

**How can avalanche bulletins be more useful for
recreationists?
Exploring three opportunities for improving
communication of avalanche hazard information**

**by
Kathryn Fisher**

B.Sc., University of British Columbia, 2012

Thesis 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

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SIMON FRASER UNIVERSITY
Summer 2021

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Name: Kathryn Fisher

Degree: Master of Resource Management

Title: How can avalanche bulletins be more useful for recreationists? Exploring three opportunities for improving communication of avalanche hazard information

Committee:

Chair: Scott Harrison
Senior Lecturer, School of Resource and Environmental Management

Pascal Haegeli
Supervisor
Associate Professor, School of Resource and Environmental Management

Reto Rupf
Committee Member
Professor, Institute of Natural Resources Sciences
Zurich University of Applied Sciences

Sean Cox
Examiner
Professor, School of Resource and Environmental Management

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Abstract

Avalanche warning services release public avalanche bulletins to help backcountry recreationists develop risk management approaches for winter backcountry trips. To safely recreate in the backcountry, recreationists must be able to understand and apply the avalanche hazard information presented in the avalanche bulletin. The goal of this research was to test how key elements of the avalanche bulletin affect users' interpretation of the hazard information within the avalanche bulletin, and to determine if modifications to the bulletin could increase its' useability among recreationists. We conducted a survey with multiple sections to test if presentation of graphic information and interactive exercises can help recreationists apply spatial hazard information, as well as how users perceive the travel and terrain advice section of the bulletin. The results of these studies can be used by avalanche warning services to improve avalanche hazard messaging in their public avalanche bulletins.

Keywords: Avalanche safety; hazard communication; regression modelling; survey data

Acknowledgements

First and foremost, thank you to Pascal Haegeli. Your guidance, support, and mentorship have made this project possible—and my appreciation of the time and energy you've spent patiently helping me cannot be overstated. What's more, the culture you've cultivated in the SARP lab has made for a rewarding graduate student experience. I'm honored and grateful to have been a part of this team.

To Patrick Mair, thank you for your help with statistics and R throughout this project. I'm in awe of your ability to clearly explain complex topics, and grateful for your patience when I struggled to understand the concepts.

I would like to thank the team at Avalanche Canada, and many others in the avalanche safety community, for your support of this research. I'd especially like to thank Grant Statham, Grant Hegleson, Karl Klassen, and Simon Trautman for contributing your expertise to help determine meaningful research priorities, as well as develop the avalanche problem scenarios and travel and terrain advice statements used in this study.

Thank you also to all those who enthusiastically responded to my survey. This thesis is my love-letter to everyone that loves the mountains in winter, and I hope that the results will help keep us all safer.

I also gratefully acknowledge the Social Sciences and Humanities Research Council (SSHRC) for the funding contributed towards this work.

To my family, friends, and partner Sam: you already know how much I have appreciated your support and encouragement over the years. Your love and friendship mean the world to me. Thank you all for being by my side through the ups and downs.

Finally, the mountain peaks that I love and that inspired me to pursue this degree are all located on the traditional and present territories of Indigenous Peoples across Turtle Island. As I reflect on my relationship to the mountains in BC, I am humbled and grateful to travel as a settler and an immigrant on the lands stewarded for generations by Indigenous caretakers.

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Chapter 1.

Introduction

Every winter, avalanches claim the lives of dozens of people across North America (Avalanche Canada, 2019; CAIC, 2020). Over 90% of these fatalities are among people travelling in the mountains for recreation and making their own decisions about avalanche safety (Haegeli, 2018). Managing avalanche risk is a complex task that involves understanding and recognizing hazardous avalanche conditions and choosing where and when to travel in the terrain to mitigate this hazard. To assist recreationists in this task, public avalanche warnings services have been founded to provide avalanche education and hazard forecasts for recreationists.

In Canada, there are several organizations that provide avalanche awareness information and education to the public to increase awareness about avalanche safety. These organizations include Avalanche Canada, Parks Canada, Alberta Parks (Kananaskis Country) and Avalanche Quebec. Of these agencies, Avalanche Canada—a non-profit, non-governmental, public agency—is the largest and is responsible for providing avalanche forecasts for over 250,000 square km (Avalanche Canada, 2018). The agency was founded in 2004 in response to an exceptionally high avalanche death toll, with the mission to encourage safe winter backcountry recreation (Avalanche Canada, 2018). A key element of this mission is the publication of daily avalanche bulletins through the winter months. Avalanche bulletins are written forecasts of avalanche hazard, produced by professional forecasters who synthesize observations about the weather, snowpack structure, and recent avalanches into an up-to-date assessment on existing avalanche conditions. Bulletins are typically organized in the form of an “information pyramid”, with a high-level overall danger rating at the top, followed by information on specific avalanche problems, and supported by a short summary of the raw observations used to formulate the forecast (EAWS, n.d). Bulletins also typically include advice on how to mitigate exposure through terrain selection through travel and terrain advice sections (e.g., NWAC, n.d; Avalanche Canada, n.d).

However, there is evidence that backcountry use has increased dramatically since the first bulletins were published (e.g., Birkeland et al., 2017; Avalanche Canada, 2018),

and therefore it is important to assess if the bulletin is an effective tool for promoting safety among backcountry recreationists. To this end, Avalanche Canada has partnered with the Avalanche Research Program at Simon Fraser University on a multi-phased study to research how recreationists are using the avalanche bulletin. Phase 1 of the study was initiated in 2017 with a series of qualitative interviews of backcountry recreationists that examined how recreationists incorporate elements of the avalanche bulletin into their risk management process, which resulted in the creation of a bulletin user typology (St. Clair, 2019). Phase 2 included a large-scale online survey of recreationists that identified how bulletin users comprehend and apply elements of the avalanche bulletin across a larger sample (Finn, 2020). This thesis represents the beginning of Phase 3, with the goal to empirically test how changes to bulletin components could be used to make the avalanche bulletin more effective for recreationists.

I identified three research priorities for testing as possible improvements for the avalanche bulletin based on the results of the first two study phases and ongoing consultations with Avalanche Canada. The first priority was to test if modifications to the graphic icon used to illustrate the location of avalanche problems in the avalanche bulletin could enhance recreationists' ability to apply the information. This was considered a high priority because the preliminary results from Finn (2020) suggested that the icons used by Avalanche Canada were not as effective as the icons used by avalanche warning services in the USA. Testing this effect in a structured way was identified as a priority to ensure that the readability of Avalanche Canada's products could be maximized.

The second priority was testing if the incorporation of interactive components into the avalanche bulletin could increase its value as an educational tool. This priority emerged from both the qualitative interviews and the online survey, in which participants explicitly requested access to additional interactive educational tools. Furthermore, St. Clair (2019) postulated that the incorporation of educational tools could help the avalanche bulletin function to advance users through the stages of the bulletin use typology.

The third priority was to better understand which avalanche bulletin users pay the most attention to travel and terrain advice statements and to test whether modifications to the statements can make them more accessible. This was identified as a priority based on consistent results from both St. Clair (2019) and Finn (2020) which suggest that many

users fail to establish comprehensive risk management plan and/or have challenges applying the information contained in the bulletin hazard information to terrain.

