondence analysis on each of the four corpora to visualize the association between bulletin user types and word frequencies. Correspondence analysis is an exploratory data technique used to analyze and graphically display a two-way contingency table to represent relationships among categorical data (Becue-Bartuat, 2019; Greenacre & Blasius, 1994; Mair, 2018). Correspondence analysis has been commonly used in psychological and ecological research (Greenacre, 2007; Mair & von Eye, 2007) and has been applied in risk research to examine risk perceptions of food-related hazards (Frewer, Howard, Hedderley, & Shepherd, 1997; Tiozzo, Mari, Ruzza, Crovato, & Ravarotto, 2017) and to investigate the relationship between keyword categories among risk communication publications (Gurabardhi, Gutteling, & Kuttschreuter, 2004). I used the anacor package in R (de Leeuw & Mair, 2009) to compute the analysis.

Correspondence analysis calculates relationships between documents and words in terms of their deviation from the average (i.e., independence) and plots a geometric representation of these relationships (Becue-Bartaut, 2019). To produce the visualization, each row and column of a DTM become a point on a multidimensional graphical map, or biplot, consisting of two or three dimensions (Doey & Kurta, 2011). In the resulting display, rows (i.e., words) with comparable values have points in proximity, and columns (i.e., bulletin user types) with comparable values have points in proximity (Doey & Kurta, 2011). Yet, while the row and column points are shown on the same graphical display, their relativities may differ, and the distance between them may not accurately represent their association. However, the Eigenvalues emerging from the analysis represent the relative dispersion (i.e., principal inertia) of the row and column

profiles, and in cases where the Eigenvalues are similar, associations between the row and column points on the resulting biplot can be interpreted (Mair, 2018).

While correspondence analysis performs the analysis on all words in the corpus, in the final steps to produce a graphic, I opted to plot a select number of words so as not to overwhelm the visualization. To make this selection, I incorporated the results from the topic model for a meaningful illustration, and I plotted 5-7 words per topic depending on the number of topics. While the word selection is a product of the topic model, the distances between words, distances between bulletin user types, and the positions of words and bulletin user types relative to the origin are a representation of the correspondence analysis.

3.3.4. Multinomial Logistic Regression Model

To more explicitly examine the relationship between words contained in an individual's interview responses and his or her bulletin use classification, I computed a multinomial logistic regression model. Multinomial logistic regression is used to examine the relationship between one or more predictor variables (nominal, binary, ordinal or interval) and a nominal response variable (Hosmer & Lemeshow 2000; James, Witten, Hastie, & Tibshirani, 2013). This method fits with the present study in that the predictors consist of the presence or absence of words (binary) and the response variable is the multi-category avalanche bulletin user type (nominal). I performed this analysis in R using the pROC (Robin et al., 2011) and glmnet (Friedman, Hastie, & Tibshirani, 2010) packages.

Building on the unsupervised and descriptive statistical methods at the bulletin user level from the topic model and correspondence analyses, the inclusion of the logistic regression model adds a supervised, inferential statistical technique computed at the participant level, enhancing the complementarity of the overall quantitative analysis. Researchers in public health have similarly paired combinations of topic models or correspondence analysis with logistic regression. For example, Steyn, Kazenellenbogen, Lombard, and Bourne (1997) used correspondence analysis and logistic regression to identify people with multiple risk factors for chronic disease, and Franz et al. (2019) combined topic models with logistic regression to identify and validate suicidal thoughts and behaviors discussed by adolescents on digital platforms. While logistic regression

models are commonly used to quantify predictive capacity, I employed this technique with a more exploratory aim to investigate rather than to verify patterns of classification.

The model-building process consisted of several steps. As with the topic model, I first reduced the complexity of the analysis by computing the tf-idf statistic to find the 50% most frequently used words. Next, I applied a lasso approach to shrink the regression coefficients of irrelevant words to zero and to yield a model that only includes relevant predictor variables (James et al., 2013). To estimate the skill of the classifier model during the lasso iterations, I used a standard k-fold cross-validation technique dividing the dataset into 10 parts (where k =10). I then applied cross-validation to ensure the λ value for the lasso was optimal for a meaningful outcome (James et al., 2013). While cross-validation is commonly used to validate a model, here, I applied the method only to optimize the lasso.

The final step of the analysis identified words of importance in classifying each bulletin user type. This involved computing the statistical significance of each word with respect to its effect on the generated model, which is reflected by a score between 0 and 100. To extract the variable importance per bulletin user type, I used the varImp function in the caret package in R (Kuhn, 2019). The results are displayed in a table, which correlates predictive terms with their word importance score and associated bulletin user type.

Chapter 4. Results

4.1. Phase 1: Applied Thematic Analysis

4.1.1. Avalanche Bulletin User Typology

The applied thematic analysis identified a five-class hierarchy in recreationists' patterns of avalanche bulletin use, increasing in the complexity of how recreationists use, understand, and apply the information. The resulting Avalanche Bulletin User Typology encompasses information seeking and processing behaviors that range from the absence of bulletin information consultation to the use of the information as a starting point of personal information gathering for a comprehensive risk management strategy and iterative hazard assessment. The five classes of the avalanche bulletin user typology are detailed as follows.

Type A: Absent

Type A recreationists do not consult formal avalanche bulletin products to make backcountry travel decisions. However, they may intercept bulletin information through other channels, such as the newspaper, radio, or trailhead signage. A non-use behavior pattern determined membership in this class.

> If the radio is on, then I hear it. Or… if avalanches are *high* in the coastal mountains, it's in the newspaper.
>
> One thing I've noticed is that when it is risky, it almost always ends up on the news. …And then when it's not a risk, it is not on the news, and then I will just rely on… those slider boards where it's red, green or orange.
>
> There's a sign on the highway when you drive in that lists the risk. Sometimes you hear it on the news, like they will tell you when it's higher risk in the backcountry…. But that's where I hear it. I don't check websites.

Their reasons for not using the product are varied. For example, one participant was not aware that avalanche risk communication products are produced for her benefit.

> Okay, so this exists? I obviously haven't looked at it.

Several Type A participants were aware of avalanche hazard and risk communication outreach, but they did not consider it relevant to where they travel or to their specific activity type.

> I usually don't think that it's that relevant to where we go.
>
> When we ice climb …we don't check the avalanche forecast. …We don't really have conversations about it. …Not to the extent like… actually not at all.
>
> I think for a recreational snowshoer …it's hard to believe that it would be relevant to where you are going.

While recreationists' lack of awareness is a more common assumption as to why they do not consult the avalanche bulletin, recreationists' perceptions of information irrelevancy have been given little attention in public avalanche safety research and require further study.

Beyond information distributed via mainstream news channels or trailhead signage, Type A bulletin users describe their risk management approach as primarily relying on familiar routes or on modeling the behaviors of other recreationists to ensure their safety.

> We plan just by talking to people, seeing what's in… looking at peoples' recent pictures.
>
> I'm trying to stay where I can see other people and on paths that have already been traveled on by other snowmobilers.
>
> I don't go to lot of places that aren't being used.
>
> We hiked the mountain in the summer too, so we are fairly familiar with it. We usually don't go to places that we really don't know.
>
> If I got there and it said *high* risk, I would probably still go out, but I would stay on the mom and pop trails. …I would also look to see how many other people are out. If it said *high* risk and the parking lot was empty, I wouldn't go out.

The preference of Type A's for peer recommendations is reflected in their feedback for bulletin products.

> It's nice when they have this anecdotal stuff, the little suggestions, because I think riders get that.

> I think things like ratings become a little bit of your experience and… it might be useful to have people's experience with these kinds of tools or frequently asked questions, because then you can kind of relate to it.
>
> For people like me, who don't have a huge amount of experience in the backcountry necessarily, I relate well to people talking about what routes they've done and what they look for… so having that personal advice or planning.

Additionally, Type A participants detailed their barriers to use of avalanche bulletin products. They voiced that they find it difficult to determine appropriate travel decisions for *moderate* and *considerable* danger ratings, that they are challenged by the level of complexity in bulletin information, and that they are critical of the relevancy of the broad forecast regions to their localized route selections.

> For someone just going out, what is *moderate*? What is *considerable*?
>
> The difference between *considerable* and *moderate* is… I mean, those words are pretty similar.
>
> To tell you the truth, the only one we really notice is *high*.
>
> *Problems… persistent slab*. So, is this geared for… people who use the backcountry on a consistent basis? Because it looks like the information is very specific.
>
> It might be useful to… simplify it a bit. …I find it very complicated.
>
> …it's just not localized enough.

The study sample included four participants classified as Type A recreationists. These recreationists consisted of two snowshoers, a snowmobiler, and an ice climber, and they were comprised of three females and one male. These recreationists primarily had no formal avalanche training, with the exception of one participant with a recreational Level 2 avalanche course.

Type B: Base a Go or No-Go Decision on the Danger Rating

As the first category of intentional bulletin users, Type B participants consult the avalanche bulletin to make a *go* or *no-go* decision primarily based on the forecasted avalanche danger rating. They use the danger rating as a directive for an all-encompassing decision as to whether or not it is safe to travel in the backcountry, which presented a clear behavioral pattern for determining membership in the class.

> I'll check the avalanche conditions and that will determine whether I will go or not.
>
> I'll only go if it said it's fine and safe to go, like risks are *low*.

Type B recreationists do not typically reference information beyond the danger rating product, as they find additional information in the bulletin difficult to comprehend.

> I don't look at it in detail, but I definitely look at what the levels are.
>
> I get most of my information definitely from the ratings. I definitely have looked at these tabs before, but I don't remember taking much away from the (avalanche) problems.
>
> Basically, all I would be interested in is whether or not it's safe, like just avalanche risk—go or don't go—kind of thing, but they have provided a whole bunch of helpful information I don't know how to interpret.

While these users primarily consult the danger ratings, they do not always find the rating level intuitive to their decision-making process. Using the danger rating as a threshold to deem their trip option safe or unsafe, Type B bulletin users find the *moderate* and *considerable* danger ratings in the middle of the scale difficult to apply.

> It said the avalanche rating was *considerable*, so I was like, "okay?"
>
> I wonder why there needs to be that distinction between those two levels at the *high* and whether it should just be combined to one and say, "You probably shouldn't be going out after it goes above the *moderate*."
>
> I wouldn't go anywhere where it was above a medium.
>
> If it's anything *considerable* or severe or anything like that, I'm more likely to go, "Okay, maybe I won't do that because I don't know enough about it to know that I'm going to be safe."

In addition to applying the danger rating, Type B recreationists also refer to carrying necessary safety equipment as important to their risk management strategy.

> I'll generally take a little bit more of an active role, making sure that we've got all the right equipment, making sure that I know where we are going is safe.

As part of this strategy, Type B bulletin users deliberate over whether their trip itinerary qualifies as a backcountry environment or not. This is not a formal recognition of avalanche terrain severity but a consideration of the environment in terms of its remote nature and subsequent gear requirements. Considering both the backcountry nature of

their trip and the danger rating, Type B recreationists are predominantly making decisions about whether to go and whether to carry safety equipment.

> If I'm going further in the backcountry overnight, then I'll still bring the equipment, but if I'm going to Seymour and the conditions are *low* then I might not bring it at all.

Because Type B bulletin users are not incorporating the nature of the avalanche hazard or avalanche terrain exposure into their travel decisions, they express a lack of confidence in knowing what to look for to make terrain-based or conditions-based assessments while traveling. To determine the safety of their trip, Type B recreationists rely strongly on established trails, popular routes, or the behavior modeled by other backcountry users as a risk management strategy, as opposed to an iterative assessment.

> I'm not sure if I'm consciously looking for any signs while I'm out there.
>
> We are there because we think it's going to be safe.
>
> I don't really even know what to look for honestly. Once we are there, I feel like we've made the decision like, "Hey, it's probably reasonably safe." So, we would just go for it.
>
> I make sure that I stick to what's been marked out as a relatively safe route.

The feedback from Type B participants voices a desire for stronger directives in the bulletin to assist them with determining the safety of their route on a given day.

> If I wanted to plan a trip or work out the risk for where I am going, I would love to be able to type in "Elfin Lakes" and have that show up or at least tell me that these popular trails are part of this area, so I don't have to guess myself.
>
> I think I know what the tree-line is, but I don't know if it's right. So, I would prefer, if somebody just gave me a list of the trails and gave me instructions for it. …I think that would be helpful because then you wouldn't have to… interpret it yourself necessarily and maybe get it wrong.
>
> I feel like this page is more geared towards people that know what they're looking for. Like, maybe they've had training before, and they know what these terms are. For somebody that's just your average recreational snowshoer, it's probably not going to make much sense. So, if they could like very clearly spell it out for us, …that would be really helpful.

> It could be more idiot proof I think for the lower end. Like, if you are really highly trained, maybe this is enough, but if they want it to impact just lay people, I think they need to make it a bit easier to consume the information. I find this a little too technical probably for most people.
>
> I would love if there was a site you could go to where somebody who was an expert was saying, "This is X,Y, Zed, these are the danger points on this particular hike, and this is what you have to look out for, this is what you have to be prepared for."

The study sample included seven participants classified as Type B recreationists, all of whom were snowshoers and with six out of the seven interviewees identifying as women. With one exception, Type B interviewees primarily stated that they sometimes or rarely use the avalanche bulletin and reported no formal avalanche training.

Type C: Combine the Danger Rating with Avalanche Terrain Severity to Decide if Exposure is Appropriate

Type C bulletin users combine the forecasted danger rating with a consideration of the avalanche terrain severity to decide where to travel. Their decision-making process determines whether exposure to avalanche terrain is appropriate on a given day provided the danger rating is below a certain threshold.

> I'll usually look at what the conditions are going to be like… That'll inform not only go/no-go but a where to go decision.
>
> If it's like red or orange (*high* or *considerable* danger), you can go out… and just do laps in the trees with your friends… and you avoid getting into the high exposure areas.
>
> *Considerable* and above may still not deter me depending on the area.
>
> If there's avalanche risk and it's *considerable* or above, then I probably wouldn't go or just get up to where there's no avalanche risk.
>
> For instance, if was *extreme* and *high* conditions at Elfin Lakes, I'd stick to the Red Heather area. …You can still find something active to do around the more safe zones.

Type C bulletin users manage their exposure to avalanche hazard by identifying areas in the mountains that are more avalanche prone. They make this assessment based on whether or not the slope angle of the terrain is steep enough to produce an avalanche and based on terrain characteristics such as slope shape and forest density. Therefore, they practice terrain avoidance as their primary avalanche risk management strategy, and they describe their field assessments as focused on terrain identification.

> I look at the slope, first of all, because that's the one thing I'm still trying to learn to visually assess, the angle of the slope.
>
> I just try to stay away from any open terrain. I don't go off anything steep. I stay away from steep stuff.
>
> I stick to safe terrain.

Type C bulletin users reference additional information in the bulletin that provides a baseline for hazard assessment, such as the avalanche problems and details; however, they find it challenging to incorporate into their travel decisions.

> I have a hard time understanding them (the avalanche problems). I would need to get into the whole thing behind it.
>
> Cornices I could distinguish from slabs. And then wind slabs, I have a hard time seeing the differences when I'm out there. So, I have a hard time being like, "Where could the wind have carried the snow?" and "How can I avoid this area?"
>
> I just don't have enough experience to be able to spot the hazards.
>
> When I do go in the backcountry, …instead of being like, "Okay, so we're in safe terrain. What doesn't look like safe terrain?", it'd probably be a good idea to be like, "That over there looks bad because of x, y, z." So, maybe that's something I need to be more cognizant of.

Given their difficulty incorporating detailed hazard information, Type C recreationists express a preference for avoiding situations that require its application or for deferring to more experienced or highly trained partners to make decisions for them. This speaks to their need for a more complete risk management strategy and an awareness of their limited approach.

> I have not gone to places that I really need to evaluate.
>
> I can understand in my limited experience of being in the backcountry, the difference between *low* and *moderate*. I can understand in my mind between *moderate* and *considerable*, but I'm not too sure I'd be able to spot that on the hill itself. So, I just tend to not go when it's *considerable* and just to avoid it. If I could go with someone who is very knowledgeable and who would be able to take me there safely, that would help a lot.
>
> I defer more to the experts, where they choose to go.
>
> If they are experienced and if they go, then I would go with them.

> I defer to more knowledgeable people, definitely. If I was like, "Oh my gosh it says *considerable*," and they were like, "No, don't worry, that's not dangerous," I would probably listen to their experience.
>
> I'm kind of allowing them to judge because I always feel like they're more experienced than me, so I'm relying on them.

Although Type C recreationists prioritize mitigating their exposure with terrain selection in lieu of relying on hazard assessments, they still review the detailed hazard information as a learning opportunity.

> I usually read the snowpack summary and sort of get the details… that's almost more from a learning perspective. I'd like to start having a deeper and better understanding of what goes into the forecast, but I'd say the ratings and the problems are really what makes decisions for me, especially ratings.
>
> I'm looking at those little clues as to what may happen, but at this point in my experience, it's a lot of learning still.

The distinguishing factor for classifying Type C participants was not an absence of avalanche hazard references but a distinct pattern in when participants discussed detailed hazard information during the interview. Type C participants did not mention the specific nature or distribution of the avalanche hazard in their opening discussions of their planning process. However, during the sections of the interview that utilized the mock-up bulletin website, these participants reviewed and discussed the avalanche problem information and details. Interestingly, in their responses to the final application exercise using the Ortovox 3D mountain model, Type C participants exhibited a consistency with their initial descriptions of their planning process in that they did not apply the detailed avalanche problem information and, instead, resorted primarily to recognizing areas of greater avalanche terrain severity for avoidance.

In their bulletin feedback, Type C participants voice a desire to increase their level of comprehension from bulletin information. They offer detailed definitions, interactive planning exercises, or visual explanations as suggestions for facilitating their skill-building.

> What would be nice would be to have something like a newbie link or "You want to learn more about this?" …so, a deeper explanation in terms of what their thinking was about it.
>
> I think at one point they had a tool where… you would be able to route plan up, and it would sort of tell you if your route was safe or not…. That

> I found was useful as a learning tool. So, the learn component, if it could be improved or redone.
>
> In addition to the wording, if there were some visuals… that would sort of give you a little bit more information as to why conditions may cause a change from *moderate* to *considerable*, then that would help.

The study sample of 10 Type C recreationists was comprised of participants representing various backcountry activities (i.e., snowshoers, mountain snowmobilers, backcountry skiers and snowboarders) and with both men and women equally represented. These recreationists had primarily completed a Level 1 recreational avalanche course, although three Type C interviewees reported no formal training. These recreationists encompassed all categories of bulletin use frequency including rarely, sometimes, each trip, and every day.

Type D: Distinguish and Integrate Avalanche Problem Conditions into a Complete Risk Management Framework

Type D bulletin users distinguish and integrate the nature and distribution of the avalanche problem conditions into a comprehensive risk management strategy. They apply bulletin information about the hazard (i.e. avalanche problem type, likelihood, size, and distribution across elevations and aspects) to open and close terrain appropriate for travel.

> Which aspects and which elevations are going to be a hazard… we would've probably picked a spot that wasn't going to be as hazardous.
>
> I will look at problems, and I will go through each to look at what elevations, what slopes are most risky, what the chances are, and the expected size, and any advice that they are giving.
>
> So, for me, when I click on the (avalanche) problems it… makes me think, "Okay, what's open?"

Generally, Type D bulletin users can recall the definitions of the various avalanche problem types and understand how the distinctions between them translate into risk mitigation strategies.

> Persistent slab scares me. Sluff doesn't.
>
> It might change what time we head out in the day and which slope we pick.

Although Type D recreationists apprehend the implications of the forecasted avalanche problems, they voice difficulty confidently translating the information to a slope-scale hazard assessment.

> I'm not good enough to say to everybody, "Oh, that's a wind slab."

Moreover, in general, they express reservations with the reliability of their interpretations.

> I like to get as many opinions as I can, so I can make a very confused opinion.
>
> I like to think I have a good sense of it, but I've never really gotten feedback on my assumptions. So, I might be just thinking I understand something, and I don't really.

Therefore, Type D recreationists may not initiate relevant observations independently, recognize hazardous conditions different from those forecasted, or identify hazard conditions without an avalanche forecast product. Rather than relying on accurate self-assessment of the hazard where they are traveling, this class of bulletin users places greater weight on their pre-determined terrain closures from the forecasted bulletin information.

> It'll tell me whether I can cater my terrain selection or not. So, typically, the aspect and elevation are really what I'm taking out of it.

Type D participants' consistent incorporation of detailed hazard information throughout their interview responses and expressed difficulty with self-determined hazard assessment distinguished them in the thematic analysis. Type D participants' feedback for bulletin improvements reflects their desire to build confidence in their interpretations and hazard assessment skills.