For all of the mentioned research priorities, the goal was not only to test the impacts of the modifications to the bulletin elements, but also to understand how different segments of the recreational public would be impacted based on characteristics such as the level of avalanche education they had completed, their years of experience, and their bulletin user type.

To tackle the three research priorities, I conducted a large-scale online survey in the winter of 2020. While the survey included questions relating to all three priorities, I have prepared the results as three standalone manuscripts, each separately describing the specific research questions and survey approach for a particular research priority. The three manuscripts, which have been a collaboration with my supervisory team, are included in this thesis as 2-4. Publication information and the contributions of my co-authors are included with the relevant manuscripts where applicable.

The goal of this work is to provide actionable, data-driven advice for Avalanche Canada to apply to the development of avalanche bulletins. A full summary of recommendations and lessons from across all three studies is included as the conclusion section of this thesis.

Chapter 2.

Impact of information presentation on interpretability of spatial hazard information: Lessons from a study in avalanche safety

This chapter has been accepted for review in Natural Hazards and Earth System Sciences as Fisher, K., Haegeli, P., and Mair, P. "Impact of information presentation on interpretability of spatial hazard information: Lessons from a study in avalanche safety". As co-author I designed and executed the study and prepared the original draft with Pascal Haegeli, and Patrick Mair provided support with statistical analysis and review. The manuscript is under review and public comments are available to view at <https://nhess.copernicus.org/preprints/nhess-2021-147/#discussion>. The content is distributed under the Creative Commons Attribution 4.0 License, and reproduction of the material for thesis submission is permitted. The work has been updated to include preliminary responses to reviewers and reformatted per SFU guidelines.

Abstract

Avalanche warning services publish avalanche condition reports, often called avalanche bulletins, to help backcountry recreationists make informed risk management choices regarding travel in avalanche terrain. To be successful, these bulletins must be interpreted and applied by users prior to entering avalanche terrain. However, few avalanche bulletin elements have been empirically tested for their efficacy in communicating hazard information. The objective of this study is to explicitly test the effectiveness of three different graphics representing the aspect and elevation of avalanche problems on users' ability to apply the information.

To address this question, we conducted an online survey in the spring of 2020 that presented participants with one of three graphic renderings of avalanche problem information and asked them to rank a series of route options in order of their exposure to the described hazard. Following completion of route ranking tasks, users were presented with all three graphics and asked to rate how effective they thought the graphics were. Our analysis dataset included responses from 3,056 backcountry recreationists with a variety of backgrounds and avalanche safety training levels. Using a series of generalized linear mixed effects models, our analysis shows that a graphic format that combines the

aspect and elevation information for each avalanche problem is the most effective graphic for helping users understand the avalanche hazard conditions because it resulted in higher success in picking the correct exposure ranking, faster completion times, and was rated by users to be the most effective. These results are consistent with existing research on the impact of graphics on cognitive load and can be applied by avalanche warning services to improve the communication of avalanche hazard to readers of their avalanche bulletins.

2.1. Introduction

Snow avalanches are a serious threat that destroys property and claims the lives of people in mountainous regions around the world every year. While catastrophic avalanches hitting mountain villages are responsible for the largest number of fatalities in mountain ranges such as the Himalayas, most avalanche deaths in western countries involve individuals heading into avalanche terrain for recreation. In North America, for example, avalanches claimed the lives of 334 recreationists between 2011 and 2020 (Avalanche Canada, 2019; CAIC, 2020), and even though there are no reliable statistics, it is suspected that many more recreationists are caught in avalanches but manage to escape the most severe outcome. While a small number of affected individuals were guides or ski patrollers professionally engaged in managing the avalanche risk for paying guest or clients, the vast majority were lay people making their own decisions about when and where to recreate in the backcountry. When travelling in the backcountry avalanche risk is managed by carefully assessing the nature and severity of the hazard using weather, snowpack and avalanche observations (e.g., McClung, 2002). This assessment must be combined with additional information about the terrain exposure of an intended backcountry trip to the avalanche hazard to make an informed decision about whether going ahead with a trip is acceptable to the individual under the observed conditions. Under most circumstances, recreationists are responsible for completing this complex assessment without professional guidance to inform their decisions. To assist recreationists with understanding the existing avalanche hazard conditions and making these assessments, most western countries have established avalanche warning services that publish daily condition reports, commonly known as avalanche bulletins, forecasts, warnings, or advisories, that summarize the current snowpack and avalanche situation across predefined forecast areas. These reports are intended to give recreationists the information needed to make an informed risk assessment of a planned backcountry trip.

While the specific design of avalanche bulletins differs from country to country, they all present the information in a tiered structure that is referred to as the “information pyramid” (EAWS, n.d). At the top of the pyramid is the avalanche danger rating, which describes the overall severity of the avalanche conditions using the signal words and colors of the ordinal, 5- level avalanche danger scale. The 5-level scale was introduced in 1993, and while there are subtle differences between the European and North American versions (EAWS, 2018; Statham et al., 2010), it is the cornerstone of public avalanche risk communication around the world. The next level of the information pyramid describes the nature of the avalanche hazard in more detail. Over the last decade, the concept of avalanche problems has established itself as a useful framework for explaining the nature of avalanche hazard in a structured way. Avalanche problems represent actual avalanche risk management concerns that can be described in terms of their type, location, likelihood and size of avalanches. In North America, the conceptual model of avalanche hazard (Statham et al. 2018a) defines nine different avalanche problem types, and avalanche bulletins describe the nature of up to three active avalanche problems using a combination of iconic graphics and text. European avalanche warning services utilize a smaller list of avalanche problem types, and even though conceptually similar, use less formalized terminology to explain the location and nature of the present problems. The next level of the information pyramid provides users with more detailed but still synthesized overviews of existing weather conditions, relevant snowpack structures and avalanche activity observations. Some avalanche warning services also include links to raw data such as weather, snow profile or avalanche observations in their bulletins. These observations are the foundation of the hazard assessment presented in the bulletin and represent the final level of the information pyramid. The intent of the pyramid is to present information about a complex hazard in an easily accessible and concise way while allowing users with greater information needs and more advanced skills to explore more details.

Avalanche warning services belong to a wider range of warning services and government agencies whose mandate is to communicate information about a complex and spatially variable natural hazard to the public in a meaningful way. Weather forecasters and local governments routinely issue statements to communities faced with fire, flood or storm watches and warnings. In these disciplines, considerable attention has been paid to improving risk communication products by testing which elements of risk communication messages are effective and which may lead to unintended consequences

(see, e.g., Cuite et al., 2017; Morss et al., 2016; Rickard et al., 2017). For example, research into storm surge messaging identified that recipients that saw messages about extreme storm surges were more likely to express intentions to evacuate, but also were more likely to rate the information as more overblown and the source less reliable (Morss et al., 2016). Similar efforts to empirically test the effectiveness of warning messages and safety signage are underway in the outdoor recreation field (e.g., Saunders et al., 2019; Weiler et al., 2015) to provide managers with evidence-based guidance on how to communicate with their visitors

Recognizing the crucial importance of the avalanche bulletin for the safety of backcountry recreationists, the avalanche safety community has recently started to examine its effectiveness more systematically. These efforts can be divided into three main research themes. Several recent projects have examined the quality and consistency of the information presented in avalanche bulletins as providing accurate hazard information is crucial for effective risk communication (Lundgren & McMakin, 2018). Example studies of this research theme include Lazar et al. (2016) who presented public avalanche forecasters with a series of avalanche danger scenarios to see whether they interpret them the same, Techel et al. (2018) who examines the spatial consistency and bias of avalanche danger ratings in avalanche bulletins in the European Alps, Statham et al. (2018b), who studied the consistency of avalanche problem assessments among the warning services in the Canadian Rocky Mountains, and Clark (2019) who studied the link between avalanche problem assessments and danger ratings in Canadian avalanche bulletins. All of these studies highlighted considerable challenges and the need to improve the production of avalanche bulletins.

The second and equally important research theme is trying to better understand how backcountry recreationists use and apply the information provided in the avalanche bulletin. The risk communication research community has stressed for a long time that having a good understanding of the target audience is a critical prerequisite for effective risk communication (Lundgren & McMakin, 2018). Traditionally, the avalanche safety community has classified avalanche bulletin users simply according to their preferred activity (e.g., backcountry skiing, mountain snowmobiling, snowshoeing), level of formal avalanche awareness training (none, introductory course, advance level course, or professional level training), and/or basic sociodemographics. Winkler and Techel (2014), for example, used data from two online surveys to determine who uses the Swiss

avalanche bulletin and how these users have changed over time. More recently, St. Clair (2019) conducted a qualitative interview study to better understand how winter backcountry recreationists use, understand and apply the avalanche bulletin information in their avalanche risk management process. Her analysis revealed a sequence of five distinct bulletin information use patterns that incorporate increasingly more complex information and are able to manage avalanche risk at higher levels of sophistication. This typology provides a valuable framework for evaluating the effectiveness of risk messages with respect to the types of decisions that the users are intending to make. St. Clair's study was followed up by Finn (2020) who conducted a large-scale online survey to examine whether bulletin users who say they use the avalanche bulletin at a certain level also have the necessary skills to do so effectively. Finn's results offer valuable insight into avalanche bulletin literacy at the different levels of St. Clair's bulletin user typology and highlights user groups that might have misconceptions about their skill levels.

The third theme of avalanche bulletin research is the explicit examination of its effectiveness. Empirically testing how messages resonate with users and whether they result in the desired behavioural response is an important but challenging part of risk communication research. Example of these types of studies in the avalanche field include Burkeljca (2013a, 2013b), who examined the usability of four different avalanche bulletin products (Canada, Catalonia, Tyrol and Utah) using a small sample of 14 that included lay people and experts from Slovenia. Winkler and Techel (2014) examined the results from the same two surveys mentioned previously to shed light on how the complete revision of the Swiss avalanche bulletin in 2014 affected users' perceived quality and usability of the product. Similarly, Engeset et al. (2018) conducted an online survey to better understand the effectiveness of the Norwegian avalanche bulletin. This study explicitly asked participants about their preferences for different forms of information presentation (text, symbols, or pictures) and empirically assessed users' comprehension of two hazard situations as a function of the type and amount of information presented. The authors used both the appropriateness of the risk management approaches chosen by participants and their self-reported effectiveness rating to assess the efficacy of the avalanche hazard descriptions.

Since assessing the suitability of backcountry trips requires recreationists to relate the information provided in the bulletin to the terrain characteristics of their intended trips, the description of the spatial distribution of avalanche hazard within a forecast area is a

crucial component of the avalanche bulletins. While there is considerable complexity in how avalanche hazard interacts with terrain (e.g., Bühler et al., 2013; Bühler et al., 2018), the primary location information included in avalanche bulletins focuses on elevation and aspect. However, current avalanche bulletin products exhibit substantial variability in what the elevation and aspect information refers to and how it is presented. Swiss avalanche bulletins, for example, state a single danger rating for a forecast region and the accompanying aspect and elevation information highlights the core zones where the stated avalanche danger applies the most (SLF, 2020). The French avalanche bulletins use the same approach as the Swiss (MeteoFrance, n.d), whereas the Norwegian bulletins also just publish a single danger rating per forecast region, but aspect and elevation information is used to describe where the identified avalanche problems are most prevalent (Varsom, n.d). The recently launched Euregio avalanche bulletin publishes elevation specific avalanche danger ratings and also provides aspect and elevation information for each of the existing avalanche problems (EAWS, n.d). Most avalanche bulletins in North America publish avalanche danger ratings for different elevations and describe the location of avalanche problems with respect to elevation and aspect. While the elevation descriptions in European avalanche bulletins are generally specific (e.g., above 2200 m) and change daily depending on conditions, North American bulletins use predefined elevation bands (alpine, treeline or near treeline, below treeline) to specify avalanche danger and the location of the avalanche problems.

In addition to these differences in the use of elevation and aspect information, there are also different styles on how this information is presented. While most of the European and Canadian avalanche warning services use separate graphics for communicating aspect and elevation information, the warning services in the United States and New Zealand use so-called aspect-elevation rose diagrams that show the elevation and aspect information together in a single graphic (NZAA, n.d; USFS, n.d). Within each of these groups, we can find slight variations in design. The aspect-elevation rose diagrams of the Northwest Avalanche Center and the Colorado Avalanche Information Center are straight octagons with grey shading, the aspect-elevation rose of the New Zealand avalanche warning service has an extra corner in each aspect segment and the shading reflect the danger rating of the elevation band, and the Utah Avalanche Center used a three-dimensional aspect-elevation rose diagram (CAIC, n.d; UAC, n.d; NWAC, n.d; NZAA, n.d).

The goal of this study is to contribute to our understanding of the efficacy of avalanche bulletins by empirically testing the effectiveness of individual components. Our starting point is the fact that a multitude of graphics are used by avalanche warning services around the world to communicate avalanche problem characteristics. Several studies have demonstrated that graphics used might not be well understood and users struggle to combine the information when making terrain choices (e.g., Burkeljca, 2013a; Burkeljca, 2013b; Engeset et al., 2018; Finn, 2020). To better advise avalanche warning services on which graphics are most effective with users, we conducted an online survey to experimentally test if altering the presentation format of the location information of avalanche problems can improve users' ability to apply it to hypothetical terrain choices. The results of this study help warning services to improve their avalanche bulletin design so that recreationists can make better informed choices about when and where to travel in the backcountry.

2.2. Methods

In the spring of 2020, we conducted a large-scale online survey to empirically examine different options for improving the presentation of location information in North American avalanche bulletins. The three main questions that the survey aimed to shed light on were:

1. How does the presentation format of the avalanche problem location information (i.e., aspect and elevation) affect users' ability to apply this information when assessing the exposure of routes to avalanche hazard?
2. Can adding an interactive exercise help improve users' ability to apply the avalanche problem location information?
3. How well do the travel advice statements included in avalanche problem section of North American avalanche bulletins resonate with users?

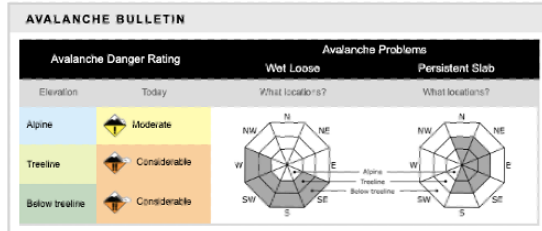
The focus of this paper is to present the insight we have gained about the first research question. The results that relate to the other two questions are described in separate manuscripts.