> What's surface hoar? Sugary facets? What's a convex roll? ….If we had that described, what it is and the picture to show you, then it would definitely connect much more meaningfully, like education. Now, you… have a legend that educates what this means.
>
> I remember doing something like this at one point… They had like a… photo of a scene and it was like, "how do you get up this mountain, if you want to get from A to B," and you had to click a line. I thought that was so helpful.
>
> If you had pictures like this, where you could like quiz yourself and find out if you are right or wrong, that would be cool. I would say that is definitely an area that could be improved upon for the site, which is

> providing more tools, whether it's quizzes for people to take, definitions, photos, just more educational tools.

The study sample of 19 Type D recreationists consisted of mountain snowmobilers and backcountry skiers and snowboarders, and it was comprised of 15 males and four females. These recreationists reported a range of formal avalanche education spanning from no training (two participants) to a Level 1 (11 participants) and Level 2 (six participants) recreational avalanche course. Type D interviewees predominantly reported referencing the avalanche bulletin for each backcountry trip, although three participants reported reading it only sometimes and four participants stated that they reference it every day.

Type E: Extend Evaluation of Bulletin Information to a Localized Assessment of Avalanche Hazard

Participants in the Type E bulletin classification use the bulletin as a starting point from which to extend their evaluation of avalanche hazard where they are traveling.

> It's always good to make your own assessments and compare them to the website's assessments and see where it all melds together.

This class of bulletin users can translate the forecast to a slope-scale assessment, even given conditions different from what was forecasted.

> The avalanche forecast is the lower priority of the information as opposed to what I'm seeing.
>
> It makes more sense to allow the conditions to show you where you can go.

These users engage in an in-depth review of bulletin information, with a focus on the details, to find the supporting evidence behind the information icons.

> Normally I would go through and I would be like, "Why are these ratings what they are?" I would read the avalanche summary. I would read the snowpack summary and then the weather forecast.
>
> Those color ratings—they're just someone's deciphering of raw data, so I'd rather look at that raw data myself.

Type E bulletin users recognize the challenges inherent to the complexity, variability, and uncertainty of avalanche hazard not represented in the danger rating scale.

> A lot of times with *considerable*, you get out there and you're like, "This is actually really solid—like this is more *moderate*, sometimes even like *low*." But, other times, it could be *high*.
>
> It's super variable because *considerable* can be *considerable* for many, many reasons, and for over six years, I've seen it be because of completely different things.

These recreationists acknowledge the limitations of regional forecasted conditions as a predictor of hazard at the slope-scale and as a daily snapshot of stability without the context of the winter season.

> Really, it's a sampling of a very small area, when we're in a pretty big world here.
>
> It's important also to pay attention throughout the whole season. If you just look the morning of, persistent weak layers mean nothing to you.
>
> There's what's happening immediately, but also what's been going on in the snowpack over the course of the winter. What is it that we need to be aware of? It's a balance of those two things.

By taking these considerations into account, Type E participants emerged as a distinct class in the typology. Type E recreationists incorporate avalanche risk information into their travel decisions as it is intended to be used; nevertheless, their feedback still reveals an appreciation for opportunities to improve their understanding through interacting with the bulletin.

> When you show somebody tapping the top of the column and the whole things goes, it's very illustrative, and you're like, "Whoa." It really brings home suddenly what *high* avalanche concern on a persistent slab might mean.
>
> One of my favorite things is the route-finding exercises, where you have the little hut, and you have to pick a safe route up. I did those a lot. …I found them really helpful. …It's a good learning tool. So, I think having those kind of interactive exercises people can continue doing after the classroom piece of the AST (Avalanche Skills Training course) is really good.

The study sample of six Type E recreationists consisted of a mix of backcountry skiers and snowboarders, mountain snowmobilers, and ice climbers, with men in the majority (five out of six interviewees). These respondents had completed either a Level 1 or Level 2 recreational avalanche course, and they reported referencing the bulletin for each trip or every day.

4.1.2. Respondent Validation

Of the 46 total interviewees, 28 responded to the follow-up bulletin use pattern self-identification question distributed via email (61% of the sample) (Appendix E). Apart from two categories in which there was a sole respondent, interviewees from all bulletin user types, activity types, genders, age groups, and levels of formal avalanche training were well-represented, with more than 50% of the participants in any given category responding to the emailed question. For Type A recreationists and for participants in the 55+ age category, only one out of four interviewees in these categories responded.

Of the 28 interviewees who responded, 18 (64%) produced an exact match and all matched within at least one step of their prescribed classification. While only two participants (7% of the respondents) under-estimated their assigned pattern of bulletin use, it was more common for participants to over-estimate their abilities (29% of respondents). As I conducted this procedure following an additional winter season, it is possible that participants may have advanced to the next level in their pattern of bulletin use. No clear patterns in the demographics, bulletin user type, activity type, or level of training emerged among those who correctly self-identified or among those who under-estimated or over-estimated their abilities. Additional research is needed to better understand the accuracy of recreationists' self-identified abilities.

4.2. Phase 2: Quantitative Data Analysis

The results of the quantitative analyses revealed topics, word associations, and patterns of classification that offer complementary insights to the Avalanche Bulletin User Typology. Because the Type A classification does not consist of a pattern of active avalanche bulletin information seeking and processing, but rather diverse reasons for its absence, I did not include this class in the quantitative methods. This allowed me to maintain active bulletin use as a comparative metric for analysis.

4.2.1. Topic Modeling

For each of the four structurally-defined corpora of the interview script (i.e., *Planning Process, Information Influence, Bulletin Use,* and *Group Dynamics*), I computed a topic model. The analysis computed six topics as a fitting number for the

Information Influence, *Bulletin Use*, and *Group Dynamics* corpora and five topics in participants' descriptions of their *Planning Process*. The terms identified as topics and the balance of topics across the bulletin user types for each of the four corpora are shown in the corresponding word clouds and heat maps in Figures 4.1-4.8.

The topics identified by the model in participants' descriptions of their *Planning Process* highlight the defining features of the classes of Avalanche Bulletin User Typology (Figure 4.1). Topic 2 presents the most evident theme with terms primarily relating to avalanche hazard (i.e., *hazard*, *wind*, *layer*, *load*, *aspect*, *activity*, *dig*, *pit*, *temperature*). Fittingly, this topic is most prominent in the responses of Type D and Type E participants (Figure 4.2). Although strong topic saturation occurs for single bulletin user types in Topics 1, 3, and 4, a unified theme is difficult to discern in the terms listed as multiple topics seem to be present concurrently. For example, Topic 1, which is primarily discussed by Type C users, includes references to weather (i.e., *rain*, *sun*) as well as to terrain (i.e., *angle*, *pathway*, *cliff*). Although fitting with the Type C characterization, these terms do not encapsulate a single subject as is typically observed in topic model analyses. Instead, the identified topics encompass several subjects that all seem to change in parallel between bulletin user types. Despite topics comprised of multiple themes, the parallels to the typology are clear. Topic 3, predominantly discussed by Type B bulletin users, reflects a theme of dependency on established routes (i.e., *marked*), web-based resources (i.e., *online*), social organizations (i.e., *club*), and other people (i.e., *somebody*), as well as a reference to the nature of the environment (i.e., *backcountry*). While Type B users are more likely to discuss reliance on marked trails and peer influence, Type C users introduce terrain considerations, and Type D and Type E users incorporate an increasingly advanced conceptualization of avalanche hazard.

Topic 1

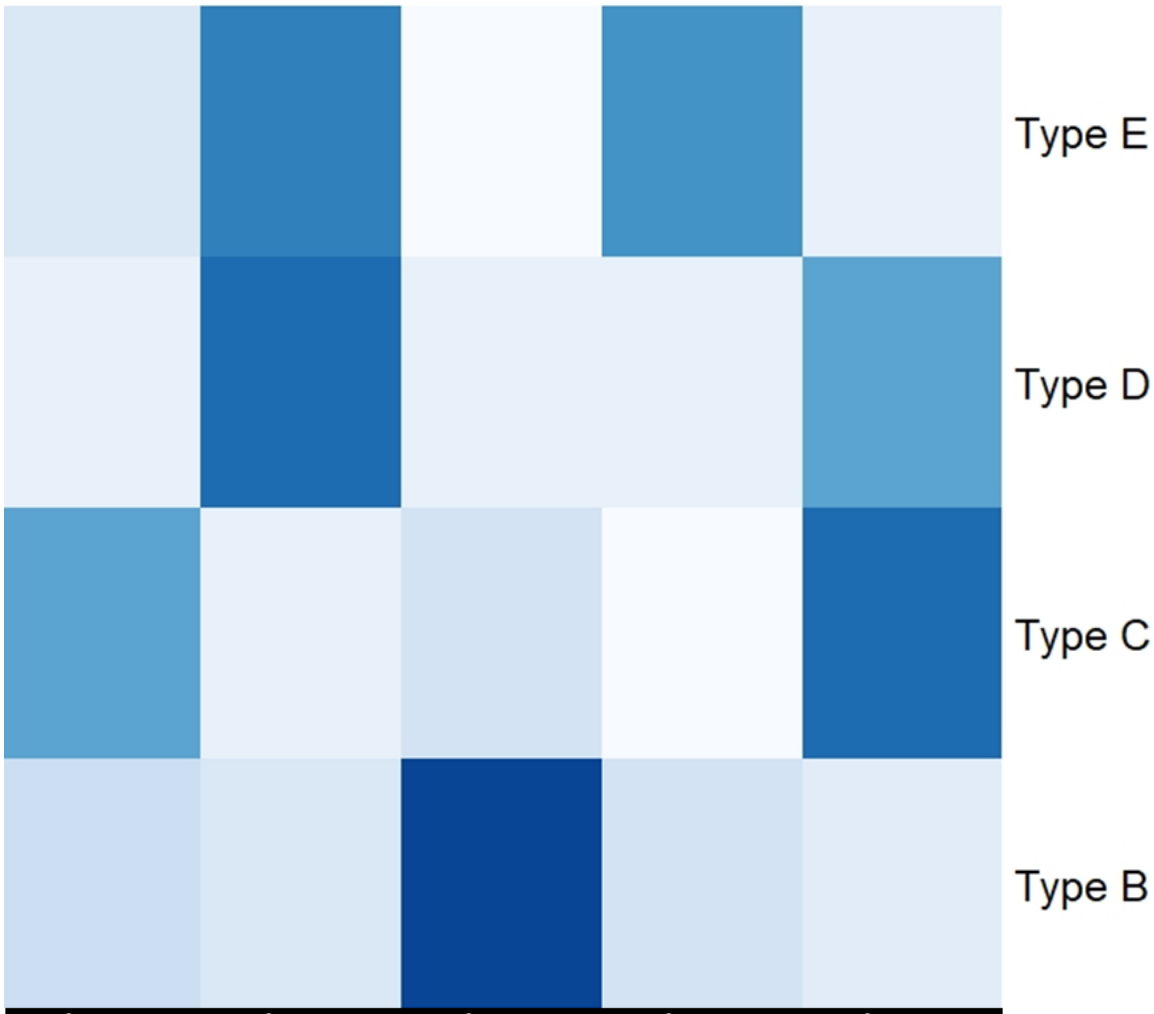
Topic 2

Topic 3

Topic 4

Topic 5

Figure 4.1 Word clouds produced by the topic model for the Planning Process corpus



Topic 1	Topic 2	Topic 3	Topic 4	Topic 5
rain	zone	marked	wind	tree
away	base	backcountry	aspect	track
consideration	less	train	early	give
lap	hazard	online	factor	course
marker	dig	club	concern	top
sun	wind	rely	important	alpine
adjust	pit	meet	rating	assess

Figure 4.2 The balance of topics across bulletin user types in the Planning Process corpus

For the *Information Influence* corpus, the topic model identified six topics (Figure 4.3). Again, several of these topics (i.e., Topics 2, 4, 5, and 6) are defined by multiple themes encapsulated by a bulletin user type than by a single subject matter (Figure 4.4). Topic 4, which is primarily discussed by Type B users, reinforces the importance of trails

and the backcountry nature of the environment, as well as training. Type C users predominantly discuss Topics 3 and 5, which contain references to general weather conditions such as *sun*, *rain*, and *cold*. Interestingly, a pattern of increasing complexity emerges in these weather-related topics. In addition to discussing the general weather factors in Topic 3, Type D bulletin users introduced a theme more directly related to the avalanche hazard illustrated by Topic 1, with terms like *wind*, *freeze*, *storm*, *slab*, and *load*. A further advancement in complexity occurs in Topic 6, mainly discussed by Type E users. These topics contain more explicit and higher-level references to weather and hazard information including raw data, weather stations, elevation, and aspect, as well as words referring to assessment, such as *validate* and *conflict*. The resulting topic distributions and progressive content sophistication depict the increased information gathering complexity across the bulletin user classes.

Figure 4.3 Word clouds produced by the topic model for the Information Influence corpus

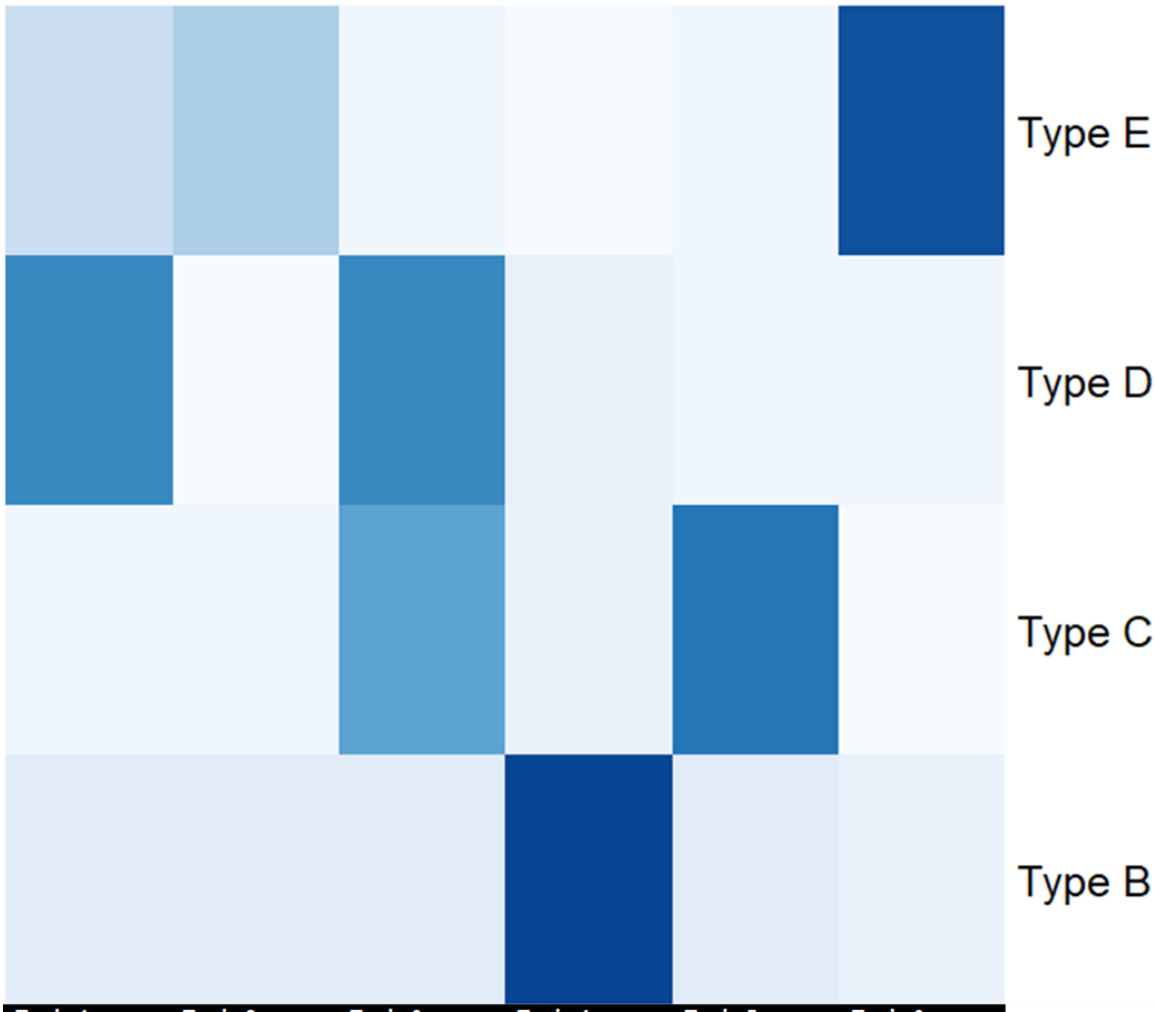


Figure 4.4 The balance of topics across bulletin user types in the Information Influence corpus

From participants' discussions of their *Bulletin Use*, the topic model identified six topics (Figure 4.5). Topic 4 presents the most discernible theme relating to modes of information access, such as phone apps or webpages, which was discussed widely across Type C, D, and E users (Figure 4.6). Topic 1 generally reinforces a previously found pattern in that Type C users tend to mention general weather factors, such as *sun*, *heat*, and *freeze*, as opposed to specific avalanche problem references. Adding further

insight to the analysis, another gradation in the topics emerged related to the depth of bulletin use and level of engagement. For example, Topic 1, mainly discussed by Type B users, reflects a degree of passive participation and introductory engagement with words like *wonder* and *answer*. Similarly, Type C participants used words such as *rather*, *tend*, *trust*, and *wait* in Topic 6. Providing contrast, Topics 2 and 5, predominantly discussed by Type E users, reflect the use of the bulletin information with hands-on engagement and higher-level application, with words such as *dictate*, *contribute*, *manage*, and *pick*, in combination with words like *probability*, *variability*, *process*, *perspective*, *ability*, and *conversation*. Overall, the topics in the *Bulletin Use* corpus mirror a complementary progression to the Avalanche Bulletin User Typology in participants' depth of bulletin use and level of engagement.

Topic 1

Topic 2

Topic 3

Topic 4

Topic 5

Topic 6

Figure 4.5 Word clouds produced by the topic model for the Bulletin Use corpus

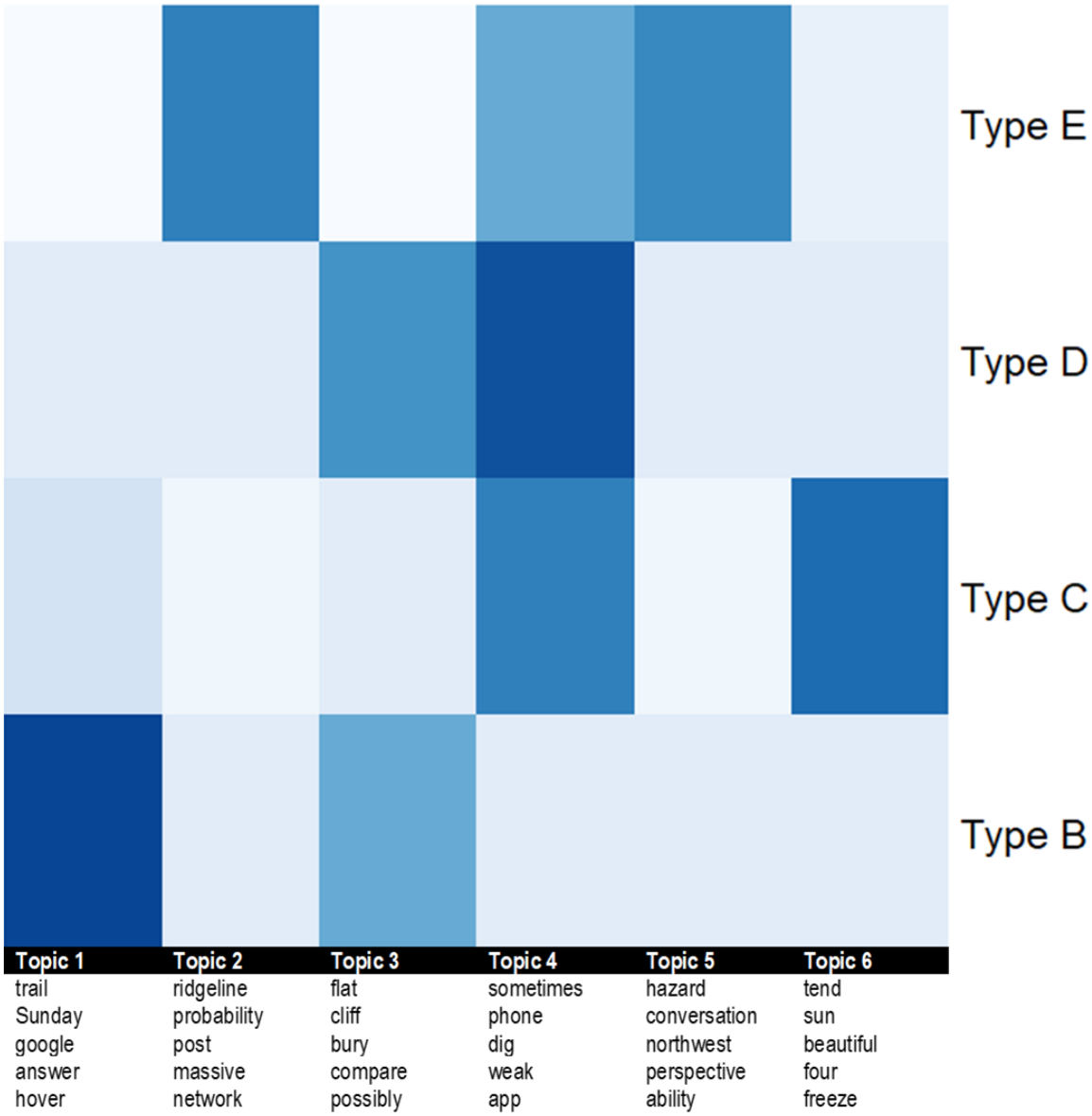


Figure 4.6 The balance of topics across the bulletin user types in the Bulletin Use corpus

In participants' descriptions of the role of *Group Dynamics* in their decision process, the topic model identified six topics (Figure 4.7). While Topics 2 and 3 include references to knowledge, education, leadership, and trust (i.e., *understand*, *trust*, *individually*, *train*, *knowledgeable*, *organize*, *lead*), Topics 5 and 6 make greater mention of the collective group and a collaborative process (i.e., *everyone*, *hear*, *voice*, *mindset*, *collaborative*). These topics give notion to themes of dependent or shared decision-

making responsibilities, and the distribution of these two themes across the bulletin user types corresponds accordingly. For example, given their characteristic dependence on additional guidance and expertise to make risk management decisions, Type B users speak less about a collaborative process; whereas, Type E users make fewer mentions of topics relating to trust, knowledge, and leadership (Figure 4.8).