2.2.1. Survey Design

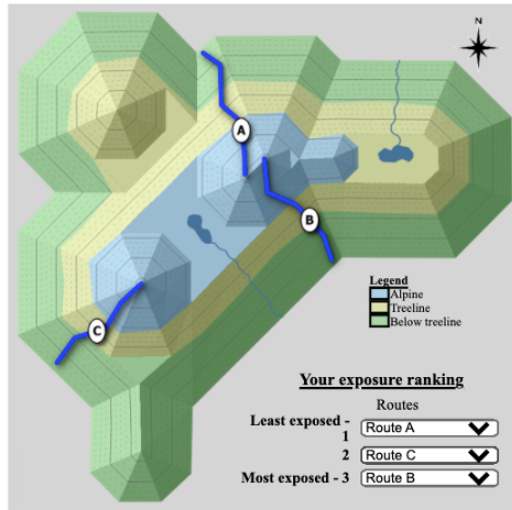
To systematically test whether the presentation format of the avalanche problem location information affects users' ability to apply the information, our survey included a series of route ranking task where participants were presented with an avalanche bulletin with two avalanche problems and a custom-built topographic map with three routes (Figure 2.1). The terrain map depicted a simplified mountainscape with slopes of consistent incline on all aspects and elevation bands. The task of participants was to study the avalanche bulletin information and then rank the three depicted routes according to their exposure to the described avalanche problems. The correct solution for the ranking task could be determined by counting the number of aspect and elevation segments each route crossed where avalanche problems were present. The more avalanche problem aspect and elevation segments a route crossed, the more exposed it was to avalanche hazard. Participants were explicitly alerted that overhead hazard and terrain traps should not be included in their assessment

Route Ranking Task (1 of 4)

Consider the avalanche hazard information provided to you below and rank the described backcountry routes according to their exposure to the mentioned avalanche problems. Remember that it is not necessary to consider overhead hazard, assume the worst time of day, and flat terrain is not exposed to avalanche hazard.

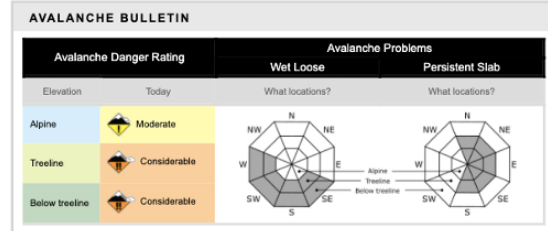


Please rank the three routes presented on the map below according to their exposure to mentioned avalanche problems from least to most exposed. * You must rank all routes, and every rank can only have a single route.



Route Ranking Task (2 of 4)

Consider the avalanche hazard information provided to you below and rank the described backcountry routes according to their exposure to the mentioned avalanche problems. Remember that it is not necessary to consider overhead hazard, assume the worst time of day, and flat terrain is not exposed to avalanche hazard.



Please rank the three routes presented on the map below according to their exposure to mentioned avalanche problems from least to most exposed. * You must rank all routes, and every rank can only have a single route.

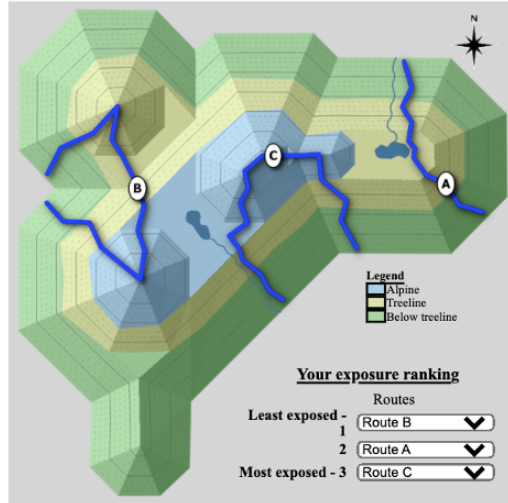


Figure 2.1. Example of route-ranking exercises with avalanche bulletin scenario and custom-built topographic map with three simple routes and three complex routes.

In our experiment, the avalanche problem information was presented in one of three graphic formats (Figure 2.2). The first format had aspect and elevation information separated for each avalanche problem similar to the graphic used in Canadian avalanche bulletins, while the second format had aspect and elevation combined into a single aspect-elevation rose graphic for each avalanche problem like in the US bulletins, and the third format presented the aspect and elevation information for all avalanche problems combined. Throughout the rest of this paper, we will refer to these three presentation formats as Separate, Aspect-Elevation Rose, and Combined. To prevent the specifics of the avalanche bulletin information to affect our results in unintended ways, our experiment included six different avalanche bulletin scenarios (see Appendix), all of which were

developed in conjunction with avalanche industry experts to ensure they represent realistic real-world conditions

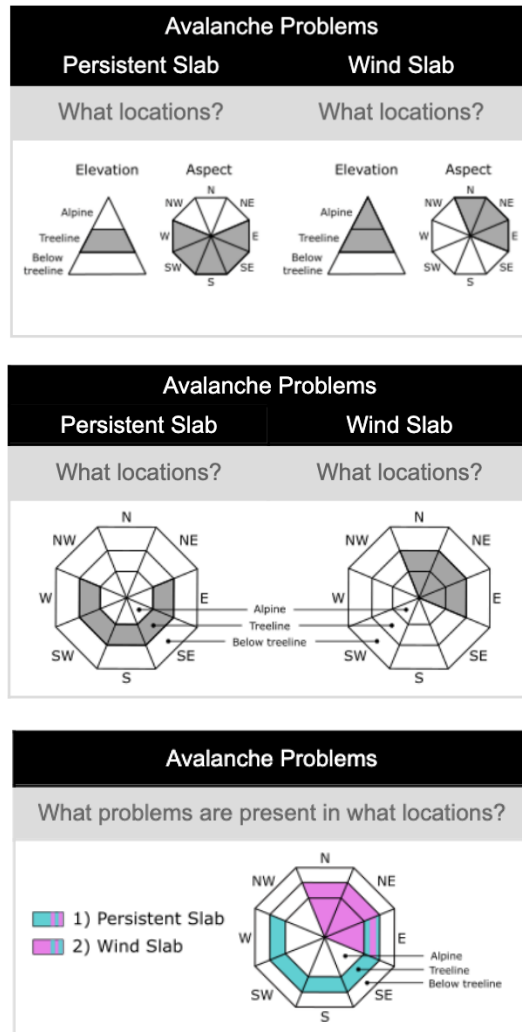


Figure 2.2. Presentation formats for location information of avalanche problems: Separate graphics (top panel), Aspect-Elevation Rose diagram (middle panel), and Combined graphic (bottom panel)

Each survey participant was presented with two random avalanche bulletin scenarios using one of the three aspect and elevation information presentations, and they completed two route-ranking exercises for each of the bulletin scenarios. The first ranking exercise for each bulletin scenario included “simple” routes that crossed only one aspect, whereas the second exercise had “complex” routes that crossed multiple aspects. Between the two avalanche bulletin scenarios, participants were presented with a range of different feedbacks to examine how an interactive exercise can affect participants’

ability to apply the avalanche problem information to terrain. However, this part of the experiment is not the focus of this manuscript. In summary, the experimental portion of the survey included four route-ranking tasks that were complete in the following sequence:

1. Avalanche bulletin scenario 1 – Simple routes
2. Avalanche bulletin scenario 1 – Complex routes
3. Feedback (none, articulate process, solution, solution with explanation)
4. Avalanche bulletin scenario 2 – Simple routes
5. Avalanche bulletin scenario 2 – Complex routes

After completion of the route-ranking tasks, participants were shown all three avalanche problem information graphics and asked to rate their effectiveness for communicating the location information of avalanche problems on a scale from 0 (not effective at all) to 100 (extremely effective). In addition, participants were given the opportunity to provide additional comments in a text box.

Our survey included a wide range of background questions to contextualize the results of the route-ranking exercise and the effectiveness ratings. We drew from questions included in Finn's (2020) survey and asked participants to indicate their primary modes of recreating in the backcountry, which avalanche bulletin region they recreate in, how often they check the bulletin, how many years and days per year of experience they had, what their overall attitude towards avalanches is, the level of avalanche training they had completed, and their bulletin user type as described by St. Clair (2019). Additional questions asked participants to identify how much weight they ascribe to different bulletin sections and rate their confidence in their abilities to understand the bulletin, recognize hazardous conditions in the field, make safe choices, and read topographic maps. Also included in the survey was a question explicitly testing users topographic map reading skills, as well as basic sociodemographic questions including self-identified gender, age, education level, location of residence, and colorblindness.

The survey was developed during the early part of the 2019/20 winter season and extensively tested in February and March 2020 prior to release. Survey testing began with an initial round of testers with moderate to high levels of winter backcountry recreation experience and avalanche industry experts. A second round of testing included users from

novice to expert participants. The survey was also reviewed and approved by the Office for Research Ethics of Simon Fraser University (SFU ethics approval 2020s0074).

2.2.2. Recruitment and Survey Development

The primary target audience for our survey was North American avalanche bulletin users, which we recruited in a variety of ways. The foundation of our recruitment were 3047 bulletin users who participated in previous avalanche bulletin surveys conducted by our research program and indicated that they were interested in participating in future studies. The survey was officially launched on March 23, 2020 by sending invitation emails to 300 individuals from this existing panel of prospective participants. This soft launch allowed us to monitor the initial responses and address any survey issues if necessary. However, the survey worked as designed and no modifications were required. On March 26, 2020, we sent invitation emails to the rest of our panel of prospective participants (2747 individuals) and between March 26 and April 1, 2020 the survey was also actively promoted by our partnering avalanche warning services (Avalanche Canada, Parks Canada, Colorado Avalanche Information Centre, Northwest Avalanche Center). Each of these warning services helped us recruit participants by including a banner on their bulletin website and promoting the survey through their social media channels. We also advertised our study by posting on various social media sites popular among winter backcountry users, such as South Coast Touring and Backcountry YYC on Facebook, and by reaching out to community leaders to distribute the survey among their followers.

To ensure meaningful and even samples for each of the experimental treatments included in our survey (type of location information graphic, type of feedback), participants were stratified according to their preferred winter backcountry activity and bulletin user type before being assigned to one of the experimental treatments. This guaranteed that all treatment combinations had representation from each winter backcountry activity and bulletin user type even if they were relatively small

The survey sample for the present analysis was drawn on May 31, 2020, after which no additional surveys were included in analysis. At the close of the survey 6789 individuals had started our survey and 3668 (55.3%) completed it. The vast majority of the dropouts (1829, 58.6% of dropouts) did not continue after looking at the first page of the survey that described the objective of the study and structure of the survey. The dropout

rate for individual survey pages was 1% or less except the page that introduced the route-ranking task (57, 3.4%). Of the individuals who completed the survey, 1600 (44.6%) were participants of previous survey studies of our research group who received an invitation email. Other substantial recruitment sources included announcements on avalanche bulletin websites (17.5% of participants who completed survey), social media posts by collaborating avalanche warning services (9.2%), and other posts in social media groups (e.g., Facebook, Instagram) focused on winter backcountry recreation (21.5%).

2.2.3. Data Analysis

We focused on a triad of performance metrics to assess the effectiveness of the three different aspect-elevation graphics in a meaningful way:

- The correctness of participants' answers in the route-ranking exercise,
- Participants' completion time of the route-ranking exercise, and
- Participants' perceived effectiveness of the three graphics

with an initial hypothesis that a more effective presentation would be associated with a higher percentage of correct answers, quicker completion times and higher perceived effectiveness ratings. This combination of measures provides a comprehensive perspective on the effectiveness of the different graphics that builds on existing research into the role of cognitive load in the success of different graphic types. Response time and response accuracy of primary and secondary tasks was used by Dindar et al. (2015) to measure the cognitive load of static and animated graphics on students learning English. The authors additionally used self-reported cognitive load as an additional metric to estimate cognitive load. In this study, we replaced the subjective, explicit request to estimate cognitive load with a question asking about perceived effectiveness. We also focused our study on a single type of task because of our interest in directly measuring how the graphic influences application of bulletin information. Our single-task approach is similar to Martin-Michiellot and Mendelsohn (2000) who measured response time and assessment accuracy in relation to different computer manual presentation formats.

Our analysis approach started with the use of standard descriptive statistics to describe the nature of the analysis dataset and explore the relationships between different variables. The core of our analysis consisted of three generalized linear mixed effects

models (GLMM) that explored the three different performance measures outlined above. GLMMs are an extension of generalized linear models that properly account for the correlations that emerges from repeated measure designs or nested data structures (Harrison et al., 2018; Zuur et al., 2009). To accommodate these data structure, GLMMs include both fixed and random effects in the regression equations. The fixed effects, which are equivalent to the intercept and slope estimates in traditional regression models, capture the relationship between the predictor and response variables for the entire dataset. While traditional regression models assign the remaining unexplained variance in the data (i.e., randomness) entirely to the overall error term, mixed-effect models partition the unexplained variance that originates from groupings within the dataset into random effects. Thus, random effects highlight how groups within the dataset deviate from the overall pattern described by the fixed effects included in the model. While there is some judgment involved in deciding what predictors are included in a GLMM as a fixed or random effect, it is generally the grouping variables that are not explicitly of interest that enter the analysis as random effects.

To assess how the graphics influence participants' ability to complete the route-ranking task correctly, their responses were graded as follows. Participants who ordered all three routes correctly received a passing grade whereas all other responses were assigned a failing grade. This means that we ended up with a binary response variable, which we examined with a logistic mixed effects regression model that uses a logit link to model the relationship between a binary response variable and one or more predictors. The random effects included in this model were participant ID and the ranking task avalanche scenario. To examine the effect of the graphics on completion time in seconds, we used a gamma mixed effects regression model, which is suitable for a continuous, positive, potentially right-skewed response variable. Similar to the model for correctness, we included participant ID and ranking task scenario as random effects.

The third and last GLMM included in this analysis explored the relationship between the graphics and participants' ratings of perceived effectiveness. Since these ratings were on a bound scale from 0 to 100, we used a beta mixed effect regression model for this analysis (Cribari-Neto & Zeileis, 2010). Similar to the logistic regression model, a beta regression uses a logit link to relate the response variable to the predictors in a constrained way. Prior to analysis, we divided participants' ratings by 100 to scale them down to 0 to 1 and transformed them with $y_{trans} = (y_{orig}(n - 1) + 0.5)/n$ as

suggested by Smithson and Verkuilen (2006) to eliminate values that are exactly 0 or 1 since they cannot be handled by the beta regression. In this model, participant ID was the only random effect as each participant rated all three graphics but there were no scenarios.