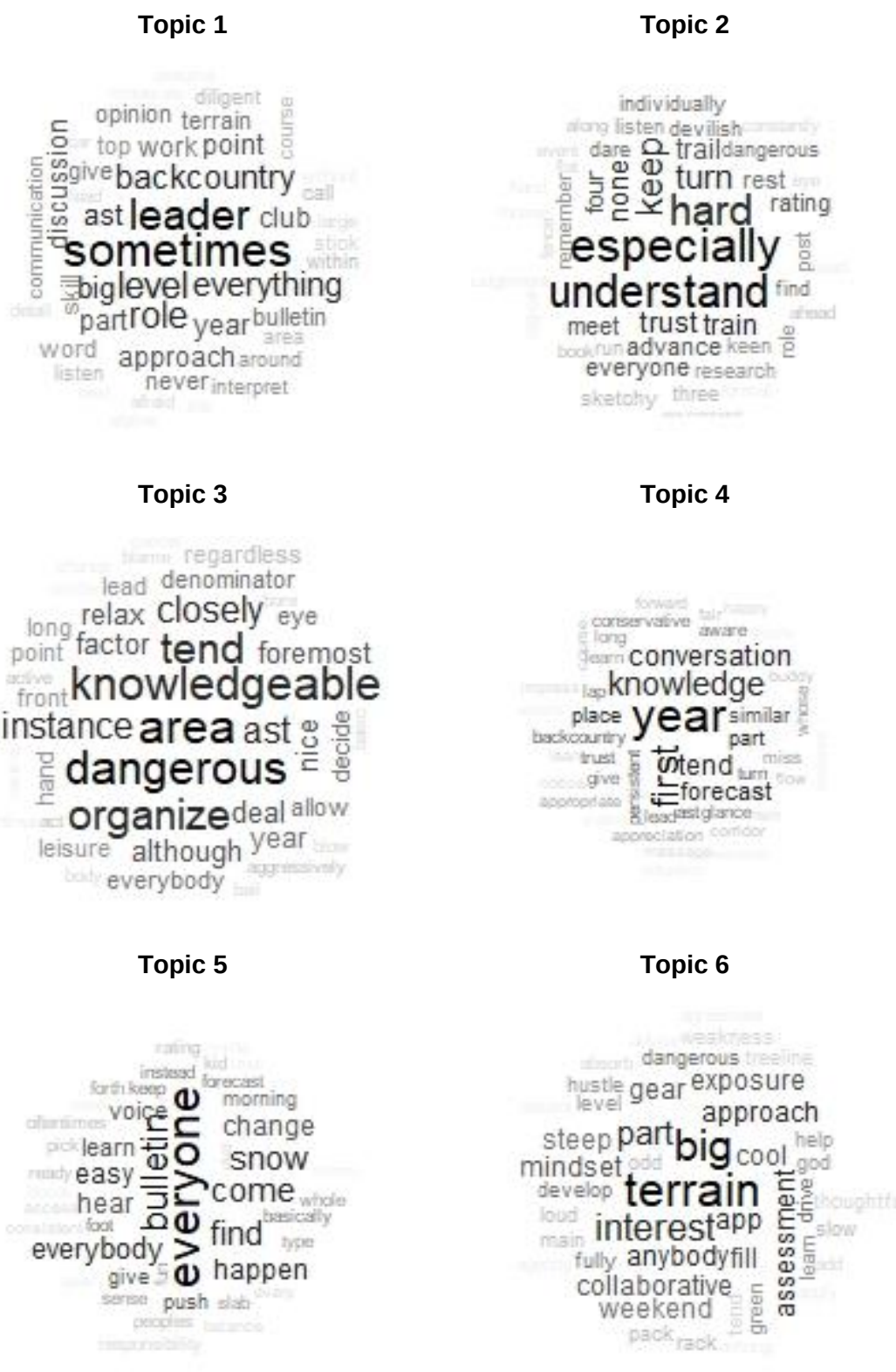


Figure 4.7 **Word clouds produced by the topic model for the Group Dynamics corpus**

Note: The abbreviation “ast” refers to the Avalanche Skills Training recreational education course curriculum in Canada.

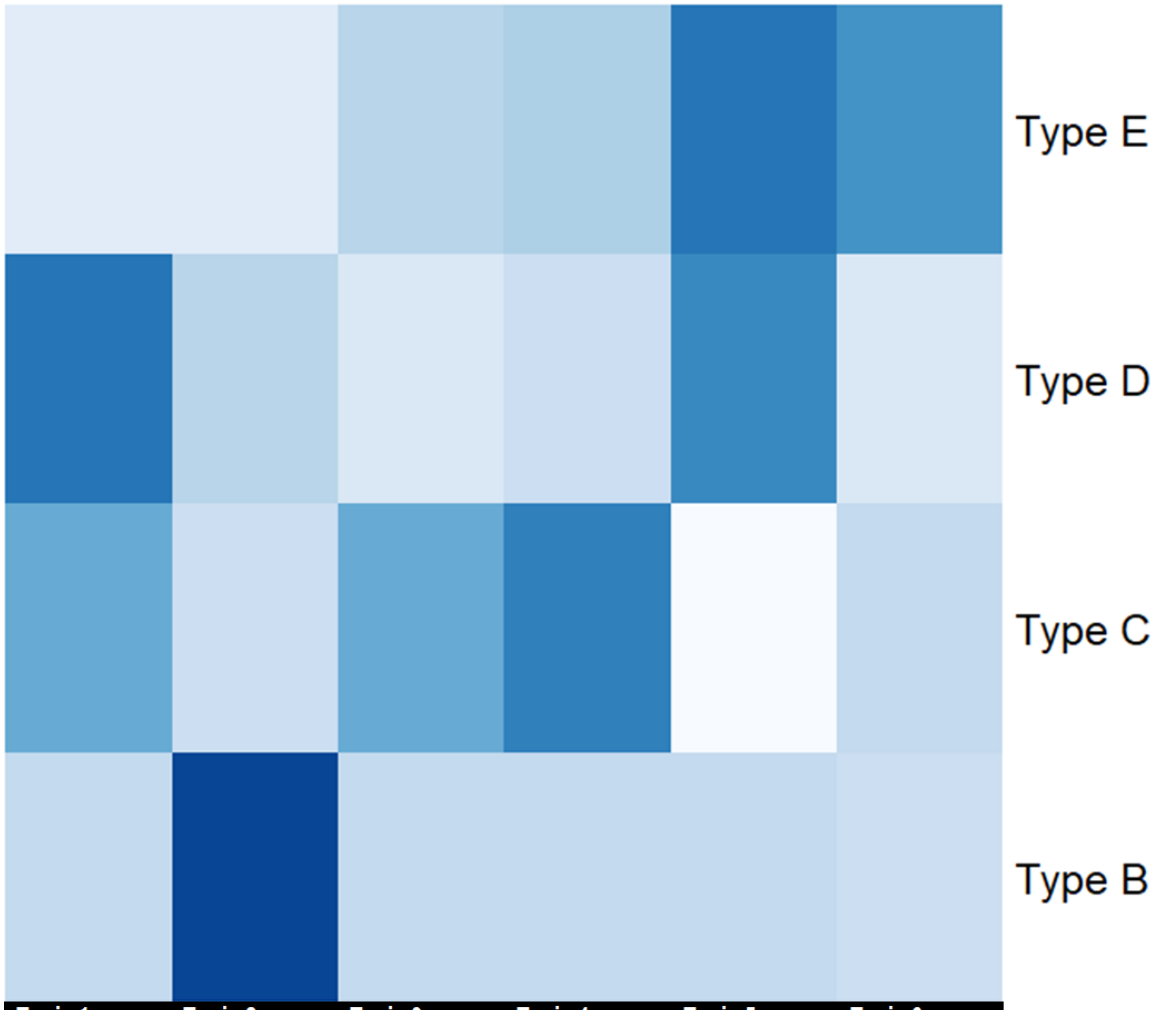


Figure 4.8 The balance of topics across the bulletin user types in the Group Dynamics corpus

4.2.2. Correspondence Analysis

I conducted four separate correspondence analyses on the same corpora as in the topic model analysis: *Planning Process, Information Influence, Bulletin Use,* and *Group Dynamics*. While the topic models presented general themes contained in participant responses, the correspondence analyses illustrate explicit relationships between bulletin user types and individual words. The resulting visualizations for each of the four corpora are shown in Figures 4.9-4.12. Words from the same topic produced by the topic model are plotted in the same color.

From participants' descriptions of their *Planning Process*, the correspondence analysis plotted the bulletin user types across four disparate dimensions (Figure 4.9). The Type B bulletin use pattern presents the greatest divergence from the average, and the Type C, D and E user classes align in a linear pattern reflecting an ordered association in the dimensions. The *Planning Process* correspondence analysis produced Eigenvalues for both the row and column principal inertias with similar values, or 0.67 and 0.55 respectively, meaning that distances between words and bulletin user types in the resulting biplot are relatively interpretable. The two dimensions visualized by the biplot cover a cumulative 74.3% of the dispersion in the data. The resulting biplot shows Type B users strongly associated with marked trails, danger ratings, and online resources. Type C users present an association with terrain use references, including *lap*, *adjust*, *tree*, *track*, highlighting the importance of terrain use in their decision process. Type D and Type E users occupy a dimension with explicit mention of avalanche hazard corresponding with words such as *hazard*, *wind*, *dig*, *early*, and *aspect*. As a result, the dimensional divides and corresponding words depict the distinctions that delineate the user typology.

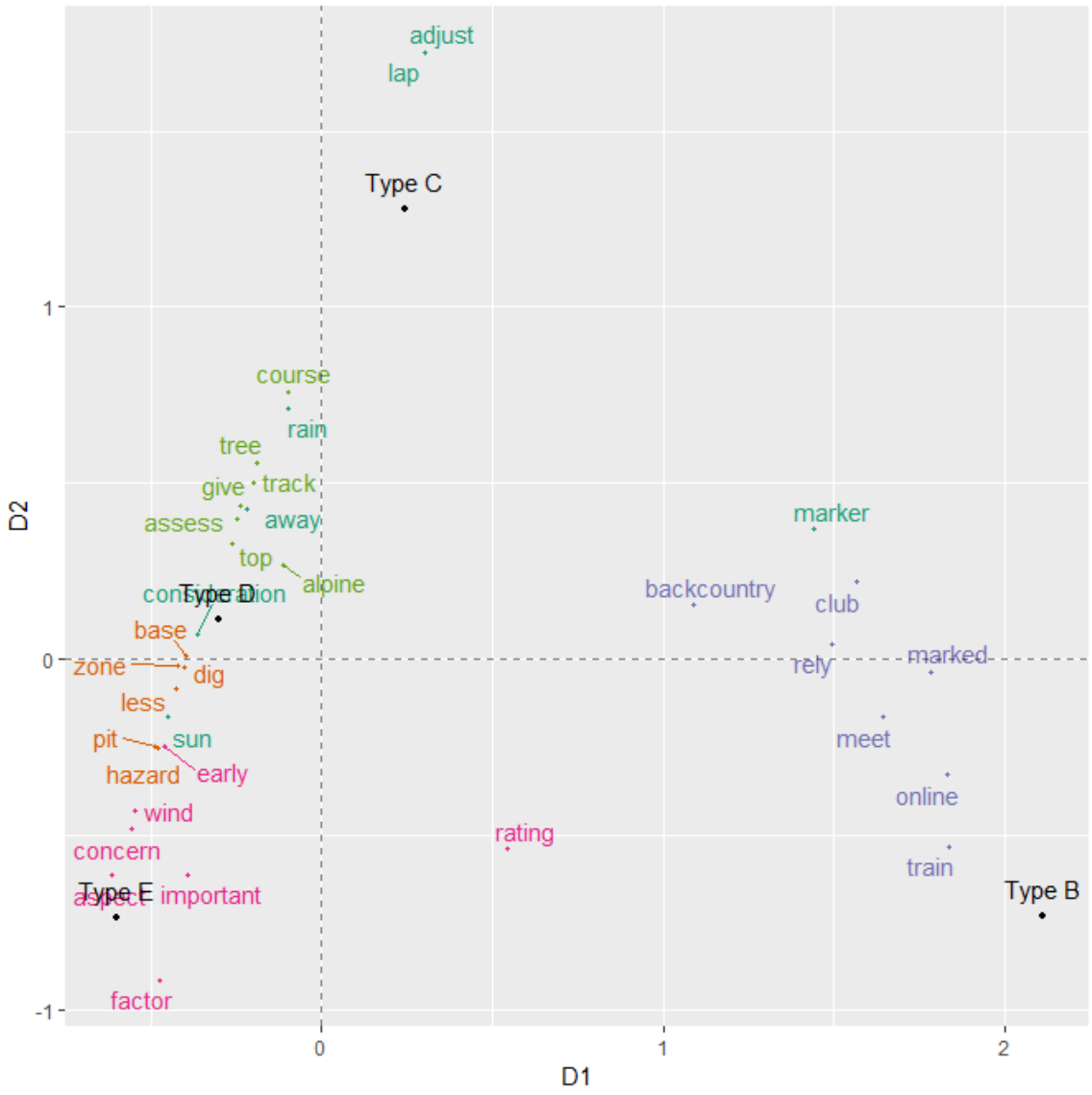


Figure 4.9 Associations between word frequencies and bulletin user types in the Planning Process corpus

Note: Word colors correspond with the topics produced by the topic model

Likewise, the correspondence analysis for the *Information Influence* corpus plotted the bulletin user types with a linear pattern for Types C, D, and E users (Figure 4.10). The *Information Influence* correspondence analysis produced Eigenvalues of similar value (0.64 and 0.57) and illustrates 73.3% of the dimensionality in the data. Again, Type B bulletin users emerge as the most disparate user type with a distinct mention of trails, training, dependence, and a backcountry environment. Here, Type C

and Type D users are more closely associated and plotted in the same dimension. However, the plot makes a meaningful distinction between these user types in that Type C recreationists are more closely associated with words relating to conditions in general terms (i.e., *sun*, *hot*, *rain*, *cold*, *alpine*, *tree-line*), whereas Type D respondents correlate with terms distinctly related to avalanche problems (i.e., *wind*, *slab*) and with more specific spatial references (i.e., *north*, *south*, *aspect*). The order of complexity in the information incorporated by the various user types is illustrated in the linear alignment across Type C, D, and E users, culminating in words relating to raw data and assessment (i.e., *datum*, *important*, *choice*) associated with Type E participants.

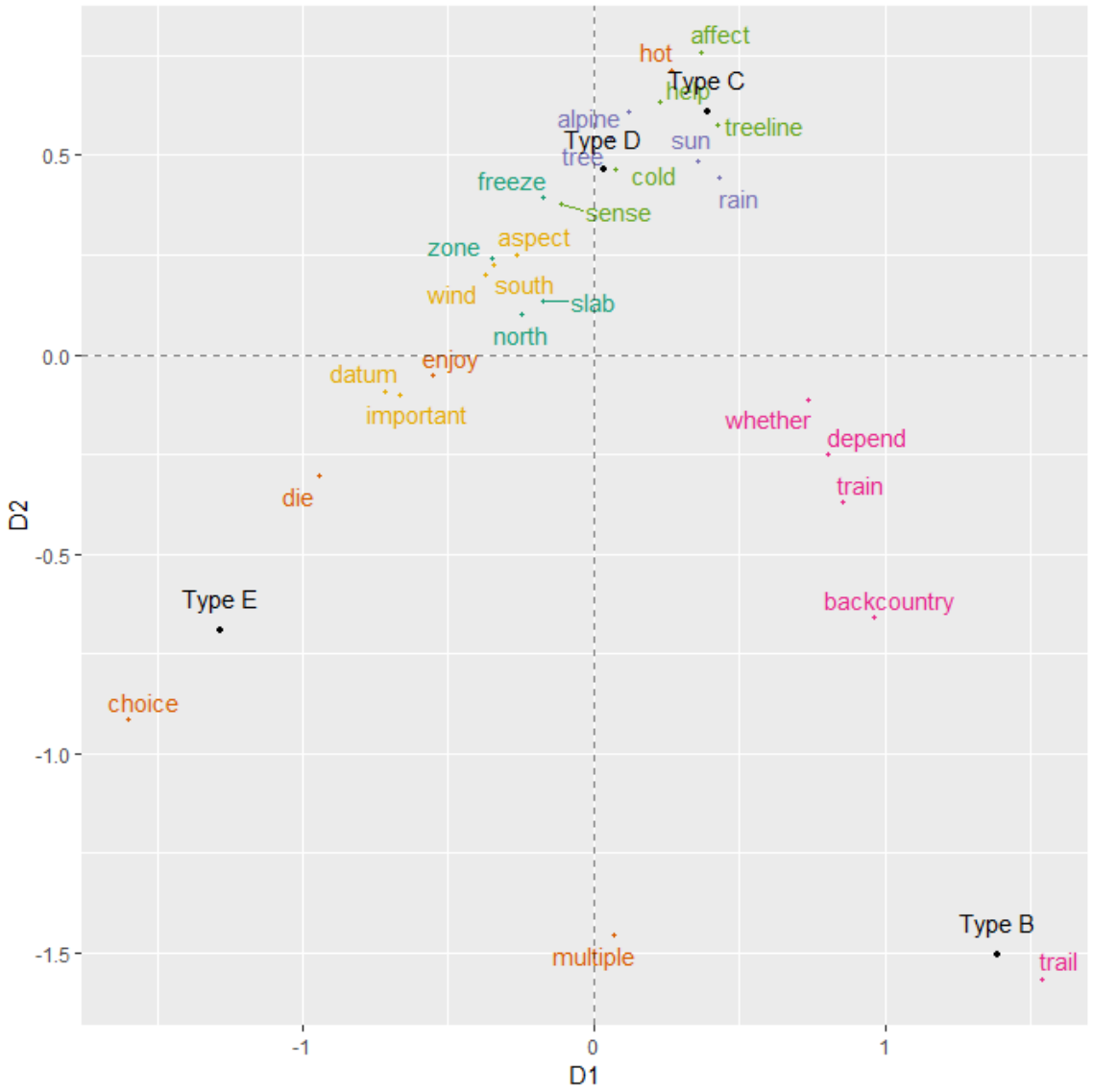


Figure 4.10 Associations between word frequencies and bulletin user types in the Information Influence corpus

Note: Word colors correspond with the topics produced by the topic model

The *Bulletin Use* correspondence analysis produced similar Eigenvalues for the two principal inertias (0.59 and 0.51), which guarantees the interpretability in the distances between words and bulletin user types (Figure 4.11). The two dimensions visualized by the biplot cover a cumulative 71.7% of the dispersion in the data. In terms of how participants described their *Bulletin Use*, the correspondence analysis plotted the user types across four different quadrants, again with Type C and Type D users most

closely associated. Considering the patterns in the biplots in combination, the proximity between Type C and Type D users in the *Information Influence* and *Bulletin Use* biplots reveal similarities in how they reference information (Figure 4.10, 4.11) but a distinct difference in how it manifests in their *Planning Process* (Figure 4.9). Consistent with previous results, Type B recreationists are most closely associated with online resources, trails, and directives (i.e. *google*, *trail*, *answer*), and they are most isolated in those associations. Type C recreationists characteristically correspond with terrain references (i.e., *cliff*, *flat*). Moreover, Type C participants describe their bulletin use more passively with words like *tend*, *possibly*, and *sometimes*, as compared to the more engaged and advanced approach of Type E users illustrated by words such as *conversation*, *dig*, *ability*, *perspective*, and *probability*.