Since assessing the impact of the graphic and how this effect might vary among different levels of avalanche training is the main objective of this study, the initial versions of all three models included the type of aspect-elevation graphic and participants' level of formal avalanche training as predictor variables (both as main and interaction effects). The correctness and completion time models also included the following variable describing the nature of the ranking task: complexity of the route options (simple or complex), whether it was the first or second set of route-ranking tasks, and what type of feedback was provided between the two sets. In addition to these default predictors, the effects of other participant characteristics (e.g., primary winter backcountry activity, whether survey was completed on a smartphone, score on the map reading test) and route-ranking task attributes (e.g., overall number of correctly completed ranking tasks, which graphic was used in ranking tasks) were explored during the model building process. The predictors were only kept in the models if they contributed to the model as determined by a Type II Wald chi-squared test with a p-value smaller than 0.050 and the size of their effects were meaningful. Differences between model variants were assessed with likelihood ratio tests, and BIC (Schwarz, 1978) and model interpretability were used to guide final model selection.

We conducted our entire analysis in R (Version 4.0.5; R Core Team, 2021) and used the glmmTMB package (Brooks et al., 2017) to estimate our mixed effects models. The Type II Wald chi-squared tests were calculated using the Anova function of the car package (Fox & Weisberg, 2019). To assess violations in model assumptions, we simulated quantile residuals (Dunn & Smyth, 1996) as implemented in the DHARMA package (Hartig, 2020). Visual inspection of the resulting diagnostic plots (e.g., Q-Q-plot for uniformly distributed residuals) did not suggest any substantial model violations. Due to the logit link function and the presence of both main and interaction effects, the parameter estimates emerging from the regression models in this study are difficult to interpret directly. To make the results more tangible, we calculated marginal means of the response variables (i.e., correctness, completion time, perceived effectiveness) for the levels of different predictor variables and followed up with post-hoc pairwise comparisons to assess whether these estimates were significantly different from each other. We

performed this part of the analysis using the functions included in the emmeans package (Lenth, 2019). To counteract the issue of Type I error inflation from multiple comparisons, we calculated Holm-corrected p-values. The results of these analyses are presented in so-called effects plots, which display the differences between levels of a predictor variable of interest while holding all other predictor variables constant at their base levels. Hence, it is more important to look at the differences between the attribute levels of the predictor variable of interest than the absolute values.

2.3. Results

2.3.1. Participant Demographics

To ensure meaningful results, we only included participants in our analysis dataset who completed all pages of the survey, whose reported residence was in Canada or the United States, who were over the age of 20, and whose choices for primary activity and avalanche awareness training aligned with the predefined options. In addition, we excluded participants who took less than 10 minutes or more than 2 hours to complete the survey, or who spent longer than 10 minutes completing the route ranking tasks or reading feedback between the tasks. These cut-offs were chosen after a visual inspection of the distribution of page viewing times and are expected to represent participants who either did not engage with the survey or got interrupted. The final analysis dataset consisted 3,056 participants, which represented 83.3% of the 3668 individuals who completed the survey. The median completion time of the survey was 24.6 minutes with an interquartile range of 18.5 to 32.6 minutes.

Of the 3,056 participants, 76.9% self-identified as male (2,328 participants), 36.9% (1,125 participants) were between 25 and 34 years old, and 79.8% had a university-or-higher education (2,426 participants). In terms of avalanche safety training, 46.9% (1,433 participants) had taken an introductory level recreational avalanche safety course, 18.9% (577 participants) an advanced level recreational course, and 16.4% (501 participants) had completed a professional training course. Backcountry skiers represented the highest proportion of recreationists in the study with 78.3% of the sample (2,394 participants) identifying backcountry skiing as their primary backcountry winter activity. Additional types of recreationists present in our sample included out-of-bounds skiers (7.4%, 227 participants), snowshoers (5.5%, 168 participants), snowmobilers (5.1%, 156

participants), and less than two percent ice climbers and snowmobile-accessed backcountry skiers. The largest group of participants (31.3%, 955 participants) were relatively new to their sport, with 2 to 5 years of backcountry experience. However, the second largest group of participants (24.5%, 750 participants) had over 20 years of experience. Bulletin user types 'D—Distinguish Problem Conditions' and 'E—Extends Analysis' made up 75.6% of participants (2,312). Finally, 69.8% (2,134) of responses were from residents of the USA.

2.3.2. Correctness of Participants' Answers

Overall, our analysis dataset included 12,224 individual route-ranking tasks, of which 74.6% were completed correctly. Our final model for the probability of completing the route-ranking task correctly included seven fixed effects. The main effect for type of feedback as well as the interaction effects between graphic type and participants' level of formal avalanche training and the interaction effects between type of feedback and participants' level of formal avalanche training were eliminated due to p-values larger than 0.05 (Type II Wald chi-square test). The parameter estimates from the regression analysis are presented in Table 2-1, but the effects plots (Figure 2.3) show the key results in a more tangible way.

Table 2.1. Parameter estimates of regression model examining the correctness of participants' responses in the route-ranking exercise. Dashes (-) indicate that the level represents the base level of the attribute. (Number of Obs = 12,224)

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
<i>Predictor</i>	<i>Level</i>				
Graphic type	Separate	-	-	-	0.0082
	Aspect-Elevation	0.1564	0.0736	0.0334	
	Rose				
Avalanche training	Combined	-0.0500	0.0734	0.4961	<0.0001
	None	-	-	-	
	Introductory	0.3475	0.0774	0.0002	
	Advanced	0.3571	0.0942	<0.0001	
Route type	Professional	0.5152	0.0992	<0.0001	<0.0001
	Simple	-	-	-	
	Complex	-0.8008	0.0479	<0.0001	

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Set number	First set of two	-	-	-	0.0003
	Second set of two	0.1693	0.0468	0.0003	
Map literacy	Fail	-	-	-	<0.0001
	Pass	0.4488	0.0606	<0.0001	
Primary activity	Snowshoeing	-	-	-	<0.0001
	Ice climbing	0.0432	0.2343	0.8537	
	Out-of-bounds skiing	0.1743	0.1541	0.2579	
	Backcountry skiing	0.2200	0.1230	0.0737	
	Snowmobile-accessed backcountry skiing	-0.5146	0.2309	0.0258	
	Snowmobiling	-0.4262	0.1648	0.0097	
	Response via phone	No	-	-	-
	Yes	-0.1731	0.0613	0.0047	
Intercept		0.9078	0.3013	0.0026	
Random effects		Number	Variance	Std. Dev	
Individual participant		3056	0.6818	0.8257	
Avalanche problem scenario		6	0.4253	0.6521	

The avalanche problem information graphic that a participant saw during the task exercises had a significant main effect on whether a participant completed the tasks correctly (Figure 2.3). Comparing the three information formats shows that participants who saw the Aspect-Elevation Rose graphic were the most likely to complete the tasks correctly (probability = 0.752). 1 Participants who saw the Combined graphic had significantly lower probability (0.711, p-value < 0.008)¹ 2 of completing the tasks correctly than those who saw the Aspect-Elevation Rose. Similarly, participants seeing the Separate graphic were less likely to complete the tasks correctly than those seeing the Aspect-Elevation Rose (0.722), but the difference was statistically not significant (p-value = 0.085). Furthermore, there was no statistically significant difference in the performance

¹ All p-values presented in the model sections are from post-hoc pairwise comparisons. They are Holm-corrected p-values to counteract the issue of Type I error inflation from multiple comparisons.

between participants who were presented with the Separate and Combined graphic (p -value = 0.775).

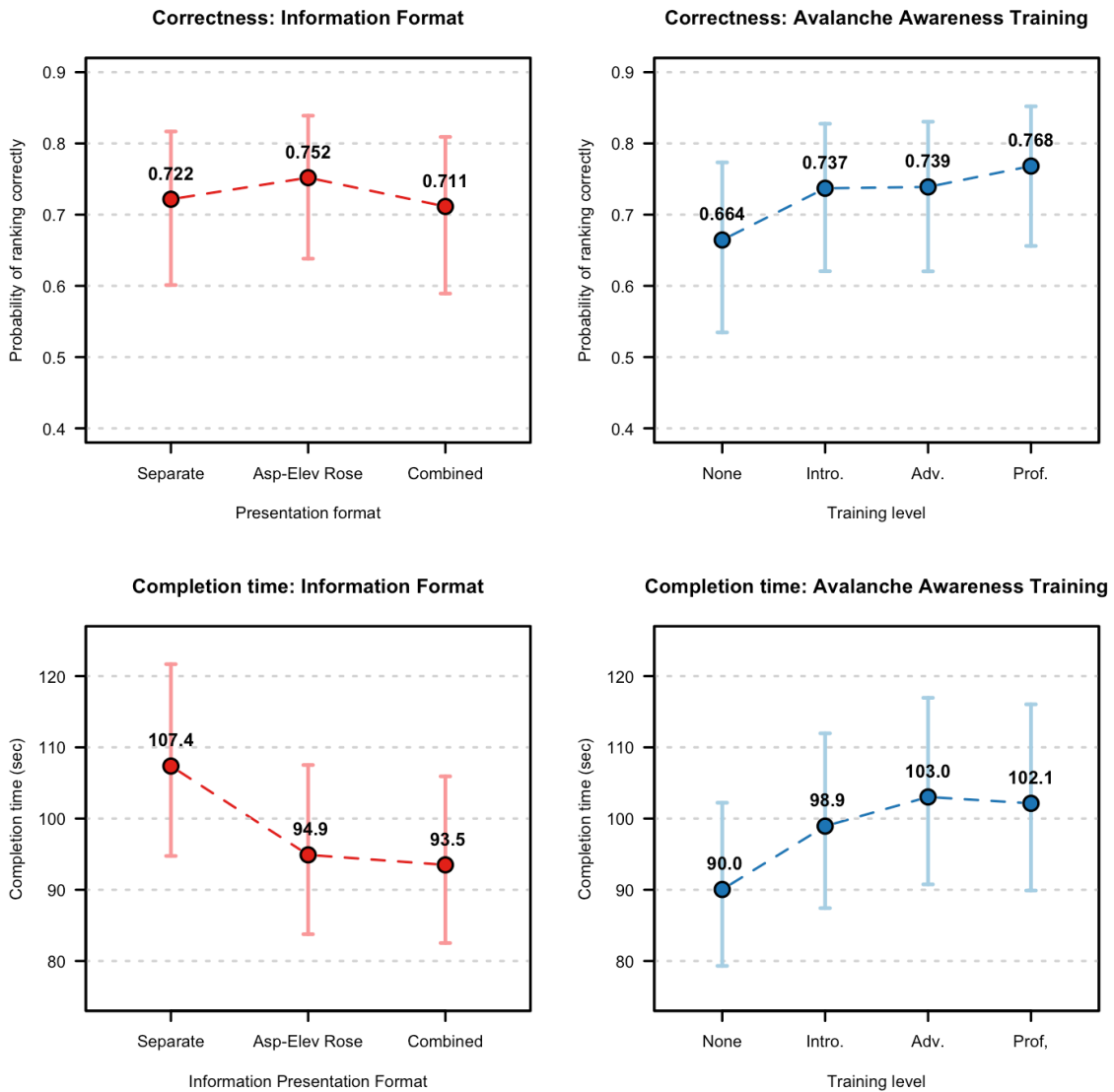


Figure 2.3. Effects plots illustrating the main effect for the presentation format and avalanche awareness training levels in the correctness and completion time model. Error bars represent 95% confidence intervals for probability of ranking correctly and completion time calculated from the subsample for the particular parameter level.

The level of avalanche training a participant had completed was also a significant predictor of completing the task correctly (Figure 2.3). Participants with professional training had the highest probability of completing the task correctly (0.768) followed by participants with advanced and introductory recreational-level training (0.739 and 0.737).

The probability of participants with no training completing the tasks correctly was 0.664. Our examination of the differences between consecutive levels revealed that the difference between participants with no training and introductory level recreational training was significant (odds ratio: 1.42; p-value < 0.001). The increase between recreational and professional level training was not statistically significant (p-value = 0.259).

Additional factors that changed the probability of completing the tasks correctly included route type and task set. Participants were more likely to complete tasks correctly with the simple routes than the complex ones (0.800 versus 0.643, p-value < 0.001), as well as during the second set of tasks rather than the first set (0.745 and 0.712, p-value < 0.001). Participants' probability of completing the tasks correctly was also related to characteristics such as their primary backcountry activity, success on the map reading task, and phone use. Within our sample, individuals who identified snowmobiling as their primary activity were significantly less likely to complete the tasks correctly than backcountry skiers (0.656 versus 0.784, p value < 0.001). Snowmobile accessed backcountry skiers exhibited a similar pattern to snowmobilers, with a probability of 0.636 of completing the tasks correctly. Participants who passed the map test were more likely to complete the tasks correctly than those who failed it (0.771 versus 0.682, p-value < 0.001). Participants who completed the survey on a phone were less likely to complete the tasks successfully than those who used a desktop (0.711 versus 0.745, p-value = 0.005).

2.3.3. Participants' Completion Time

Participants took a median of 87.0 seconds to complete the route-ranking task exercises and the interquartile range of completion times was from 60.0-134.0 s. Our final model describing completion time of the task exercises included seven main effects, and individual participants and bulletin scenarios were included as random effects (Table 2.2). As in the correctness model, the interactions effects between graphic type and participants' level of formal avalanche training as well as between type of feedback and participants' level of formal avalanche training were eliminated due to p-values larger than 0.05 (Type II Wald chi-square test).