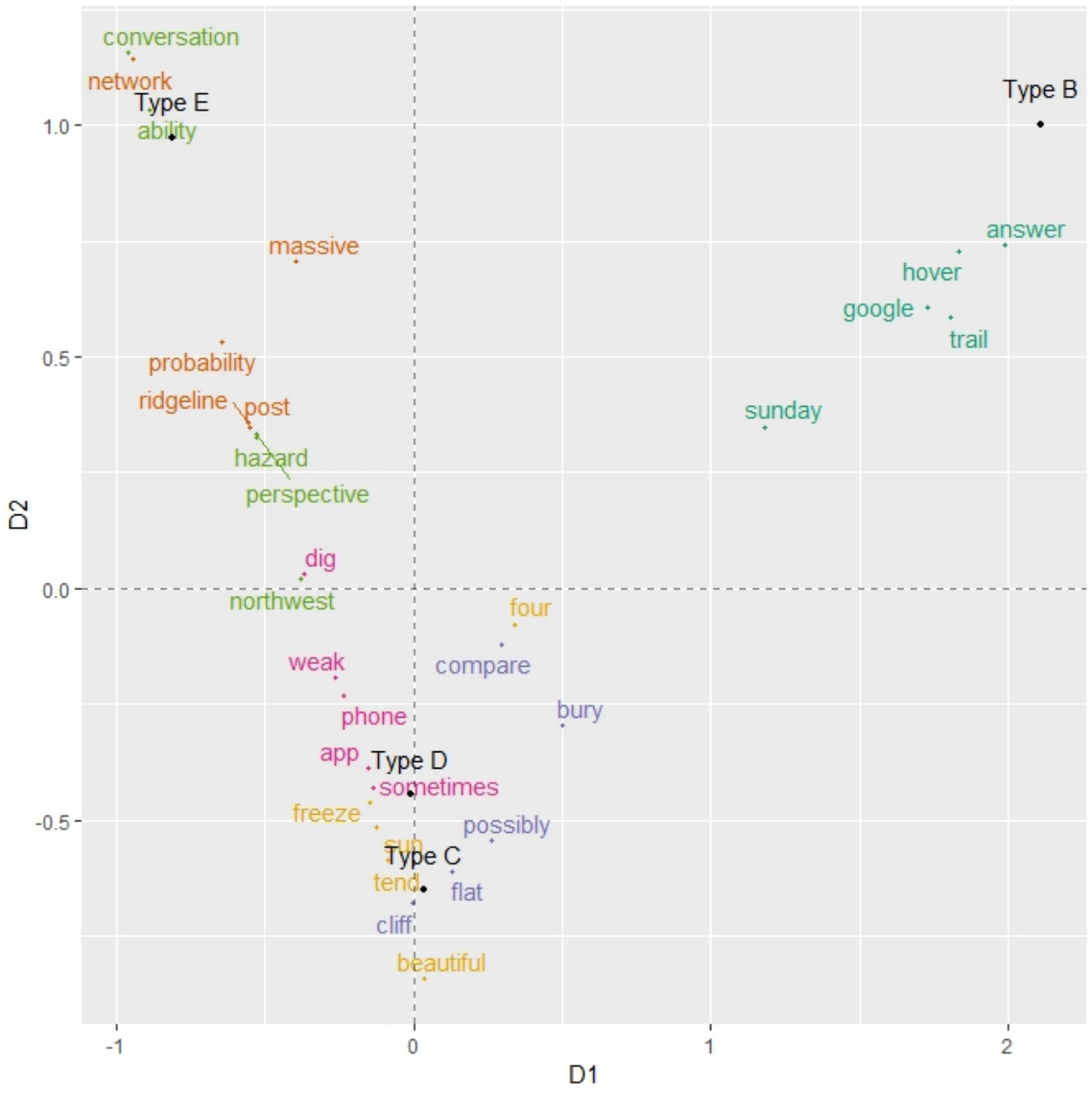


Figure 4.11 Associations between word frequencies and bulletin user types in the Bulletin Use corpus

Note: Word colors correspond with the topics produced by the topic model

The correspondence analysis for the *Group Dynamics* corpus depicts a different configuration, with Type D and Type E users occupying the same dimension (Figure 4.12). Similar to the other correspondence analyses, the interpretation of the distances between words and user types in the *Group Dynamics* correspondence analysis is guaranteed due to the comparable Eigenvalues (0.56, 0.52) of the two dimensions. Overall, the biplot covers 71.2% of the dispersion in the data. The Type B user class

remains the most divergent from the average. The words associated with Type B and Type C participants reflect their characteristic reliance on others for leadership and expertise (i.e., *organize*, *turn*, *leader*, *knowledge*, *knowledgeable*, *understand*). Additionally, Type C participants reference the difficulty of a trip location (i.e., *hard*, *area*, *terrain*, *level*). This keeps Type B and C users separate from Type D and E participants and distanced from their distinguishing references to the group as a collective body (i.e., *everyone*, *conversation*, *anybody*).

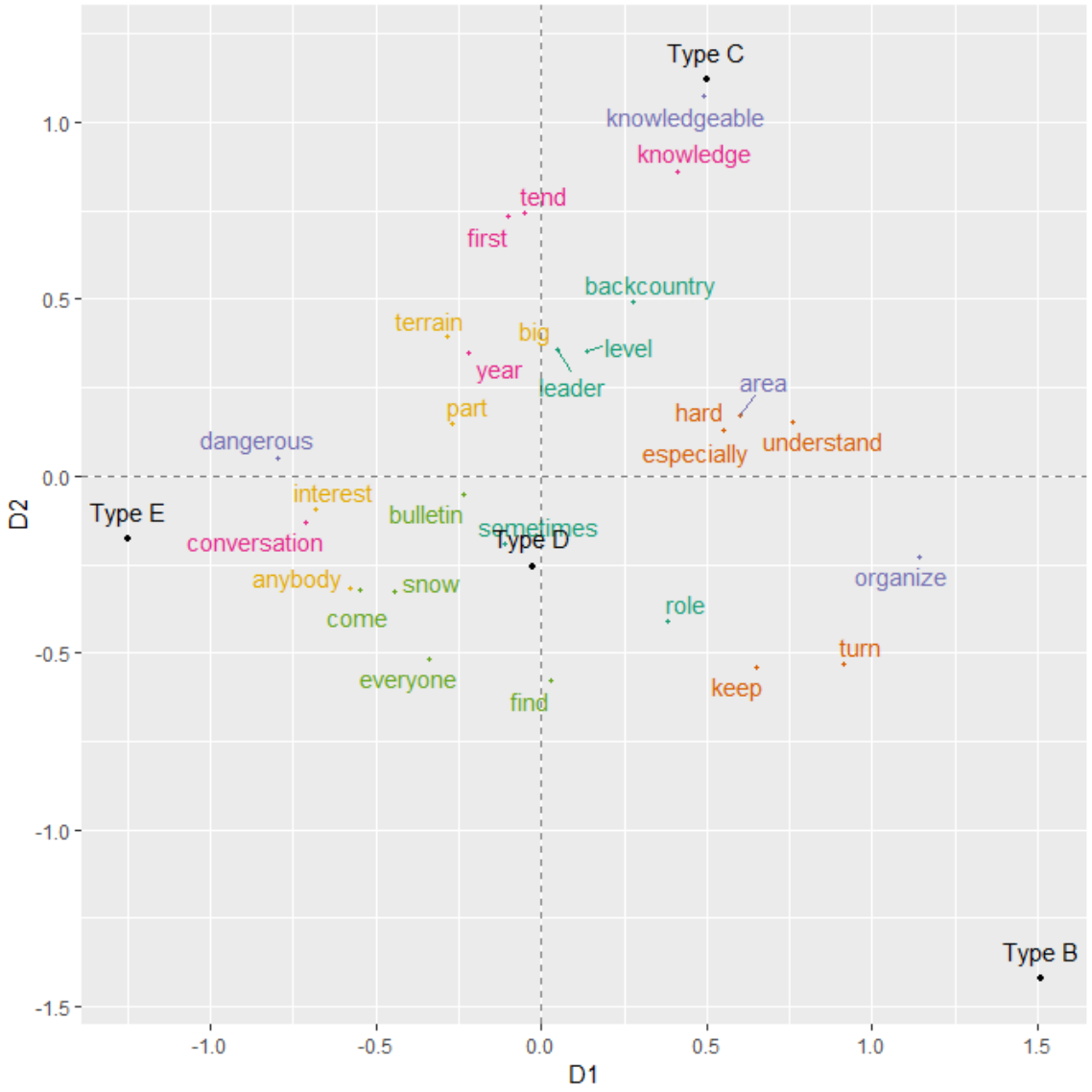


Figure 4.12 Associations between word frequencies and bulletin user types in the Group Dynamics corpus

Note: Words colors correspond with the topics produced by the topic model

4.2.3. Multinomial Logistic Regression Model

To take the quantitative exploration one step further, I applied a multinomial logistic regression model to explore the possibility of classifying participants based on the presence or absence of words in their responses. I computed the model for each of the four corpora to examine how they play a role in distinguishing patterns. The model did not detect a pattern of classification in the *Information Influence* and *Group Dynamics* corpora, placing all participants in a single group (Table 2, Table 4). In participants' descriptions of their *Planning Process*, the model identified a pattern of classification correctly classifying 33 out of 42 participants (79%) in the same class of the typology per the qualitative analysis (Table 1). Interestingly, in the *Bulletin Use* corpus, the model classified participants in an identical pattern to the Avalanche Bulletin User Typology (Table 3). For these two detected patterns of classification, the logistic regression model identified terms important to making the distinctions and calculated subsequent word importance scores between 0 and 100, which are outlined in Table 5 and Table 6.

Table 1 Comparision of patterns of participant classification between the multinomial logistic regression model and the Avalanche Bulletin User Typology for the Planning Process corpus

Planning Process				
Model Prediction	**Avalanche Bulletin User Typology**			
	Type B	**Type C**	**Type D**	**Type E**
Type B	5	0	0	0
Type C	0	6	0	0
Type D	2	4	19	3
Type E	0	0	0	3

Table 2 **Comparision of patterns of participant classification between the multinomial logistic regression model and the Avalanche Bulletin User Typology for the Information Influence corpus**

Information Influence				
Model Prediction	**Avalanche Bulletin User Typology**			
	Type B	**Type C**	**Type D**	**Type E**
Type B	0	0	0	0
Type C	0	0	0	0
Type D	7	10	19	6
Type E	0	0	0	0

Table 3 **Comparision of patterns of participant classification between the multinomial logistic regression model and the Avalanche Bulletin User Typology for the Bulletin Use corpus**

Bulletin Use				
Model Prediction	**Avalanche Bulletin User Typology**			
	Type B	**Type C**	**Type D**	**Type E**
Type B	7	0	0	0
Type C	0	10	0	0
Type D	0	0	19	0
Type E	0	0	0	6

Table 4 **Comparision of patterns of participant classification between the multinomial logistic regression model and the Avalanche Bulletin User Typology for the Group Dynamics corpus**

Group Dynamics				
Model Prediction	**Avalanche Bulletin User Typology**			
	Type B	**Type C**	**Type D**	**Type E**
Type B	0	0	0	0
Type C	0	0	0	0
Type D	7	10	19	6
Type E	0	0	0	0

The words important to identifying patterns in participants' descriptions of their *Planning Process* build on previously established themes (Table 5). Type B recreationists are distinguished by the words *trail*, *online*, and *bail*, Type C users by terrain references (i.e., *exposure*) and regard for expertise (i.e., *instructor*), and Type E users by their references to hazard assessment and decision-making (i.e., *aspect*, *quality*, *pull*, *convince*). Following further investigation of the frequency table, the words *club* and *marked* distinguished the Type D bulletin user type due to their absence in Type D responses. This pattern of classification produced by the logistic regression model supports several meaningful distinctions in the Avalanche Bulletin User Typology.

The pattern identified by the logistic regression model in participants' descriptions of their *Bulletin Use* detects keywords associated with quintessential characteristics in the typology (Table 6). For example, although Type B recreationists do not incorporate bulletin information to purposely mitigate the nature of the hazard or avalanche terrain exposure, they deliberately plan to mitigate their vulnerability by carrying the necessary safety gear. Accordingly, the frequency with which Type B participants mention equipment markedly sets them apart in their discussion of their bulletin use in the logistic regression model. Likewise, Type C recreationists characteristically discuss their need to defer to more experienced or more highly trained partners to interpret and recognize hazardous conditions. The results of the model capture this representative reliance with the word *knowledgeable* as a keyword for classifying Type C users. Similarly, the word *academic* plays a prominent role in classifying Type E users and is consistent with their conceptually-advanced bulletin use. While not all words make a direct contextual contribution to the Avalanche Bulletin User Typology, the words of greatest distinction reveal complementarity in the quintessential qualities of the classes.

Table 5 **Distinguishing terms and word importance scores from the logistic regression model for the Planning Process corpus according to bulletin user type**

Planning Process

Type B		Type C		Type D		Type E	
trail	32.8	January	100.0	club	3.1	quality	51.4
online	13.6	instructor	62.8	marked	3.0	pull	44.7
bail	2.5	awful	43.5	whumphing	0.4	convince	33.5
		direction	23.8			aspect	4.0
		exposure	9.4				
		hang	5.2				

Table 6 **Distinguishing terms and word importance scores from the logistic regression model for the Bulletin Use corpus according to bulletin user type**

Bulletin Use

Type B		Type C		Type D		Type E	
equipment	100.0	knowledgeable	75.2	include	28.0	academic	82.0
April	83.6	complaint	55.1	apart	27.0	anymore	27.7
western	33.5	corridor	54.6	educate	19.5	typical	18.8
literally	24.0	awful	49.4	hate	18.3	variability	17.0
answer	9.9	geography	35.5	grain	14.0	conversation	15.9
steady	4.7	instability	25.7	comfort	12.2	folk	10.2
border	4.4	glossary	23.0	split	9.1	dramatically	7.1
		tend	6.8	simple	7.9	argue	5.9
		steepness	6.6	forget	7.2	aspect	3.1
		heat	4.1	towards	7.2		

Chapter 5. Discussion

5.1. The Avalanche Bulletin User Typology as a Stage Theory

Considered in combination, the qualitative and quantitative analyses provide a foundational understanding for how recreationists incorporate bulletin information into their travel decisions. The resulting Avalanche Bulletin User Typology presents a five-level hierarchy ranging from the absence of bulletin information consultation to the use of the information as a starting point for a comprehensive risk management and iterative hazard assessment strategy—the way it is intended to be used. Through the complementary insights from the mixed analysis, the patterns emerge as progression in recreationists' depth of bulletin use, degree of comprehension, and extent of information application, with each class of the typology building on the pattern set by the previous class.

This hierarchy of advancement is not continuous; rather, it takes shape in a series of discrete and discernible stages. Type B recreationists are the first class within the typology to intentionally consult bulletin information, primarily the danger rating, although without incorporating the nature of the hazard or avalanche terrain exposure. From the results from the correspondence analyses, Type B users constitute the most disparate bulletin use pattern. Type C users emerge as the first class to use bulletin information in combination with knowledge of avalanche terrain severity to inform decisions about backcountry travel, and Type D users exhibit the stage in which recreationists distinctly incorporate the avalanche problem information to account for both the nature and distribution of the hazard in their travel decisions. Type E users signify the stage at which the regional bulletin information is evaluated through a localized assessment of avalanche hazard in the field.

The emerging typology reveals a hierarchy of defined, ordered stages, with common barriers to change facing people in the same stages and different barriers to change facing people in different stages; thereby, the Avalanche Bulletin User Typology operates as a stage theory (Weinstein et al., 1998). Stage theorists emphasize the importance of addressing specific barriers to audience advancement and suggest developing a series of explanatory equations, one for each stage transition (Weinstein &

Sandman, 2002). Weinstein & Sandman (2002) describe this as “a much more complicated goal than finding a single prediction rule, but it offers the possibility of greater accuracy, greater intervention effectiveness, and greater intervention efficiency” (p. 2). In pursuit of this goal, I compared the Avalanche Bulletin User Typology with theories and taxonomies across disciplines, finding an explanatory framework within the field of education.

The identified patterns in the Avalanche Bulletin User Typology precisely parallel a structured hierarchy of observed learning outcomes (the SOLO taxonomy), a well-established progression of learning quality in the field of education (Biggs & Collis, 1982) (Figure 5.1). The SOLO Taxonomy evaluates and classifies the level of learning quality, providing “a systematic way of describing how a learner’s performance grows in complexity” (Biggs & Tang, 2011, p. 76). Like the Avalanche Bulletin User Typology, as learners progress in the SOLO taxonomy, each stage of the five-level hierarchy becomes the foundation on which further learning is built. There are two main changes that mark the stage transitions: (1) a quantitative increase in the amount of detail in the response (knowing more) and (2) a qualitative conceptual restructuring that integrates details into a structural pattern (deepening understanding) (Biggs & Tang, 2011). The first three stages of the SOLO taxonomy present a quantitative increase in what is grasped; whereby, learners may miss the point (prestructural), identify one relevant aspect (unistructural), or combine several relevant aspects (multistructural) (Biggs & Collis, 1982) (Figure 5.1). Correspondingly, the first three stages of the Avalanche Bulletin User Typology present a quantitative increase in what recreationists incorporate from the bulletin into travel decisions; whereby, Type A recreationists do not incorporate bulletin information, Type B users apply the danger rating, and Type C users combine the danger rating with avalanche terrain exposure considerations. The subsequent stages and stage transitions outlined by the SOLO taxonomy involve a qualitative, conceptual restructuring of the components, either by recognizing the systems and their integrated parts (relational) or by extending the subject into a new dimension (extended abstract) (Biggs & Collis, 1982). Accordingly, Type D recreationists recognize and integrate the components of avalanche hazard into a complete risk management framework, and Type E recreationists extend bulletin information to a slope-scale hazard assessment. The correspondence between the Avalanche Bulletin User Typology and the SOLO taxonomy is illustrated in Figure 5.1.

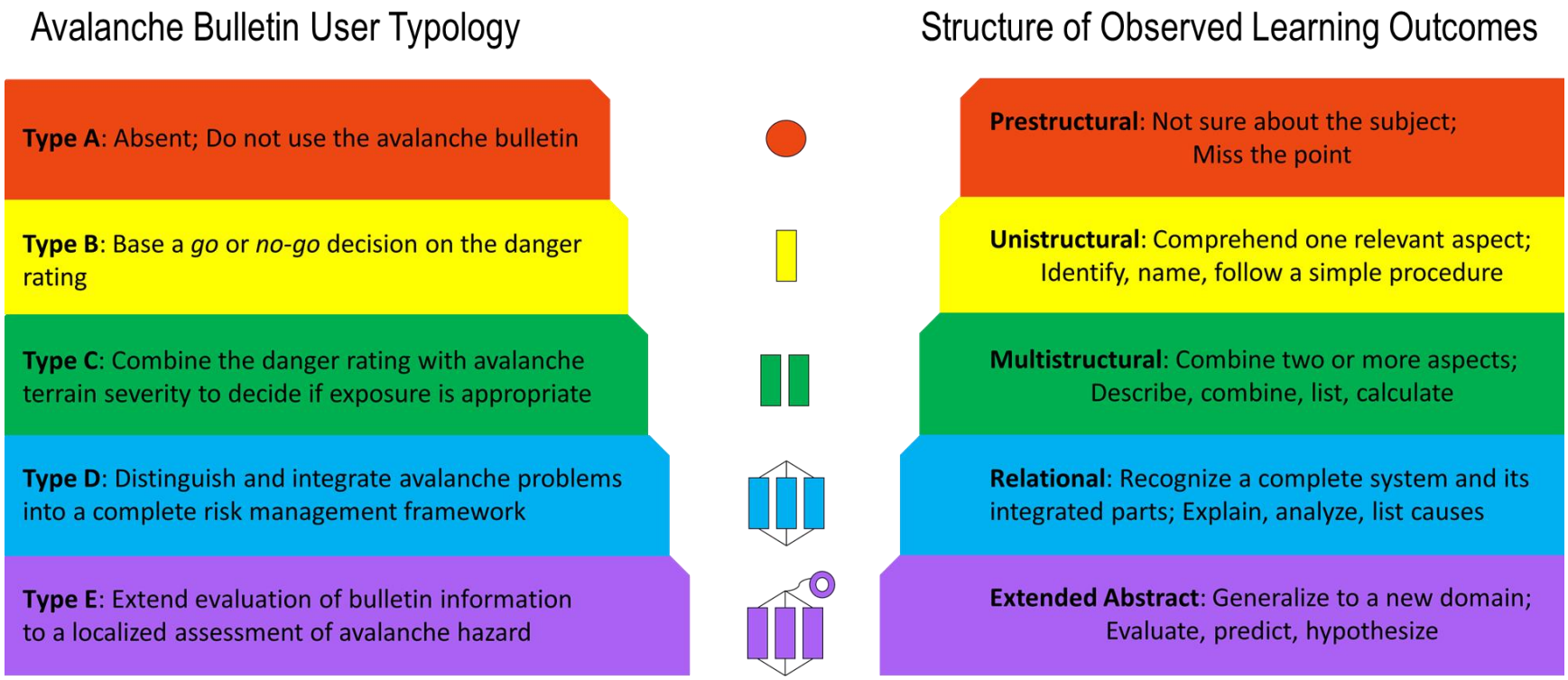


Figure 5.1 Link between the Avalanche Bulletin User Typology and the SOLO Taxonomy (Biggs & Collis, 1982)

Applying the SOLO taxonomy to the Avalanche Bulletin User Typology as an explanatory framework enhances the definitions of the stages and outlines the transition criteria for recreationists to advance to the next level in the hierarchy. In keeping with this framework, Type A and Type B recreationists require a quantitative increase in the amount of detail incorporated into their travel decisions, either by knowing more about existing bulletin products or by knowing more about avalanche terrain severity. Type C and Type D recreationists require a qualitative, conceptual restructuring of bulletin information to better inform a complete risk management approach or an accurate hazard assessment in the field.

With the aim to improve the effectiveness of education, the proposed solution stemming from the SOLO taxonomy for best practice in curriculum design prescribes constructively aligning lessons to produce these outcomes (Biggs, 2014). Biggs (2014) defined constructive alignment as an outcomes-based approach to teaching in which the learning outcomes that students are intended to achieve are defined before teaching takes place. The equivalence between the two classification systems suggests that designing risk messages with an outcomes-based approach targeting specific stages or quantitative or qualitative advances in bulletin use practices may offer a suitable and promising solution to improve the effectiveness of the avalanche bulletin.

5.2. Recommendations for Avalanche Bulletin Improvements

Through the explanatory link to the SOLO Taxonomy, the Avalanche Bulletin User Typology establishes a framework for constructing and evaluating product designs to improve information comprehensibility. The findings suggest that the avalanche bulletin could be more effective if products were deliberately designed to (a) resonate with specific stages and/or (b) explicitly improve users' ability to conceptualize and incorporate the information into decisions. Considering avalanche bulletin product design in this way not only offers the possibility for improved information transfer but also introduces an exciting opportunity for the avalanche bulletin to facilitate audience advancement.

For specific bulletin products, such as the danger rating, an outcomes-based design approach aligned with stages in the typology offers a purposeful process for

drafting and evaluating improvements to promote greater information transfer. Previous studies confirm that the danger rating scale presents challenges in comprehension for the recreational audience, especially for the middle levels of the scale (Ipsos Reid, 2009; Statham et al., 2010). Eyland (2018) estimates that 74%-90% of the days that recreationists choose to travel in the backcountry are rated at either *considerable* or *moderate* danger, and avalanche warning services in the U.S. report the distribution of avalanche fatalities concentrated on days with a *moderate* or *considerable* rating (Logan & Green, 2018). These danger rating levels prove to be both common and problematic for recreationists, and researchers have confirmed their importance and their cause for confusion in recreational decision-making (Engeset et al., 2018; Furman et al., 2010; Furman, Shooter, & Tarlen, 2013). The results from the present study reinforce recreationists' dependency on the product and their difficulty interpreting the middle range of the scale. However, these findings are accompanied by detailed insights into which stages are involved (i.e., Type B and C users), the process by which the product is used (i.e., a binary go versus no-go or terrain exposure versus terrain avoidance decision), and the explicit challenges at the intersection of this process and product (i.e., *moderate* and *considerable* avalanche danger rating interpretability and an incomplete risk management strategy relying on the input from peers or other sources). The Avalanche Bulletin User Typology establishes opportunities to evaluate the effectiveness of existing products based on how well they transfer the intended message in their most meaningful contexts.

The findings from this study also introduce the possibility for avalanche bulletin products to facilitate audience advancement through targeting specific stage transitions. The complementary insights from the mixed analysis reveal that as recreationists progress within the typology, they become less dependent on alternate information sources for avalanche risk management guidance. While Type A, B, and C recreationists discussed relying on peer recommendations, online trip reports, or social media to complete their risk management approach, Type D and Type E recreationists derive more risk management direction from bulletin information. Hence, promoting movement up the Avalanche Bulletin User Typology can push greater numbers of backcountry users towards a more complete avalanche risk management strategy from a more consistent and accurate source of information.

However, the progression from Type A/B/C to Type D/E poses a particularly difficult challenge considering that this transition requires a qualitative, conceptual restructuring. Existing research in public avalanche safety has pointed to these particular challenges in recreationists' conceptual understanding. For example, previous studies have identified avalanche problem information as not well understood or practiced in the backcountry community (Haegeli & Strong-Cvetich, 2018; Klassen et al., 2013; Wagner & Hardesty, 2014). Moreover, in an evaluation of recreational avalanche education curriculum in the U.S., Balent, Johnson, Hendrikx, and Shanahan (2018) concluded that recreational avalanche courses can only go so far in terms of developing the ability to assess risk and exercise judgment in novel and unpredictable settings. However, participants suggestions for bulletin improvement collected in the present study offer valuable insight as to how bulletin products could incorporate improvements to foster higher levels of conceptualization. Fittingly, these requests came from users within the corresponding classes of the typology (i.e., Type C, D, and E users), and their suggestions reflect a desire for a deepened understanding.

> What would be nice would be to have something like a newbie link or "You want to learn more about this?", so a deeper explanation in terms of what their thinking was about it.
>
> In addition to the wording, if there were some visuals… that would sort of give you a little bit more information as to why conditions may cause a change from *moderate* to *considerable*, then that would help.
>
> When you show somebody tapping the top of the column and the whole things goes, it's very illustrative, and you're like, "Whoa." It really brings home suddenly what *high* avalanche concern on a persistent slab might mean.

Notably, respondents' recommendations for improvement suggest an interactive feedback component as a possible design solution. This took form in requests for route-planning exercises and quizzes with an opportunity to calibrate their conceptual understanding through corrective feedback.

> I think at one point they had a tool where… you would be able to route plan up, and it would sort of tell you if your route was safe or not…. That, I found, was useful as a learning tool.
>
> If you had pictures where you could like quiz yourself and find out if you are right or wrong, that would be cool. I would say that is definitely an area that could be improved upon for the site, providing more tools,

> whether it's quizzes for people to take, definitions, photos, just more educational tools.
>
> One of my favorite things is the route-finding exercises, where you have the little hut, and you have to pick a safe route up. …I found them really helpful. …It's a good learning tool. So, I think having those kind of interactive exercises people can continue doing after the classroom piece of the AST (Avalanche Skills Training course) is really good.

These suggestions for improvement are fitting both within the SOLO taxonomy's explanatory framework as well as given the winter backcountry's wicked learning environment, where recreationists have few corrective feedback opportunities from which to learn despite their repeated exposure. For example, one participant details the benefits of an interactive online route-planning tool in this wicked learning context:

> It's awesome because you finally get feedback. You can ski forever and never set off an avalanche, but you could've made a thousand bad decisions. But, to get feedback, unless you're skiing with someone who's more experienced that can teach you, then that (interactive activity) is one of the only ways you can get it… unless you're making mistakes, which is not fun.

Several studies have documented positive public reception to interactive exercises, videos, and online learning platforms for deepening public understanding of the published information (Diegel & Tremper, 2012; Harvey, Aegerter, & Landolt, 2013; Landrø et al., 2013; Mayer, 2018; Nairz, Ruetz, & Kris, 2018). Additionally, in the suggestions from students following a recreational avalanche education course, Balent et al. (2018) reported that students found activities that incorporated feedback from the instructor to be the most valuable. Given that an interactive component poses a solution grounded in the SOLO theoretical framework and adapted for a wicked learning environment, bulletin interactivity presents a possibility for advancing recreationists' conceptual understanding.

The combined results of the present study suggest that avalanche bulletins could be more effective if they were not only viewed as conditions reports but rather as educational tools that explicitly define how they improve users' ability to conceptualize and manage the risk. Thinking in this way requires re-framing the avalanche bulletin within the context of a broader education system dedicated to public avalanche safety, including the integrated suite of products and programs (i.e., awareness initiatives, formal avalanche education curriculum, and social media outreach campaigns) that are

designed to support recreationists' risk management decision-making. Adams (2004) advocates for a systems thinking approach for designing effective avalanche accident prevention schemas. Systems thinking offers a holistic mode of understanding in which a system is built by bridging connections rather than dividing into parts (Senge, 1990; Wheatley, 1999). The Avalanche Bulletin User Typology provides a critical stepping stone for identifying which programs and products are best for bridging connections within this systems-based approach to provide recreationists with the information they need for decision-making at their particular stage and to advance them to more proficient avalanche bulletin users most effectively. Re-envisioned in this way, the avalanche bulletin becomes a central component of the education system as a key provider of up-to-date avalanche information uniquely positioned to reach and engage a wide-ranging audience on a routine basis. Re-defining avalanche bulletins in terms of their connections within an avalanche education system presents a relevant application for systems thinking to public avalanche safety and establishes a meaningful direction for improvements and future research.

5.3. Limitations

The findings of the present study should be considered in light of several limitations. Due to the sample size and regional recruitment, the conclusions that can be drawn from this qualitative research of recreational bulletin use patterns do not extend to explanations as to who makes up the bulletin user classes or what factors might explain membership in a particular class. Additional research conducted at the population scale is required to address these questions conclusively. However, for the purpose of pattern identification, the study sample of 46 participants largely exceeds established estimates for data saturation in qualitative interviews. Guest, Bunce, and Johnson (2006) posit that data saturation occurs in qualitative research with a sample of 12 interviews. Given the variation across recreationists in terms of their experience, skills, demographics, and activity types, I intentionally recruited a larger sample to account for the known heterogeneity. The resulting robust sample size in combination with the inclusive range of recreationists as well as the results of the analysis that link the Avalanche Bulletin User Typology to the well-established SOLO taxonomy substantiates the quality of the sample for the research objective and challenges assumptions of regional bias.

While the sample size was more than sufficient for the qualitative analysis, it posed some challenges for the quantitative analyses and their interpretability. The relatively small sample of participants prevented me from explicitly testing and quantifying the multinomial logistic regression's capacity to predict participants' bulletin user type based on their word choices in the interviews. While model validation is common practice in regression analysis, the purpose behind the inclusion of the regression model in this study was to explore patterns of participant classification within the sample rather than to create a predictive model for future use.

For the quantitative methods in general, the interpretability of the results is limited by the multiple contextual meanings that can be associated with a single word, which are not accounted for in the word frequencies across participants (i.e., *avalanche education course* and the phrase, *of course*). However, the mixed analysis orchestrated a multi-faceted pattern analysis that yielded stronger inferences through identifying complementarity across the results. I supported my interpretations of words' contextual meanings using these complementary insights from the qualitative phase of the analysis and from across the three methods of quantitative statistical analysis, as opposed to a stand-alone interpretation.

Chapter 6. Conclusion

The avalanche bulletin is tasked with consistently communicating sophisticated, accurate hazard information in a comprehensible format while simultaneously satisfying the various preferences, motivations, and levels of competency encompassed by the recreational community. The present study examined patterns of bulletin information use among the backcountry recreationists to better understand the different processes by which planning decisions are made and how bulletin information can better inform these processes. The resulting Avalanche Bulletin User Typology reveals a stage theory with defined, ordered stages and outlines distinct barriers to comprehension and advancement through an explanatory framework in the Structure of Observed Learning Outcomes (SOLO) taxonomy.

The first class of the Avalanche Bulletin User Typology does not consult avalanche bulletin information (Type A). The following two classes apply the danger rating to either deem the backcountry a safe environment for travel in general (Type B) or to decide what level of avalanche terrain severity is appropriate for backcountry travel (Type C). Recreationists making a transition to these stages require a quantitative increase in the amount of information incorporated into their travel decisions, either by knowing more about existing bulletin products (Type A) or by knowing more about avalanche terrain severity (Type B). Incorporating the avalanche problem information, Type D recreationists integrate the nature and distribution of the avalanche hazard into a complete risk management strategy that applies the hazard information to open and close terrain appropriate for travel. At the final stage, Type E recreationists review all of the bulletin information products with a focus on the details so that they can confirm or disconfirm the regional hazard information with a localized assessment of the conditions where they are traveling. Recreationists making a transition to these stages require a qualitative, conceptual restructuring and deepened understanding of bulletin information to better inform their risk management approach (Type C) or to establish a starting point for their continuous hazard assessment in the field (Type D).

The Avalanche Bulletin User Typology establishes an evidence-based framework for constructing and evaluating bulletin product designs to improve information comprehensibility. The framework defines the stages of bulletin information use, details

the product challenges for users in different stages, outlines the explicit barriers to comprehension and progression, and organizes the recreational audience in terms of how to reach them with risk communication products. To communicate more effectively, the findings suggest deliberately designing products to resonate with specific stages and/or to explicitly improve users' ability to conceptualize and incorporate the information into decisions. Considering avalanche bulletin product design in this way offers the possibility for improved information transfer and introduces an opportunity for the avalanche bulletin to facilitate audience advancement. Effectively enacting these recommendations requires engaging a systems thinking perspective to best integrate and optimize the complete landscape of public avalanche safety initiatives to most effectively reach recreationists at particular stages or advance them to more proficient avalanche bulletin users. Additional research of avalanche bulletin comprehensibility is necessary to build on this foundation. Topics for future study include examining the characteristics of backcountry users at the different stages of the typology and studying the effectiveness of stage-based or transition-focused interventions.

By establishing the criteria that both define the stages and govern the movement between them, the Avalanche Bulletin User Typology captures the full complexity in audience understanding and outlines prescriptive recommendations for improving the connection between a risk communication product and the intended behavioral response. Rather than a descriptive audience profile or a comparison between expert and public conceptual models, this research approach produces an ordered series of opportunities for risk communication to better facilitate audience understanding at multiple stages. The distinction between describing people and describing the role of information in a decision process is key to identifying tangible opportunities that are actionable. In addition, the close similarity between the Avalanche Bulletin User Typology and SOLO taxonomy establishes an interdisciplinary link to the field of education with the potential to further enhance and inform the direction of future risk communication research.

Creating risk communication products to intentionally resonate with specific stages of information processing offers various exciting research and development opportunities at the interface between risk communication and decision theory. First, the proposed outcomes-based design focused on user skill for risk communication products seems to parallel Thaler and Sunstein's (2009) choice architecture that proposed

intentionally designing decision-making contexts to optimize the interplay of System 1 and 2 thinking. Furthermore, the Avalanche Bulletin User typology might emerge as an important covariate for studying the biases and errors that arise from this decision-making interplay in recreationists' actual travel behavior. Tracing the typology into real-time decision processes introduces an exciting opportunity for future research to better understand the path between risk communication products and behavioral response and offers valuable insight for how potential challenges might be addressed with enhanced avalanche bulletin products.

References

Arksey, H., & Knight, P. T. (1999). *Interviewing for social scientists*. London, UK: SAGE Publications, Ltd.

Adams, L. (2004). Supporting sound decisions: A professional perspective on recreational avalanche accident prevention in Canada. *Proceedings of the 2004 International Snow Science Workshop*, Jackson Hole, WY, 1-10.

Adams, L. (2005). *A systems approach to human factors and expert decision-making within Canadian avalanche phenomena*. M.A. thesis. Royal Roads University.

Anupriya, P., & Karpagavalli, S. (2015). LDA based topic modeling of journal abstracts. *Proceedings of the 2015 International Conference on Advanced Computing and Communication Systems*, Coimbatore, India, 1-5. doi:10.1109/ICACCS.2015.7324058

Atkins, D., & McCammon, I. (2004). Differences between avalanche experts and novices, *Proceedings of the 2004 International Snow Science Workshop*, Jackson, WY, 452-459.

Avalanche Canada. (2018a). Avalanche Canada 2018 Annual Report. Retrieved from https://issuu.com/avalancheca/docs/ac_2019_annual_reportissuu

Avalanche Canada. (2018b). Avalanche Canada Profile Booklet. Retrieved from https://issuu.com/avalancheca/docs/ac_profile_booklet

Avalanche Canada. (2019). Avalanche Canada 2019 Annual Report. Retrieved from https://issuu.com/avalancheca/docs/ac_2019_annual_reportissuu

Azusa, D., & Yusuke, H. (2013). Establishing an avalanche community and communication in Japan. *Proceedings of the 2013 International Snow Science Workshop*, Chamonix, France, 1118-1121.

Balent, C., Johnson, J., Hendrikx, J., & Shanahan, E. A. (2018). Theory and Practice in Introductory Avalanche Education. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1462-1466.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215. http://dx.doi.org/10.1037/0033-295X.84.2.191

Bécue-Bertaut, M. (2018). *Textual Data Science with R*. New York: Chapman and Hall/CRC. https://doi.org/10.1201/978131521266

Biggs, J. B., & Collis, K. F. (1982). *Evaluating the quality of learning: The SOLO taxonomy*. New York, NY: Academic Press.

Biggs, J. B., & Tang, C. S. (2011). *Teaching for quality learning at university: What the student does*. Philadelphia, PA: McGraw-Hill/Society for Research into Higher Education.

Biggs, J. B. (2014). Constructive alignment in university teaching. *HERDSA Review of Higher Education, 1*, 5-22.

Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent Dirichlet allocation. *Journal of Machine Learning Research, 3*, 993-1022.

Blei, D. M. (2012). Probabilistic Topic Models. *Communications of the ACM, 55*(4), 77-84. doi:10.1145/2133806.2133826

Boase, N., White, M., Gaze, W., & Redshaw, C. (2017). Evaluating the Mental Models Approach to Developing a Risk Communication: A Scoping Review of the Evidence. *Risk Analysis 37*(11), 2132-2149.

Bostrom, A., Morss, R. E., Lazo, J. K., Demuth, J. L., & Lazrus, H. (2016). A Mental Models Study of Hurricane Forecast and Warning Production, Communication, and Decision-Making. *Weather, Climate and Society 8*(2), 111-129.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology, *Qualitative Research in Psychology, 3*(2), 77-101. http://dx.doi.org/10.1191/1478088706qp063oa

Braun, V., & Clarke, V. (2014). What can "thematic analysis" offer health and wellbeing researchers? *International journal of qualitative studies on health and well-being*, *9*. https://doi.org/10.3402/qhw.v9.26152

Burkeljca, J. (2013). Shifting audience and the visual language of avalanche risk communication, *Proceedings of the 2013 International Snow Science Workshop*, Grenoble, France, 415-422, 2013b.

Campbell, C., Bakermans, L., Jamieson, B., & Stethem, C. (2007). Current and future snow avalanche threats and mitigation measures in Canada. Canadian Avalanche Centre, Revelstoke, BC.

Canadian Avalanche Center. (2013). Canadian Avalanche Centre Annual Report 2012-2013. Retrieved from https://issuu.com/avalancheca/docs/cac_annualreport2013

Carter, S., Milton, J., & Hanke, J. (2014). Snow kiting and biking in avalanche terrain. *Proceedings of the 2014 International Snow Science Workshop*, Banff, AB, 1174-1181.

Cody, E. M., Stephens, J. C., Bagrow, J. P., Dodds, P. S., & Danforth, C. M. (2017). Transitions in climate and energy discourse between Hurricanes Katrina and Sandy. *Journal of Environmental Studies and Sciences, 7*(1), 87-101. https://doi.org/10.1007/s13412-016-0391-8

Conger, S. (2004). A review of colour cartography in avalanche danger visualization. *Proceedings of the 2004 International Snow Science Workshop*, Jackson Hole, WY, 477-482.

Coulter, J., & Helgelson, R.G. (2018). Show Don't Tell: Modelling behavior on social media as a strategy for influencing behavior in data sparse regions. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1511-1516.

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research.* Thousand Oaks, CA: Sage.

Cvetich-Strong, L. (2014). *Mountain Snowmobilers and Avalanches: An Examination of Precautionary Behaviour*. M.R.M. research project, no.586, Burnaby, BC. School of Resource and Environmental Management, Simon Fraser University.

de Leeuw, J., & Mair, P. (2009). Simple and Canonical Correspondence Analysis Using the R Package anacor. *Journal of Statistical Software, 31*(5), 1-18. http://www.jstatsoft.org/v31/i05/

Denzin, N. K., & Lincoln, Y. S. (1994). *Handbook of qualitative research*. Thousand Oaks, CA: Sage Publications, Inc.

Diegel, J. D., & Tremper, B. (2012). @utahavalanche: Was Social Media Invented for Avalanche Forecasting? *Proceedings of the 2012 International Snow Science Workshop*, Anchorage, AK, 387-391.

Doey, L., & Kurta, J. (2011). Correspondence Analysis applied to psychological research. *Tutorials in Quantitative Methods for Psychology, 7*(1), 5-14. doi:10.20982/tqmp.07.1.p005

Duncan, A., & Stewart-Patterson, I. (2016). The North Rockies Mountain Snowmobilers in the absence of a daily bulletin. *Proceedings of the International Snow Science Workshop*, Breckenridge, CO, 1134-1141.

Engeset, R. V., Pfuhl, G., Landrø, M., Mannberg, A., & Hetland, A. (2018). Communicating public avalanche warnings – what works?, *Natural Hazards Earth Systems Science, 18*, 2537–2559. https://doi.org/10.5194/nhess-18-2537-2018

Ericsson, K., & Simon, H. (1998). How to Study Thinking in Everyday Life: Contrasting ThinkAloud Protocols with Descriptions and Explanations of Thinking. *Mind, Culture, & Activity, 5*(3), 178-186.

Ewert, A., & Shultis, J. (1999). Technology and Backcountry Recreation: Boon to Recreation or Bust for Management? *Journal of Physical Education, Recreation & Dance*, *70*, 23-28. doi:10.1080/07303084.1999.10605701

Eyland, T. (2018). Avalanche danger ratings and deaths, putting things into perspective. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1501-1505.

Fitzgerald, K., Kay, J., Hendrikx, J., & Johnson, J. (2016). Backcountry and Sidecountry Users: an Intercept Survey Approach. *Proceedings of the 2016 International Snow Science Workshop*, Breckenridge, CO, 1057-1063.

Fischhoff, B. (1995). Risk perception and communication unplugged: Twenty years of process, *Risk Analysis,15*, 137-145.

Flick, U., Kardoff, E., & Steinke, I. (Eds.) (2004). *A Companion to Qualitative Research*. London, UK: Sage.

Franz, P. J., Nook, E. C., Mair, P. & Nock, M. K. (2019). Using Topic Modeling to Detect and Describe Self-Injurious and Related Content on a Large-Scale Digital Platform. *Suicide Life-Threatening Behavior*. doi:10.1111/sltb.12569

Frewer, L. J., Howard, C., Hedderley, D., & Shepherd, R. (1998). Methodological Approaches to Assessing Risk Perceptions Associated with Food-Related Hazards. *Risk Analysis, 18*, 95-102. doi:10.1111/j.1539-6924.1998.tb00919.x

Friedman, J., Hastie, T., & Tibshirani, R. (2010). Regularization Paths for Generalized Linear Models via Coordinate Descent. *Journal of Statistical Software, 33*(1), 1-22. http://www.jstatsoft.org/v33/i01/

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. doi:10.1177/0018720810377069

Furman, N., Shooter, W., & Tarlen, J. (2013). Environmental factors affecting the predicted decisions of backcountry skiers: an examination of the Obvious Clues Method decision aid. *Journal of Outdoor Recreation, Education, and Leadership, 5*(3), 226-241. doi:10.7768/1948-5123.1168

Glanz, K., Rimer, B. & Lewis, F. (2002) *Health behavior and health education. Theory, research and practice*. San Francisco CA: Wiley & Sons.

Glaser, B., & Strauss, A. L. (1967). *The Discovery of Grounded Theory. Strategies for Qualitative Research*. Chicago IL: Aldine.

Greenacre, M. J., & Blasius, J. (1994). *Correspondence analysis in the social sciences: Recent developments and applications*. London, UK: Academic Press.

Greenacre, M. (2007). *Correspondence analysis in practice* (2nd ed.). Boca Raton, LA: Chapman & Hall/CRC.

Griffin, R., Powell, M., Dunwoody, S., Neuwirth, K., Clark, D., & Novotny, V. (2004). Testing the Robustness of a Risk Information Processing Model. Presented to the Communication Theory and Methodology Division, Association for Education in Journalism and Mass Communication, at the August 2004 *AEJMC Annual Convention*, Toronto, ON. doi:10.13140/2.1.3856.0960

Grün, B., & Hornik, K. (2011). topicmodels: An R Package for Fitting Topic Models. *Journal of Statistical Software*, *40*(13), 1-30. doi:10.18637/jss.v040.i13

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods, 18*(1), 59-82. http://dx.doi.org/10.1177/1525822X05279903

Guest, G., Macqueen, K.M., & Namey, E.E. (2012). *Applied thematic analysis*. Thousand Oaks, CA: SAGE.

Gunn, M. (2010). *Out of Bounds Skiers and Avalanche Risk: High-Risk Cohort Identification and Characterization*. M.R.M. research project, no.604, Burnaby, BC. School of Resource and Environmental Management, Simon Fraser University.

Gurabardhi, Z., Gutteling, J.M., & Kuttschreuter, M. (2004). The development of risk communication. *Science Communication*, *25*, 323-349.

Haegeli, P., McCammon, I., Jamieson, B., Israelson, C., & Statham, G. (2006). The Avaluator‑A Canadian rule-based avalanche decision support tool for amateur recreationists. *Proceedings of the 2006 International Science Workshop,* Telluride, CO, 254-263.

Haegeli, P. (2010). Avaluator Avalanche Accident Prevention Card – Second Edition (v2.0). Revelstoke, BC: Canadian Avalanche Centre.

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), 185-209.

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. http://doi.org/10.1007/s11121-012-0282-5

Haegeli, P., Falk, M., Procter, E., Zweifel, B., Jarry, F., Logan, S., Kronholm, K., Biskupi˘c, M., & Brygger, H. (2014). The effectiveness of avalanche airbags. *Resuscitation*, *85*,1197-1203.

Haegeli, P. (2018). "The Alpine Club of Canada's State of the Mountains Report." L. Parrott, Z. Robinson, D, Hik (Eds.), *1*, 19-21.

Haegeli, P., & Strong-Cvetich, L. (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*, ISSN 2213-0780. doi:10.1016/j.jort.2018.01.007

Hallandvik, L., Svarstad Andresen M., & Aadland, E. (2017). Decision-making in avalanche terrain‑How does assessment of terrain, reading of avalanche

forecast and environmental observations differ by skiers' skill level? *Journal of Outdoor Recreation and Tourism, 5*(20), 45-51.

Harvey, S, Aegerter, S., & Landolt, D. (2013). White Risk 2.0 – A new web-based platform for avalanche education. *Proceedings of the 2013 International Snow Science Workshop*, Grenoble, France, 507-510.

Herzog, C., Hanke, C., & Hitters, E. (2019, in press). Analyzing Talk and Text II: Thematic Analysis. Van den Bulck, H., Puppis, M., Donders, K. & Van Audenhove, L. (Eds.) *The Palgrave Handbook of Methods for Media Policy Research*, Ch. 22. Basingstoke, England: Palgrave Macmillan.

Hogarth, R. M. (2001). *Educating Intuition*. Chicago, IL: University of Chicago Press.

Hogarth, R. M., Lejarraga, T., & Soyer, E. (2015). "The Two Settings of Kind and Wicked Learning Environments." *Current Directions in Psychological Scienc*e, 24(5), 379-385. https://doi.org/10.1177/0963721415591878

Hosmer, D. W., & Lemeshow, S. (2000). *Applied logistic regression*. New York, NY: Wiley.

Ipsos Reid. (2009). Avalanche Danger Scale Test, Avalanche Bulletin Users, Final Report. Report for the Canadian Avalanche Centre.

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). *An introduction to statistical learning: With applications in R*. New York, NY: Springer.

Jamieson, J. B., & Stethem, C. J. (2002). Snow Avalanche Hazards and Management in Canada: Challenges and Progress. *Natural Hazards, 26*(1), 35-53. https://doi.org/10.1023/A:1015212626232

Jekich, B., Drake, B. Nacht, J., Nichols, A., Ginde, A., & Davis, C. (2016). Avalanche Fatalities in the United States: A Change in Demographics. *Wilderness & Environmental Medicine*, *27*, 46-52. https://doi.org/10.1016/j.wem.2015.11.004

Kahlor, L. (2010). PRISM: A Planned Risk Information Seeking Model, *Health Communication, 25*(4), 345-356. https://doi.org/10.1080/10410231003775172

Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin, & D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgment,* 49-81. New York, NY: Cambridge University Press. http://dx.doi.org.proxy.lib.sfu.ca/10.1017/CBO9780511808098.004

Kahneman, D. (2003). A perspective on judgment and choice: mapping bounded rationality. *The American psychologist, 58*(9), 697-720.

Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Farrar, Straus and Giroux.

Kandula, S., Curtis, D., Hill, B., & Zeng-Treitler, Q. (2011). Use of topic modeling for recommending relevant education material to diabetic patients. *AMIA Annual Symposium proceedings. AMIA Symposium*, *2011*, 674-682.

Kolini, F. & Janczewski, L. (2017). Clustering and Topic Modelling: A New Approach for Analysis of National Cyber security Strategies. *Proceedings of the 2017 PACIS,* 126. http://aisel.aisnet.org/pacis2017/126

Klassen, K. (2012). Incorporating terrain into public avalanche information products. *Proceedings of the 2012 International Snow Science Workshop*, Anchorage, AK, 209-213.

Klassen, K., Haegeli, P., & Statham, G. (2013) The role of avalanche character in public avalanche safety products. *Proceedings of the 2013 international snow science workshop*, Grenoble, France, 493–499.

Kuhn, M. (2019). caret: Classification and Regression Training. R package version 6.0-84. https://CRAN.R-project.org/package=caret

Landrø, M., Kosberg, S., & Müller, K. (2013). Avalanche problems; an important part of the Norwegian forecast, and a useful tool for the users. *Proceedings of the 2013 International Snow Science Workshop*, Grenoble, France, 215-218.

Lanzanasto, N., Boninsegna, A., Cestari, P., Kriz, K., Nell, D., Pucher, A., & Mitterer, C. (2018). Project ALBINA: The technical framework for a consistent, cross-border and multilingual regional avalanche forecasting system. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1045-1051.

Lazar, B., Trautman, S., Cooperstein, M., Greene, E., & Birkland, K. (2016). North American Danger Scale: Are Public Backcountry Forecasters Applying it Consistently? *Proceedings of the 2016 International Snow Science Workshop*, Breckenridge, CO, 457-465.

Lazrus, H., Morss, R. E., Demuth, J. L., Lazo, J. K., & Bostrom, A. (2016). Know What to Do If You Encounter a Flash Flood": Mental Models Analysis for Improving Flash Flood Risk Communication and Public Decision Making. *Risk Analysis, 36*(2), 411-427.

Lee, K., Jung, H. & Song, M. (2016). Subject–method topic network analysis in communication studies. *Scientometrics, 109*, 1761. https://doi.org/10.1007/s11192-016-2135-7

Logan, S., & Greene, E. (2018). Forecast Avalanche Danger and Avalanche Accidents in Colorado, USA, Winters 2014 to 2018. *Proceedings of the 2018 International Snow and Avalanche Workshop*, Innsbruck, Austria, 1071-1074.

Lindell, M., & Perry, R. (2011). The Protective Action Decision Model: Theoretical Modifications and Additional Evidence. *Risk analysis*, *32*, 616-32. doi:10.1111/j.1539-6924.2011.01647.x.

Maddux, J. E., & Rogers, R. W. (1983). Protection motivation and self-efficacy: A revised theory of fear appeals and attitude change. *Journal of Experimental Social Psychology, 19*(5), 469-479. http://dx.doi.org/10.1016/0022-1031(83)90023-9

Maguire, L. (2014). The Human Behind the Factor: A Brief Look at How Context Informs Practice in Recreational Backcountry Users. *Proceedings of the 2014 International Snow Science Workshop*, Banff, AB, 942-948.

Mair, P., & von Eye, A. (2007) Application scenarios for nonstandard log-linear models. *Psychological Methods, 12*, 139-156.

Mair, P. (2018). *Modern Psychometrics with R*. New York, NY: Springer.

Mannberg, A., Hendrikx, J., Landrø, M., Stefan, M. (2018). Who's at risk in the backcountry? Effects of individual characteristics on hypothetical terrain choices, *Journal of Environmental Psychology*, *59*, 46-53. ISSN 0272-4944. https://doi.org/10.1016/j.jenvp.2018.08.004

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, 49*, 78-85.

Martin, S. R., & Pope, K. (2012). The influence of hand-held information and communication technology on visitor perceptions of risk and risk-related behavior. *Wilderness visitor experiences: Progress in Research and Management*, 119-126.

Mayer, C. W. (2018). 'Backountry Ascender' Avalanche Educator-Leveraging Incentive Based Learning and Peer Accountability to Drive Avalanche Education. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1389-1393.

McCammon, I. (2002): Evidence of heuristic traps in recreational avalanche accidents. *Proceedings of the 2002 International Snow Science Workshop*, Penticton, BC, 244-251.

McCammon, I. (2004): Heuristic traps in recreational avalanche accidents: Evidence and implications. *Avalanche News*, *68*(1), 1-10.

McCammon, I. (2009). *Assessment of avalanche risk communication for out-of-bounds recreation*. Retrieved from Salt Lake City, UT.

Michaelsen, B., & Rolland, C. (2016). Observing Ski Touring and Decision making in the Alps. What Ordinary People Do or Not Do, and Why? *Proceedings of the 2016 International Snow Science Workshop*, Breckenridge, CO, 770-777.

Moner, I., Orgué, S., Gavaldà, J., & Bacardit, M. (2013). How big is big: results of the avalanche size classification survey. *Proceedings of the International Snow Science Workshop*, Grenoble, France, 242-246.

Morgan, M. G., Fischhoff, B., Bostrom, A., & Atman, C. J. (2002). *Risk Communication: A Mental Models Approach*: Cambridge University Press.

Morss, R. E., Demuth, J. L., Bostrom, A., Lazo, J. K., & Lazrus, H. (2015). Flash Flood Risks and Warning Decisions: A Mental Models Study of Forecasters, Public Officials, and Media Broadcasters in Boulder, Colorado. *Risk Analysis, 35*(11), 2009-2028.

Morss, R. E., Demuth, J. L., Lazo, J. K., Dickinson, K., Lazrus, H, & Morrow, B. H. (2016). Understanding Public Hurricane Evacuation Decisions and Responses to Forecast and Warning Messages. *Weather & Forecasting, 31*(2), 395-417.

Murzintcev, N. (2019). ldatuning: Tuning of the Latent Dirichlet Allocation Models Parameters. R package version 1.0.0. https://CRAN.R-project.org/package=ldatuning

Myslín, M., Zhu, S. H., Chapman, W., & Conway, M. (2013). Using Twitter to Examine Smoking Behavior and Perceptions of Emerging Tobacco Products. *Journal of Medical Internet Research,15*(8), e174. doi:10.2196/jmir.2534

Nairz, P., Ruetz, L., & Kriz, K. (2018). How to Assess and Communicate Persistent Weak Layers: A Forecaster's Perspective. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1553-1558.

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*, 417-421.

Onwuegbuzie, A. J., & Teddlie, C. (2003). A framework for analyzing data in mixed methods research. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research,* 351-383*.* Thousand Oaks, CA: Sage.

Onwuegbuzie, A., & Combs, J. (2011). Data Analysis in Mixed Research: A Primer. *International Journal of Education, 3*. doi:10.5296/ije.v3i1.618

Ortovox. (n.d.) Retrieved from https://www.ortovox.com/us/safety-academy/training-tools/safety-academy-mountain-3d/

Paton, D., Johnston, D., Rossiter, K., Buergelt, P., Richards, A., & Anderson, S. (2017). Community understanding of tsunami risk and warnings in Australia. *Australian Journal of Emergency Management, 32*(1), 54-59. ISSN: 1324-1540.

Paul, M.J., & Dredze, M. (2011). You Are What You Tweet: Analyzing Twitter for Public Health. *Proceedings of the Fifth International Conference on Web and Social Media.*

Procter, E., Strapazzon, G., Dal Cappello, T., Castlunger, L., Staffler, H.P., & Brugger, H. (2014). Adherence of backcountry winter recreationists to avalanche prevention and safety practices in northern Italy. *Scandanavian Journal of Medicine and Science in Sports*. https://doi.org/10.1111/sms.12094

QSR International. (2018). NVivo qualitative data analysis software. QSR International Pty Ltd. Version 12. https://www.qsrinternational.com/nvivo/home

R Core Team. (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Robin, X., Turck, N., Hainard, A., Tiberti, N., Lisacek, F., Sanchez, J. C., & Müller, M. (2011). pROC: an open-source package for R and S+ to analyze and compare ROC curves. *BMC Bioinformatics*, *12*, 77. doi:10.1186/1471-2105-12-77

Saldana, J. (2009). *The Coding Manual for Qualitative Researchers*. Los Angeles, CA: Sage Publications.

Schmiedel, T., Müller, O., & Brocke, J. (2018). Topic Modeling as a Strategy of Inquiry in Organizational Research: A Tutorial with an Application Example on Organizational Culture. *Organizational Research Methods*. doi:10.1177/1094428118773858

Schwartzer, R. (2001). Social-cognitive factors in changing health-related behavior, *Current directions in Psychological Science*, *10*, 47–51.

Schwarzer, R. (2008). Modeling health behavior change: How to predict and modify the adaptation and maintenance of health behaviors, *Applied Psychology*, *57*(1), 1-29.

Senge, P. (1990). *The fifth discipline: The art and practice of the learning organization*. New York, NY: Doubleday.

Shannon, C. (1948). A mathematical theory of communication, *Bell System Technical Journal*, Murray Hill, NJ: Bell Laboratories.

Silverton, N.A., McIntosh, S.E., & Kim, H.S. (2009). Risk assessment in winter backcountry travel. *Wilderness Environmental Medicine*. https://doi.org/10.1580/08-WEME-OR-209R1.1

Simon, H. A. (1997_1947). *Administrative Behavior: A Study of Decision-Making Processes in Administrative Organizations* (4th ed.). New York, NY: Free Press.

Sitas, N., Reyers, B., Cundill, G., Prozesky, H.E., Nel, J.L., & Esler, K.J. (2016). Fostering collaboration for knowledge and action in disaster management in South Africa. *Current Opinion in Environmental Sustainability*, *19*, 94-102.

Slovic, P. (1987). Perception of risk. *Science, 236*(4799), 280-285. http://dx.doi.org/10.1126/science.3563507

Statham, G., & Jones, A. (2006). The Backcountry Avalanche Advisory: Design and Implementation of a New Avalanche Warning System in Canada. *Proceedings of the 2006 International Snow Science Workshop*, Telluride, CO, 724-731.

Statham, G., Haegeli, P., Birkeland, K. W., Greene, E., Israelson, C., Tremper, B., & Kelly, J. (2010). The North American Public Avalanche Danger Scale.

Proceedings of the 2010 International Snow Science Workshop, Squaw Valley, CA, 80-87.

Statham, G., Campbell, S., & Klassen, K. (2012). The AvalX Public Avalanche Forecasting System. *Proceedings of the 2012 International Snow Science Workshop*, Anchorage, AK, 165-171.

Statham, G., Haegeli, P., Greene, E., Birkeland, K., Israelson, C., Tremper, 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

Statham, G., Holeczi, S., & Shandro, B. (2018). Consistency and accuracy of public avalanche forecasts in Western Canada. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1491-1495.

Statham, G., & Gould, B. (2016). Risk-based avalanche program design. *Proceedings of the 2016 International Snow Science Workshop*, Breckenridge, CO, 100-103.

Statham, G., McMahon, B., & Tomm, I. (2006). The Avalanche Terrain Exposure Scale. Proceedings of the 2006 International Snow Science Workshop, Telluride, CO, 491-497.

Steelman, T. A., & McCaffrey, S. (2013). Best practices in risk and crisis communication: Implications for natural hazards management. *Natural Hazards, 65*, 683-705.

Steyn, K., Kazenellenbogen, J.M., Lombard, C.J., & Bourne, L.T. (1997). Urbanization and the risk for chronic diseases of lifestyle in the black population of the Cape Peninsula, South Africa. *Journal of cardiovascular risk, 4*(2), 135-42.

Steyvers, M., & Griffiths, T. (2007). Probabilistic topic models. In T. K. Landauer, D. S. McNamara, S. Dennis, & W. Kintsch (Eds.), *Handbook of latent semantic analysis*, 427-448. Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Sykes, J., Hendrikx, J., Johnson, J., & Birkland, K. (2018). Travel behavior of lift access backcountry skiers adjacent to Bridger Bowl ski area, Montana, USA. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1635-1639.

Techel, F., Ceaglio, E., Colêou, C., Mitterer, C., Morin, S., Purves, R., & Rastelli, F. (2018). Spatial consistency and bias in avalanche forecasts - a case study in the European Alps. *Natural Hazards and Earth System Sciences* Discussion.

Thaler, R. H., & Sunstein, C. R. (2009). *Nudge: improving decisions about health, wealth, and happiness.* Rev. and expanded ed. New York, NY: Penguin Books.

Tiozzo, B., Mari, S., Ruzza, M., Crovato, S., & Ravarotto, L. (2017). Consumers' perceptions of food risks: A snapshot of the Italian Triveneto area. *Appetite*, *111*, 105-115. ISSN 0195-6663. https://doi.org/10.1016/j.appet.2016.12.028

Tremper, B., & Conway, J. (2006). Graphic avalanche information for the new media. *Proceedings of the 2006 International Snow Science Workshop*, Telluride, CO, 505-509.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases, *Science*, 1124-1131.

Tvinnereim, E., & Fløttum, K. (2015). Explaining topic prevalence in open-ended survey questions on climate change. *Nature Climate Change, 5,* 744-747. doi:10.1038/NCLIMATE2663

Tvinnereim, E., Fløttum, K., Gjerstad, Ø., Johannesson, M. P., & Nordø, Å. D. (2017). Citizens' preferences for tackling climate change: Quantitative and qualitative analyses of their freely formulated solutions. *Global Environmental Change, 46*, 34-41. ISSN 0959-3780. https://doi.org/10.1016/j.gloenvcha.2017.06.005

Wachinger, G., Renn, O., Begg, C. & Kuhlicke, C. (2013). The Risk Perception Paradox—Implications for Governance and Communication of Natural Hazards. *Risk Analysis, 33*, 1049-1065. doi:10.1111/j.1539-6924.2012.01942.x

Wagner, W., & Hardesty, D. (2014). Travel advice for the avalanche problems: A public forecasting tool. *Proceedings of the 2014 International Snow Science Workshop*, Banff, AB, 1229-1233.

Weinstein, N., Rothman, A. & Sutton, S. (1998). Stage theories of health behavior: Conceptual and methodological issues, *Health Psychology*, *17*(3), 290–299.

Weinstein, N., & Sandman, P. (2002). The precaution adoption process model, in *Health Behavior and Health Education*, 3rd ed (K. Glanz, B. Rimer, and F. Lewis, eds), Josey-Bass, 121-143.

Wheatley. M. (1999). *Leadership and the new science: Discovering order in a chaotic world*. San Francisco, CA: Berrett-Koehler Publishers.

Wikberg, P., & Palmgren, P. (2016). The establishment of the first public avalanche forecasting service in Sweden. *Proceedings of the 2016 International Snow Science Workshop*, Breckenridge, CO, 423-428.

Wikberg, P., Palmgren, P., Hallberg, N., Maartensson, S., & Nordlund, D. (2018). Changes in attitudes to risk and knowledge about avalanches among Swedish skiers after the introduction of a national avalanche safety program. *Proceedings of the 2018 International Snow Science Workshop*, Innsbruck, Austria, 1540-1544.

Wilbur, K., Babiker, A., Al-Okka, M., Jumaat, E., Al Saadi Al-Yafei, S. M., & Nashwan, A. J. (2015). Risk communication with Arab patients with cancer: a qualitative study of nurses and pharmacists. *BMJ Open*, *5*, e006890. doi:10.1136/bmjopen-2014-006890

Winkler, K., & Techel, F. (2014): Users rating of the Swiss avalanche forecast, in: *Proceedings of the 2014 International Snow Science Workshop*, Banff, AB, 437-444.

Winkler, K., Kuhn, T., & Volk, M. (2014). Evaluating the Fully Automatic Multi-language Translation of the Swiss Avalanche Bulletin. *Proceedings of the 4th International Controlled Natural Language Workshop 2014*, Galway, Ireland, 8625, 44-54, Springer International Publishing.

Winter Wildlands Alliance. (2018). Human Powered Snowsports: 2018 Trends and Impact Report. https://winterwildlands.org/2018-trends-impact-report/

Xavier R., Turck, N., Hainard, A., Tiberti, N., Lisacek, F., Sanchez, J., & Müller, M. (2011). pROC: an open-source package for R and S+ to analyze and compare ROC curves. *BMC Bioinformatics, 12*, 77. doi:10.1186/1471-2105-12-77

Yang, Z. J., Aloe, A. M., & Feeley, T. H. (2014), Risk Information Seeking and Processing Model: A Meta-Analysis. *Journal of Communication*, *64*, 20-41. doi:10.1111/jcom.12071

Zweifel, B., & Haegeli, P. (2014). A qualitative analysis of group formation, leadership and decision making in recreation groups traveling in avalanche terrain. *Journal of Outdoor Recreation and Tourism*, *5-6*, 17-26. https://doi.org/10.1016/j.jort.2014.03.001

Appendix A. Recruitment Sign-up Survey Questions

Name: _____

Please circle the most representative response.

1. **What is the winter backcountry activity that you most associate with?**
    - Ice climbing (IC)
    - Mountain snowmobile riding (SM)
    - Backcountry skiing or snowboarding (BC)
    - Out-of-bounds skiing or snowboarding (also BC)
    - Snowshoeing (SS)
    - Other: _____

2. **Which of the following statements best describes your thinking about avalanches?**
    1. I generally do not think about avalanches where I go.
    2. I know that avalanches can happen in some of the places I go, but avalanche danger generally does not affect the choices I make.
    3. My personal backcountry experience in the winter has provided me with all the skills I need for managing avalanche danger where I go.
    4. I sometimes worry about being caught in an avalanche. I would like to learn more about avalanche safety but have not taken a formal course with a field component (e.g., AST1 or more advanced) yet.
    5. I have taken a formal avalanche course with a field component, but I don't regularly apply what I learned.
    6. I have taken a formal avalanche course with a field component and I am practicing my skills whenever I can.
    7. I have taken a formal avalanche course and have several seasons of experience applying these skills. Avalanche risk mitigation has become an integral part of my riding practice.

3. **What is your gender?**
    - Male
    - Female
    - Other: _____

4. **Which of the following age categories describes you?**
    - Under 20
    - 20 to 24
    - 25 to 34
    - 35 to 44
    - 45 to 54
    - 55 or over

5. **If applicable, what is the highest level of formal avalanche awareness training you have completed?**
    - No training
    - Free seminar
    - Classroom session
    - AST1
    - AST2
    - Professional
    - Other: _____

6. **How often do you check avalanche conditions at avalanche.ca or on the Avalanche Canada mobile app?**
    - Every day
    - Before every trip into the backcountry
    - Before most trips into the backcountry
    - Rarely
    - Never

7. **Where is your main residence?** _____
8. **What is the best email address to reach you?** _____

Appendix B. Qualitative Interview Script

Introduction 0-4 mins

- **Welcome and thank** participants.
- Outline interview logistics: interview will last approx. one hour. Washrooms and water are available.
- Participants may opt out at any time.
- Provide **consent form**.
- Reassure participants that this is more of a conversation than an interview. There are no wrong answers! We're not interested in testing your knowledge, we're interested in hearing your thoughts.
- **BEGIN RECORDING**
- Can you **confirm the following information** from the sign-up website?

Part 1: General Motivation 4-8 mins

1. Why are you interested in engaging in winter backcountry recreation?
    a. Anything else?

2. How did you first get into the activity and how many years of experience do you have?
    a. How many times do you get out each winter?

Part 2: Planning Process 8-18 mins

General:

3. How do you plan for a day of <<participant's activity>>?

4. What are the considerations you take into account when going into the backcountry in the winter? We're looking for a thorough list of things you consider.
    a. Are there any others?
    b. Which factors do you consider more influential? Which factors do you consider least influential?

General area/specific trip:

5. How do you decide where to go? (general area and/or specific trip) (*probe for both day trips and longer trips if relevant*)
    a. If necessary, offer examples of general locations (e.g., North Shore, Whistler, Duffy Lake, Coquihalla, Interior, …)

b. Or specific trips or riding areas
   Backcountry skiers: Nak Peak, Musical Bumps
   Snowmobile riders: Brandywine Bowl, Brohm Ridge
   Snowshoers: Hollyburn, Mt Seymour

6. What might make you decide not to go on a specific trip?

In the backcountry:

7. Once you are traveling in the backcountry, how do you choose your route?

8. What do you look for to determine whether it is safe? (Ex: rely on friends, guides, tracks, specific observations of avalanche problems)
   a. If you are concerned about dangerous avalanche conditions, what type of observations do you make to decide whether it is safe or not?

Debrief (if it did not come up previously):

9. What is your role in the decision-making process?

Part 3: Sources of Information 18-28 mins

In the next questions, we want to explore your information sources and importance of several factors that may (or may not) play a role in your winter backcountry recreation choices and activities.

10. What is your definition of a successful trip? (*Based on response, select order for Avalanche versus Weather/Snow questions*)

Avalanche conditions:

11. What do you think about/pay most attention to when you consider avalanche conditions?
    a. Where do you get this information?
       i. Are there any other sources?
       ii. How is this information useful? *(For NON-AvCan sources*)
       iii. What do you like about it? *(For NON-AvCan sources*)
    b. How has this influenced your plans? (e.g., timing, terrain choice)
    c. Have you ever cancelled a trip because of information about this factor? Why or why not?
       i. What was the critical piece of information that informed the decision?
    d. When, in the planning of your trip, do you obtain this information (e.g., one week ahead, on the day you are leaving, en route to the site, update half-way through the trip, etc.)?

Weather/snow conditions:

12. What do you think about/pay most attention to when you consider weather/snow conditions?
    a. Where do you get this information?
        i. Are there any other sources?
        ii. How is this information useful? *(For NON-AvCan sources*)
        iii. What do you like about it? *(For NON-AvCan sources*)
    b. How has this influenced your plans?
    c. Have you ever cancelled a trip because of information about this factor? Why or why not?
        i. What was the critical piece of information that informed the decision?
    d. When, in the planning of your trip, do you obtain this information (e.g., one week ahead, on the day you are leaving, en route to the site, update half-way through the trip, etc.)?

Part 4: ThinkAloud exercise 28-36 mins

USERS: In the next part of the interview we are interested in knowing more about how you typically use Avalanche Canada products when preparing for a backcountry trip. Earlier you mentioned that you use the Avalanche Canada <website/app> <rarely/sometimes/every time/daily> [Interview participants will be provided with a mock-up avalanche bulletin from a specific day.]

13. Imagine you're preparing for a trip into the backcountry. We have an example of the Avalanche Canada website from last winter and we would like you to describe how you **typically use** this information when you are preparing for a backcountry trip. As you go through the information, describe to me what you're doing, thinking, and reading, etc. We are most interested in your thoughts, so elaborate as much as possible.

NON-USERS: In the next part of the interview we are interested in your impressions of Avalanche Canada products for how they might prepare you for a backcountry trip. I know you haven't used this product before, but your insights are still very valuable.

13. We have an example of the Avalanche Canada website from last winter and we would like you to describe how you would **explore** this information if you used it for preparing a backcountry trip. As you go through the information, describe to me what you're doing, thinking, and reading, etc. We are most interested in your thoughts, so elaborate as much as possible.

Part 5: Application activities 36-55 mins

USERS and NON-USERS: Let's look at the various components of the Avalanche Canada website in more detail.

Home page/map:

14. What do you get out of the map?
    a. How do you use it? (decision-making, navigation, …)
15. Is there something in particular that you like/dislike about the map?

Individual bulletin – Danger rating:
Next, we want to look at the components of an individual avalanche forecast in more detail. We are using **the South Coast forecast** region for an example.

16. Let's look at the danger ratings first.
    Questions for users:
    a. What do the terms mean to you? What type of conditions do you associate with them?
    b. How do you use them?
    c. How do you perceive the relationship between these terms? Is the difference between moderate and considerable the same as between considerable and high?
    d. Do you ever look at the danger rating outlook?
    e. Do you like how this information is presented? If not, how do you think it could be improved?

    Questions for non-users:
    a. How do you interpret the information provided on this page? What grabs your attention?
    b. What do these terms mean to you?
    c. Do you like how this information is presented? If not, how do you think it could be improved?
    d. … *(go as detailed as seems reasonable and appropriate)*

17. EXERCISE: Danger ratings are given for three elevation bands. Now I'd like for you to take a look at these photos and sort them in groups of photos that depict the different elevation bands. (*Don't mention the terms tree-line, above tree-line*)
    a. What does the term tree-line mean to you?
    b. How is it different from below tree-line and alpine?

    Prompt participants to reference the photos with the designated letter.
    Arrange photos so that they can be viewed in full but remain in their groupings.
    c. If any of the photos were challenging, what made them challenging?
    d. Which of these photos do you find generally attractive for backcountry travel? And why?

e. Given the **danger ratings** provided, which photos would you personally feel comfortable traveling in?

Individual bulletin – Avalanche problems and more:
Now we're going to look at **a different forecast region, the Sea-to-Sky**, where the danger rating is Considerable, Moderate, Moderate. Let's move on to the next tab of the avalanche forecast.

18. What do these avalanche problems mean to you?
    Questions for users:
    a. Does it matter to you which problem is forecasted?
    b. How do you use them?
    c. What different avalanche problem types do you know?
    d. What comes to mind when you think about a wind slab, persistent slab, …?
    e. Does the information about avalanche problems affect your route choices and what type of observations you make during your trip? (*If yes, then how so*?)
    f. Do you like how the information is presented? If not, how do you think it could be improved?

    Questions for non-users:
    a. How do you interpret the information provided on this page? What grabs your attention?
    b. What do these terms mean to you?
    c. Do you like how this information is presented? If not, how do you think it could be improved?
    d. … *(go as detailed seems reasonable and appropriate)*

19. EXERCISE: Given the information that is provided in the bulletin, I'd like you to imagine that you're planning a trip for Thursday and show me on the mountain model how you would apply this information. (Describe the orientation of the map and model. Identify the glacier and tree markings.) Our focus is not on your skills, but on the effectiveness of the tools. There are no wrong answers here.
    a. Using the marker, can you identify the problem areas in the mountains by making X's?

    Encourage participant to clearly mark the problem areas with the marker.
    b. Which of these route options (if any) would you choose: all, none, some or part of the runs?

    Make sure to clarify/repeat their responses for runs A, B, C, and D

20. Do you ever read the forecast details? (*Conditional*)
    a. What do you pay attention to?
    b. What do you get out of it/How do you use this information?
    c. Do you like how the information is presented? If not, how do you think it could be improved?

21. Group Considerations

    Questions for Users

    a. Do group dynamics influence how you use the bulletin? If yes, how so?
    b. Does your group discuss the avalanche bulletin information?
    c. Does everyone that you travel with read it?

    Questions for Non-Users

    a. Does your group discuss avalanche bulletin information?
    b. Do other people that you travel with read it?

Additional features and products

22. Is there anything else about the Avalanche Canada website and avalanche forecast products that you would like to comment on?
    a. Something you particularly like and find useful?
    b. Something you particularly dislike and/or find annoying?
    c. Something you find particularly confusing?

23. Do you have any suggestions about how the website and forecasting products could be improved to make them more useful to you?

Part 6: Evaluation of interview 55 – 58 mins

24. Do you have any feedback for the interviewers, the interview process, or the research project in general?

25. Is there anything else you think we should be asking?

Part 7: Conclusion 58 – 60 mins

- **Thank** participants for their time and participation.
- **Offer payment and complete receipt**.

COMPLETED INTERVIEW CHECKLIST:

- Signed consent form
- Signed receipt
- Completed sign-up information confirmation
- Save audio file
- Take photo of sorted elevation band photos
- Take photo of Ortovox SAM

Appendix C. Elevation Band Photo Sorting Exercise

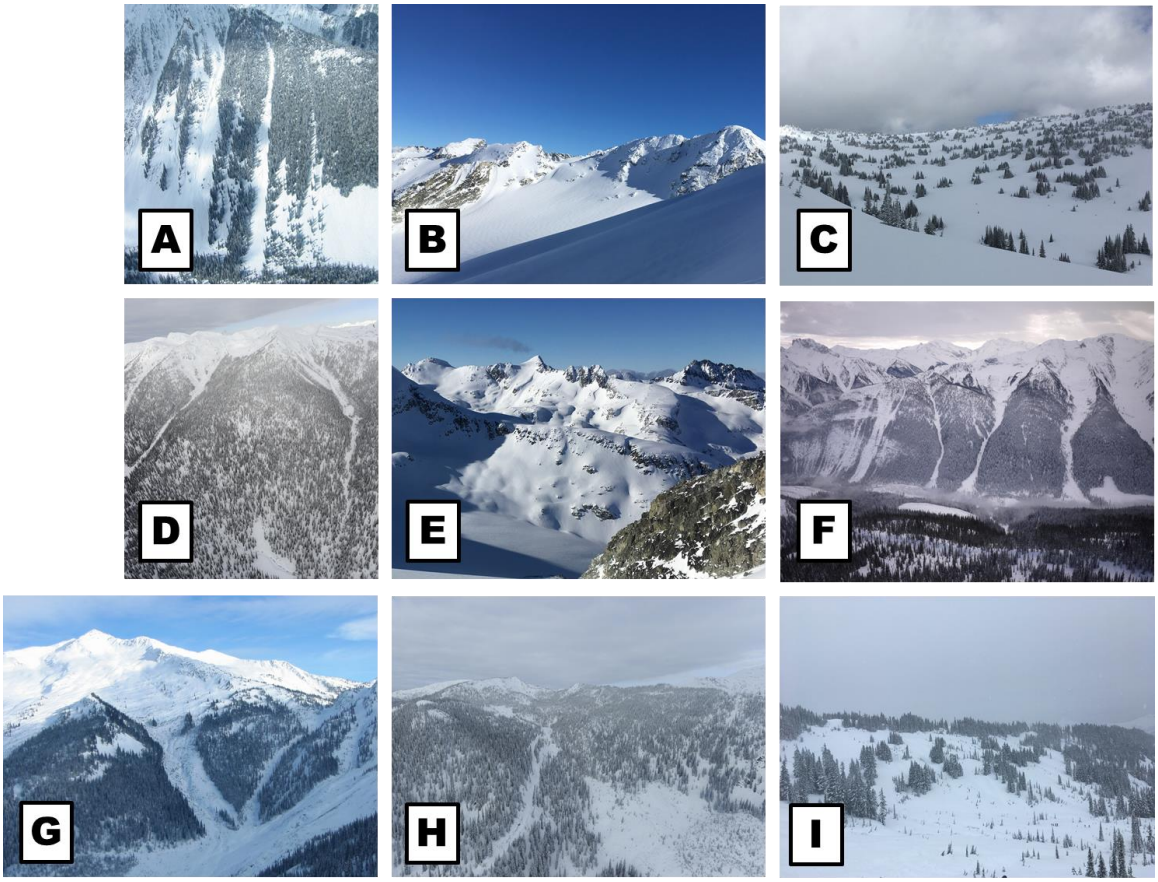


Figure C.1 Set of images provided for elevation band photo sorting activity

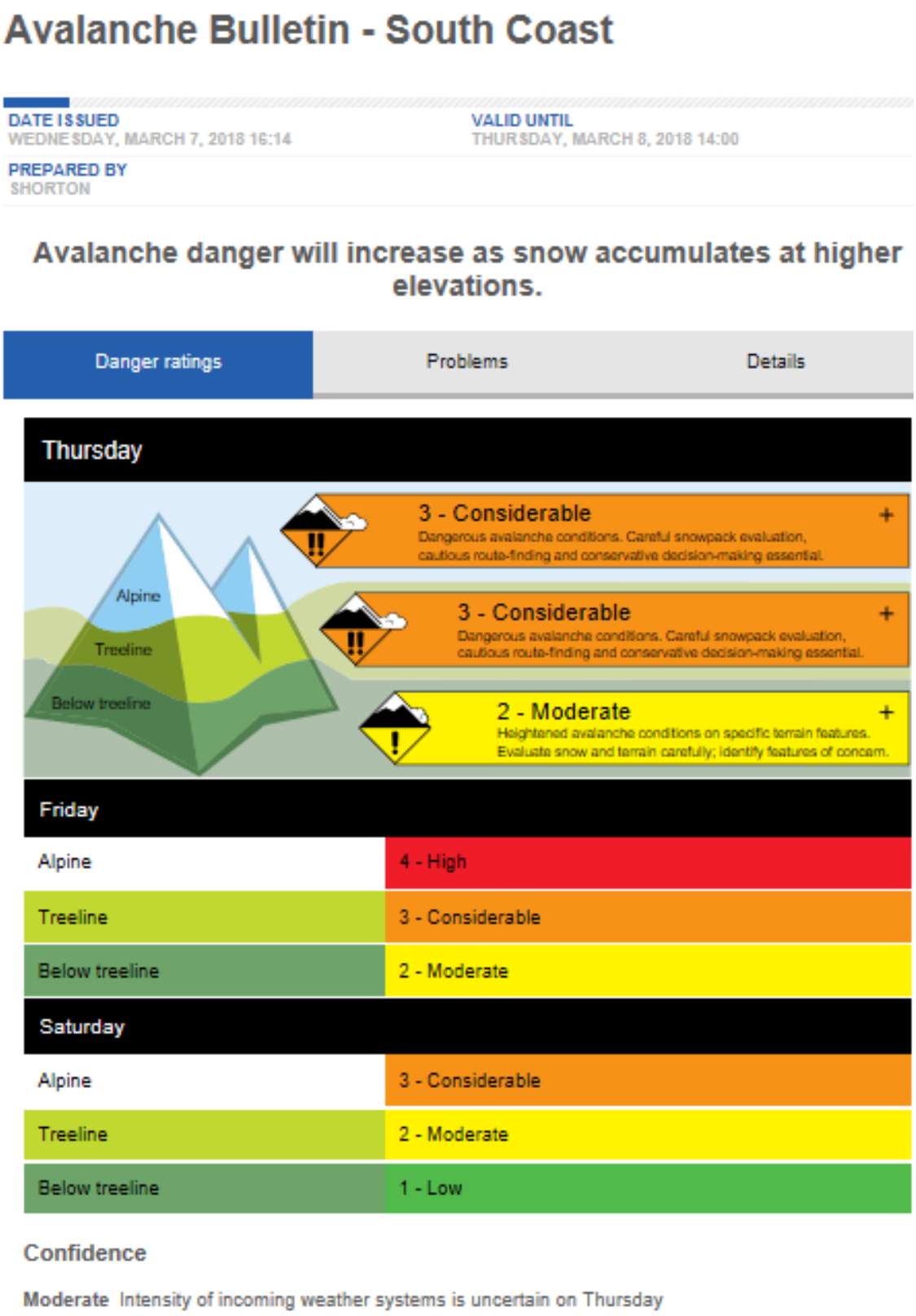


Figure C.2 Danger rating information provided for elevation band photo sorting activity

Appendix D. Bulletin Information Application Exercise Using the Ortovox Safety Academy Mountain (SAM) Model

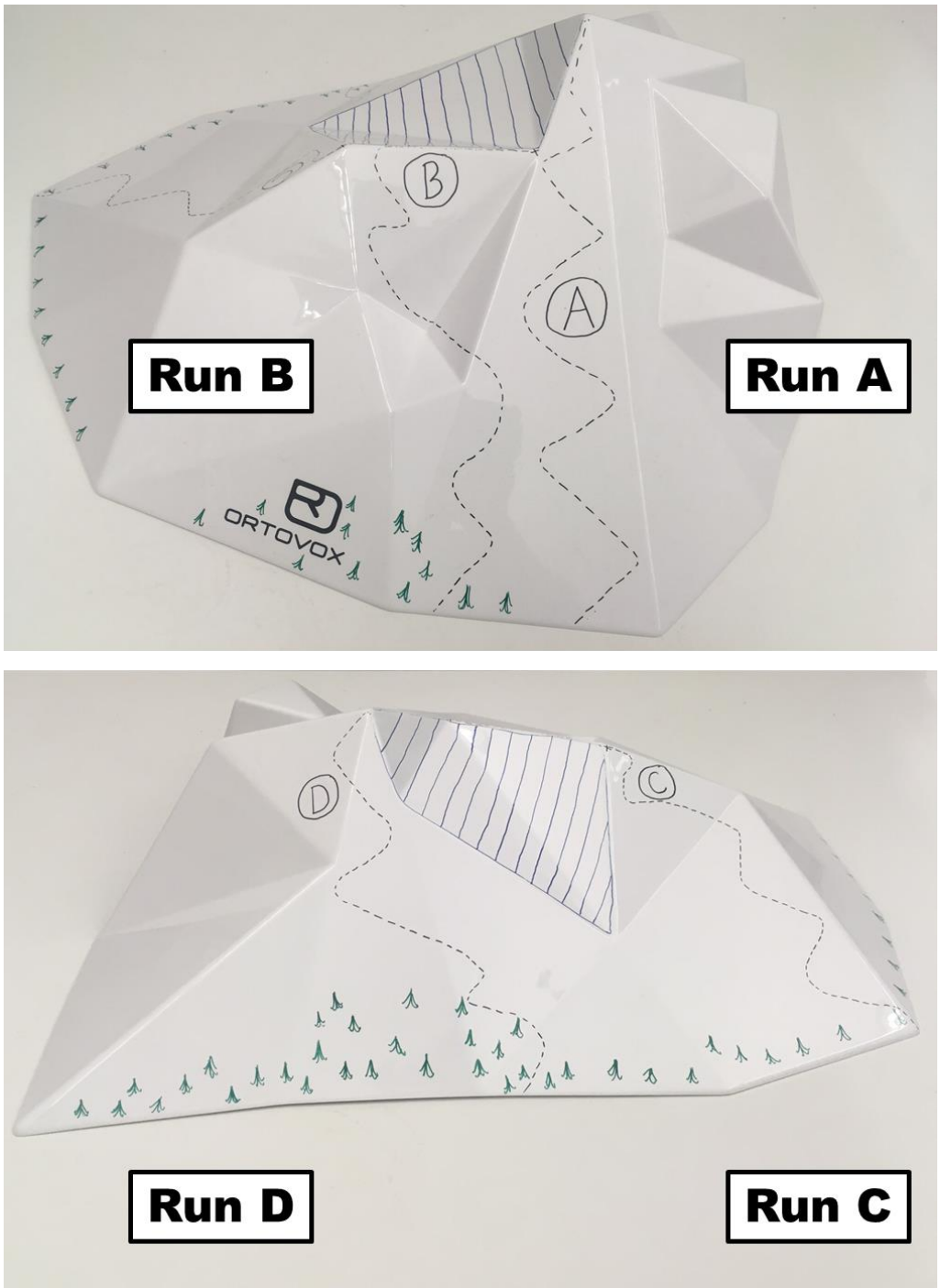


Figure D.1 **Run options for the bulletin information application exercise using the Ortovox SAM model**

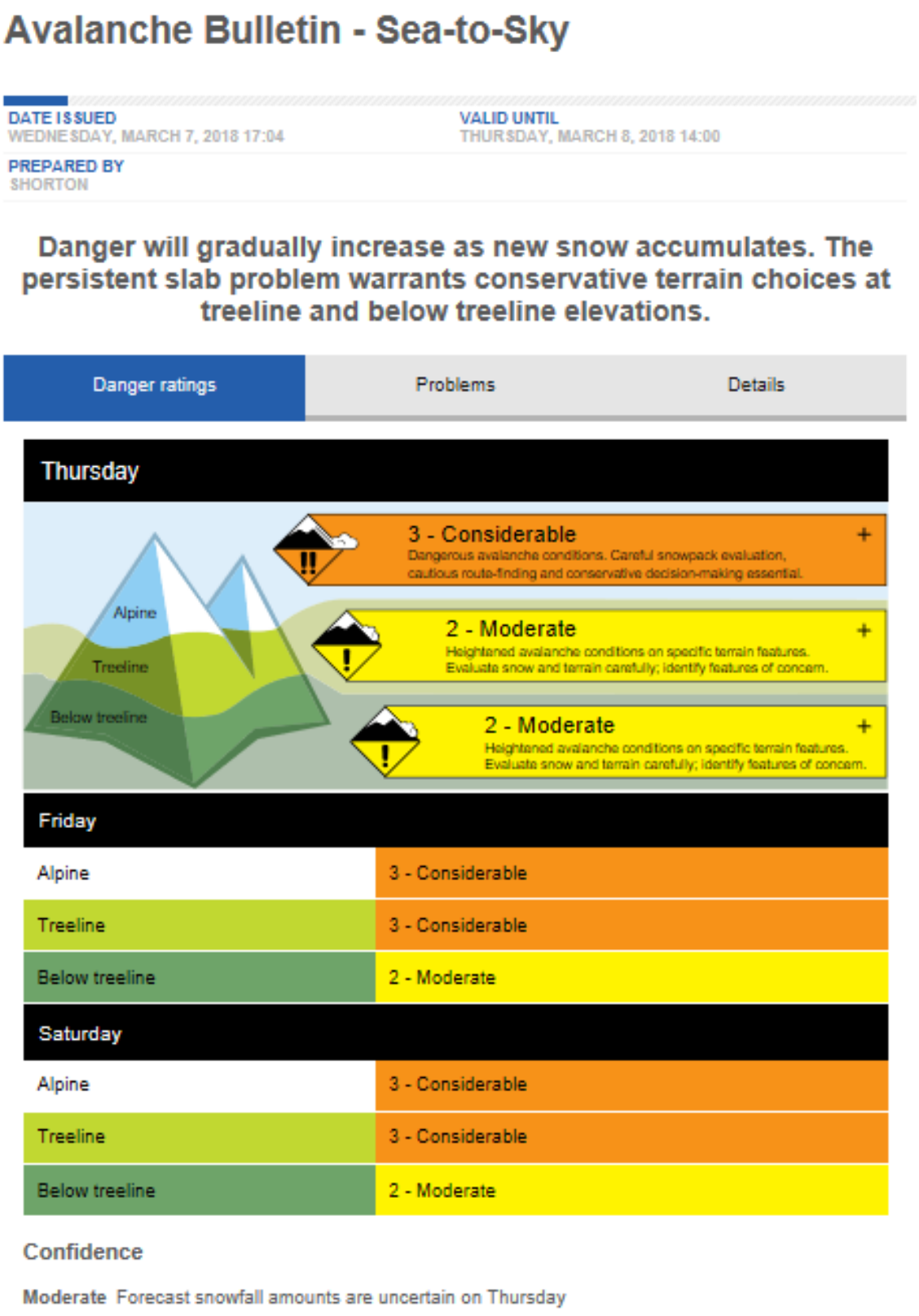


Figure D.2 Danger rating information provided for the bulletin application exercise using the Ortovox SAM model

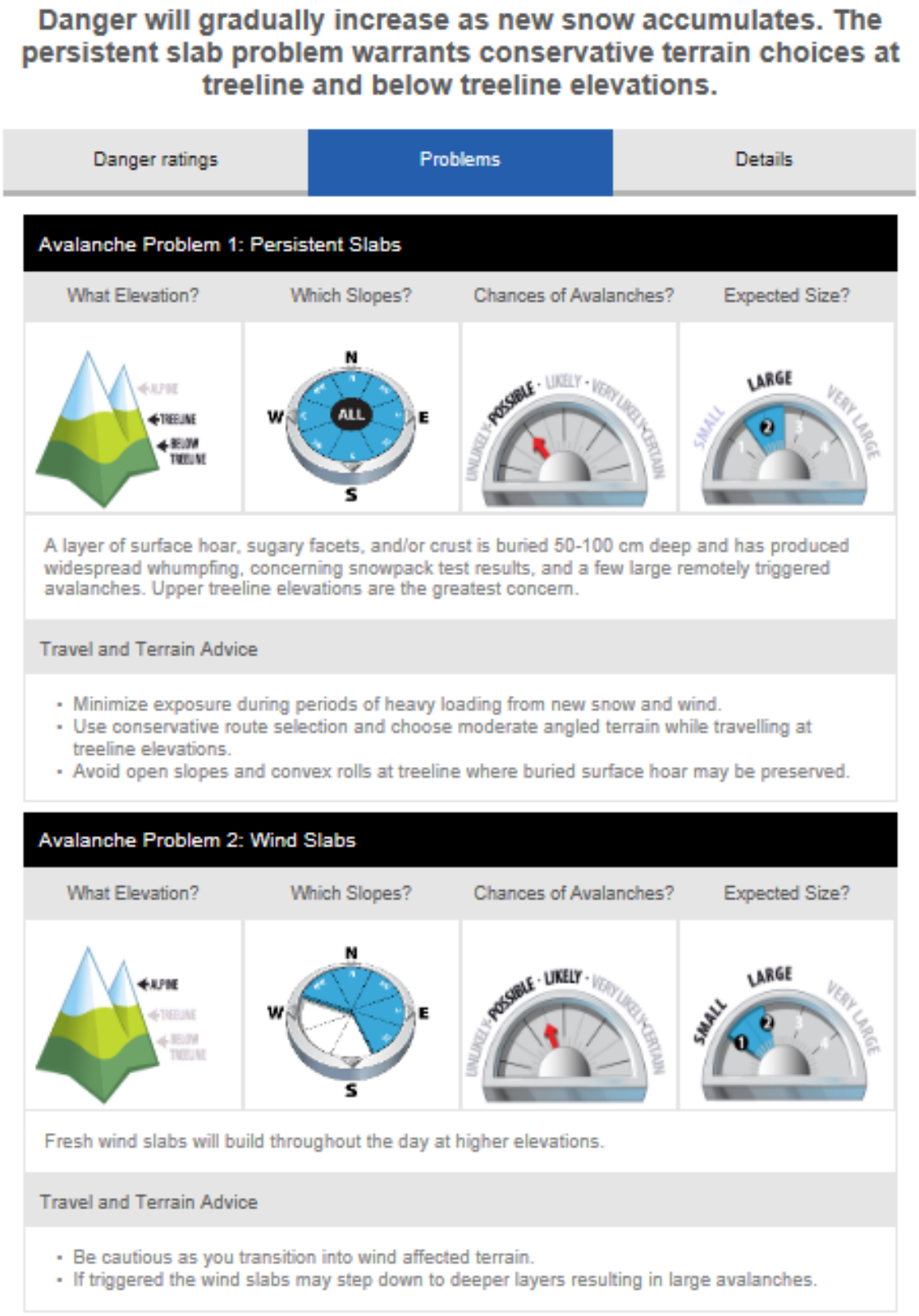
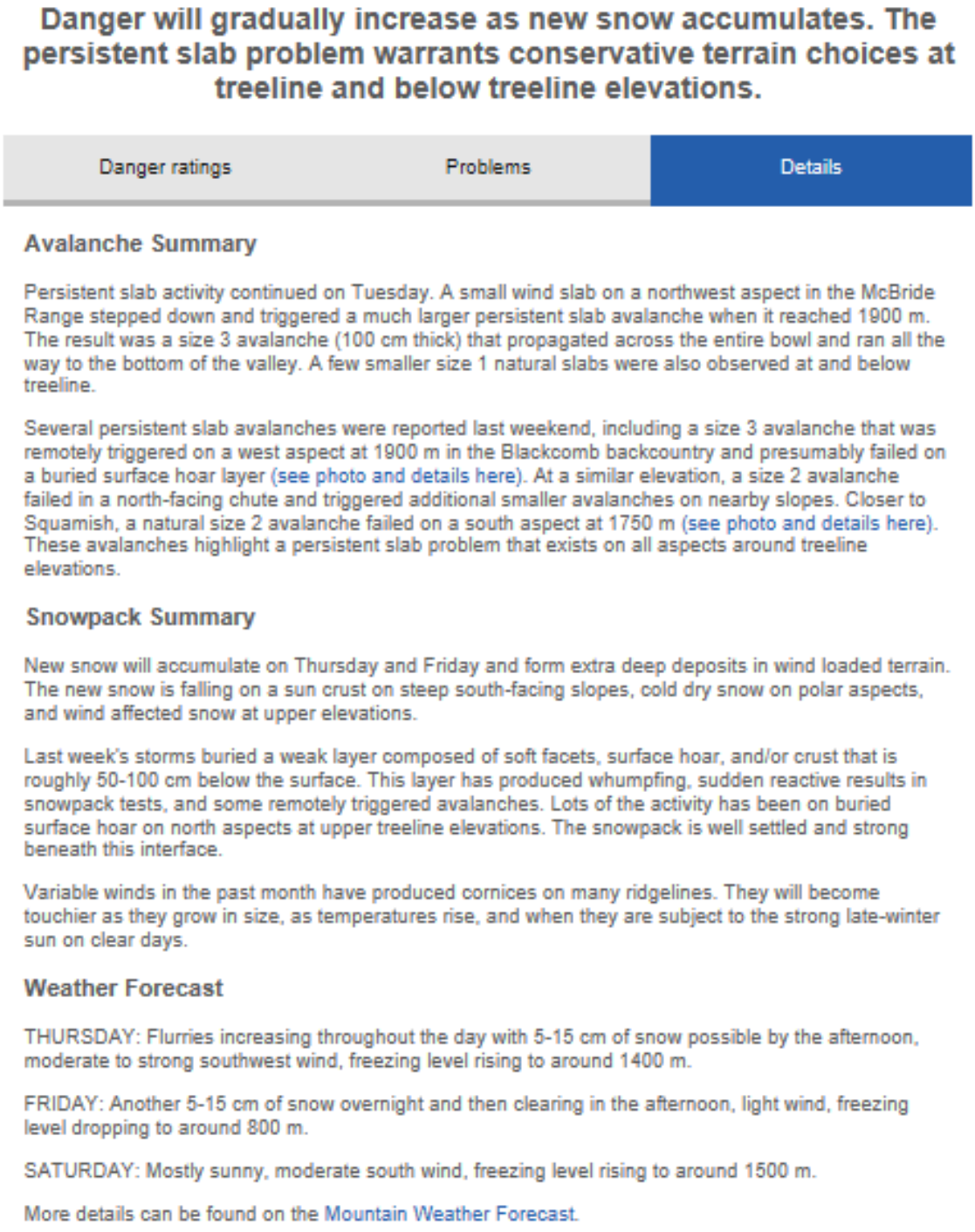


Figure D.3 Avalanche problem information provided for the bulletin application exercise using the Ortovox SAM model



Danger will gradually increase as new snow accumulates. The persistent slab problem warrants conservative terrain choices at treeline and below treeline elevations.

Danger ratings | Problems | Details

Avalanche Summary

Persistent slab activity continued on Tuesday. A small wind slab on a northwest aspect in the McBride Range stepped down and triggered a much larger persistent slab avalanche when it reached 1900 m. The result was a size 3 avalanche (100 cm thick) that propagated across the entire bowl and ran all the way to the bottom of the valley. A few smaller size 1 natural slabs were also observed at and below treeline.

Several persistent slab avalanches were reported last weekend, including a size 3 avalanche that was remotely triggered on a west aspect at 1900 m in the Blackcomb backcountry and presumably failed on a buried surface hoar layer (see photo and details here). At a similar elevation, a size 2 avalanche failed in a north-facing chute and triggered additional smaller avalanches on nearby slopes. Closer to Squamish, a natural size 2 avalanche failed on a south aspect at 1750 m (see photo and details here). These avalanches highlight a persistent slab problem that exists on all aspects around treeline elevations.

Snowpack Summary

New snow will accumulate on Thursday and Friday and form extra deep deposits in wind loaded terrain. The new snow is falling on a sun crust on steep south-facing slopes, cold dry snow on polar aspects, and wind affected snow at upper elevations.

Last week's storms buried a weak layer composed of soft facets, surface hoar, and/or crust that is roughly 50-100 cm below the surface. This layer has produced whumpfing, sudden reactive results in snowpack tests, and some remotely triggered avalanches. Lots of the activity has been on buried surface hoar on north aspects at upper treeline elevations. The snowpack is well settled and strong beneath this interface.

Variable winds in the past month have produced cornices on many ridgelines. They will become touchier as they grow in size, as temperatures rise, and when they are subject to the strong late-winter sun on clear days.

Weather Forecast

THURSDAY: Flurries increasing throughout the day with 5-15 cm of snow possible by the afternoon, moderate to strong southwest wind, freezing level rising to around 1400 m.

FRIDAY: Another 5-15 cm of snow overnight and then clearing in the afternoon, light wind, freezing level dropping to around 800 m.

SATURDAY: Mostly sunny, moderate south wind, freezing level rising to around 1500 m.

More details can be found on the Mountain Weather Forecast.

Figure D.4 Details tab information provided for the bulletin application exercise using the Ortovox SAM model

Appendix E. Respondent Validation Survey Question

Which of the following statements best describes your use of avalanche bulletins? Please select one of the following options:

A) It is not typical for me to consult avalanche bulletin information when making my backcountry travel plans.

B) I typically incorporate the danger rating into my plans to determine whether or not it is safe to travel in the backcountry.

C) I typically combine the danger rating with knowledge of how avalanche prone an area is to determine where to travel in the backcountry.

D) I typically make a decision about where or when to go based on (a) the specific nature of the avalanche conditions reported in the bulletin, (b) where they exist in the mountains, and (c) whether I feel that I can manage my travel in the terrain given these conditions.

E) I typically use information about the specific nature of the avalanche conditions as a starting point for continuous assessment to confirm or disconfirm this forecast where I am traveling.