Table 2.2. Parameter estimates of regression model examining participants' completion time of the route-ranking exercise. Dashes (-) indicate that the level represents the base level of the attribute. (Number of Obs = 12,196)

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
<i>Predictor</i>	<i>Level</i>				
Graphic type	Separate	-	-	-	< 0.0001
	Aspect-Elevation Rose	-0.1234	0.0202	< 0.0001	
	Combined	-0.1384	0.0203	< 0.0001	
Type of feedback	None	-	-	-	0.0012
	Articulate process	0.0642	0.0207	0.0020	
	Answers	-0.0137	0.0205	0.5035	
	Answers & Explanation	0.0164	0.0206	0.4276	
Avalanche training	None	-	-	-	< 0.0001
	Introductory	0.0942	0.0217	< 0.0001	
	Advanced	0.1347	0.0258	< 0.0001	
	Professional	0.1260	0.0268	< 0.0001	
Route type	Simple	-	-	-	< 0.0001
	Complex	0.1178	0.0083	< 0.0001	
Set number	First set of two	-	-	-	< 0.0001
	Second set of two	-0.1861	0.0150	< 0.0001	
Map literacy	Fail	-	-	-	< 0.0001
	Pass	0.1030	0.0172	< 0.0001	
Age category	Linear trend	0.0900	0.0063	< 0.0001	< 0.0001
Intercept		4.2820	0.0695	< 0.0001	
Random effects		Number	Variance	Std. Dev	
Individual participant		3049	0.1337	0.3656	
Avalanche problem scenario		6	0.0229	0.1512	

Our analysis revealed that the format of the avalanche problem information graphic had a significant effect on the completion time for route-ranking task (Figure 2.3). Based on the estimated model, participants who saw the information with aspect and elevation separate for each avalanche problem (Separate) took the longest time to complete the tasks (estimated marginal mean 107.4 s). Participants who saw the Aspect-Elevation Rose or Combined graphic took significantly less time to complete the tasks. The

estimated marginal means for the completion time were 94.9 s (difference: -12.5 s; p-value < 0.001) for the Aspect-Elevation Rose and 93.5 s (difference: -13.9 s; p-value < 0.001) for the Combined graphics. The difference between the Aspect-Elevation Rose and Combined graphics did not emerge as significant (1.4 s; p-value = 0.0.725).

Our analysis also revealed a significant effect of the type of feedback participants received between the two sets of route ranking exercises. Relative to receiving no feedback, participants who had to articulate their process, took significantly longer to complete the task (difference: +6.4 s; p-value 0.006), whereas receiving the solutions with or without explanations did not result in a significant difference in completion times (p-values: 0.817 and 0.752). Avalanche training had a significant effect on completion time. In general, the more recreational level training participants had completed, the longer they took to complete the task. Based on the model, participants with advanced level recreational training took the longest to complete the route ranking task (103.0 s; 13.0 s longer than participants with no formal training; p-value < 0.001), closely followed by participants with professional training who completed the tasks in 102.1 s (12.1 s longer than participants with no formal training; p-value < 0.001). Participants with introductory recreational levels training took 98.9 s (difference 8.9 s; p-value < 0.001), and participants with any training 90.0 s. This means that the biggest jump between consecutive categories occurs between no and introductory recreational-level training and effect diminishes with higher levels of training.

Other factors that emerged as significant predictors of completion time include the experimental variables route type and the task set, as well as the participants' characteristics map reading test result and age. Participants ranking a scenario with complex routes took 11.6 s longer (p-value < 0.001) than when ranking simple routes. Conversely, participants were quicker at ranking the second set of routes than the first set (89.7 versus 108.0 s; p-value < 0.001). Participants who failed the map reading test also complete the tasks substantially more quickly than participants who passed (93.5 versus 103.6 s; p-value < 0.001). Completion times increased linearly with the age category of participants with each increasing age class taking approximately 3 s longer (p < 0.001).

2.3.4. Perceived Effectiveness Rating

Our final regression model for the perceived effectiveness ratings included six main effects and three 2-way interaction effects (Table 2.3). Across all participants, the highest ratings were given to the Aspect-Elevation Rose graphic, with an estimated marginal mean rating of 78.4 out of 100. This is significantly higher than either the Separate (71.7, p -value < 0.001) or Combined graphics (71.9, p -value < 0.001). There was no significant difference between the ratings for these two graphics (p -value = 0.973). In addition to the overall effect of the information presentation format, there was also an interaction effect with a participant's country of residence (Figure 2.4). Canadian residents gave nearly identical ratings for the Separate graphics (75.0) and the Aspect-Elevation Rose diagram (74.8), with no significant difference between them (p -value = 0.990). Canadian residents rated the Combined graphic the lowest of the three formats (71.7), which was not significantly different from the other presentation formats (p -value = 0.012 and 0.017, respectively). In contrast, US residents rated the Aspect-Elevation Rose diagram significantly higher (81.6) than either the Separate (68.3, p -value < 0.001) or Combined (72.1, p -value < 0.001) graphics. Unlike, Canadian residents, US residents rated the Separate graphic significantly lower than the Combined presentation format (p -value = 0.001).

Table 2.3. Parameter estimates of regression model examining participants' perceived effectiveness ratings. Dashes (-) indicate that the level represents the base level of the attribute. (Number of Obs = 8,876)

Fixed Effects		Parameter Estimate	SE	p-value	p-value of Type II Wald Statistic
Main Effects					
<i>Predictor</i>	<i>Level</i>				
Graphic Type	Separate	-	-	-	<0.0001
	Aspect-Elevation Rose	-0.5689	0.1205	<0.0001	
	Combined	-0.4881	0.1234	<0.0001	
Country of residence	Canada	-	-	-	0.2989
	USA	-0.3305	0.0500	<0.0001	
Avalanche Training	None	-	-	-	0.2696
	Introductory	-0.0990	0.0652	0.1130	
	Advanced	-0.0717	0.0749	0.3382	
	Professional	-0.0963	0.0783	0.2192	

Fixed Effects		Parameter Estimate	SE	p-value	p-value of Type II Wald Statistic
Main Effects					
Used in task exercises	No	-	-	-	<0.0001
	Yes	0.5924	0.0479	<0.0001	
Tasks answered incorrectly	Linear trend	-0.0774	0.0220	0.0004	0.0169
Completed on phone	No	-	-	-	0.0002
	Yes	0.1157	0.0308	0.0002	
Intercept		1.0410	0.0906	<0.0001	
Interaction Effects					
<i>Predictor (levels)</i>		<i>Predictor (levels)</i>			
Graphic Type ^a	Country of residence				<0.0001
Aspect-Elevation Rose	Canada	-	-	-	
	USA	0.7328	0.0672	<0.0001	
Combined	Canada	-	-	-	
	USA	0.3478	0.0682	<0.0001	
Graphic Type	Avalanche Training				0.0068
Aspect-Elevation Rose	None	-	-	-	
	Introductory	0.1547	0.0835	0.0638	
	Advanced	0.1461	0.0998	0.1433	
	Professional	0.1977	0.1047	0.0590	
Combined	None	-	-	-	
	Introductory	0.0031	0.0851	0.9704	
	Advanced	-0.0768	0.1020	0.1433	
	Professional	-0.2145	0.1071	0.0452	
Graphic Type	Used in task exercises				<0.0001
Aspect-Elevation Rose	No	-	-	-	
	Yes	-0.3103	0.0676	<0.0001	
Combined	No	-	-	-	
	Yes	0.0171	0.0683	0.8025	
Graphic Type	Tasks answered incorrectly				<0.0001
Aspect-Elevation Rose	Linear trend	0.1982	0.0294	<0.0001	
Combined	Linear trend	0.1290	0.0300	<0.0001	
Random Effects		Number	Variance	Std. Dev	
Individual Participant		3056	0.132	0.3633	
Overdispersion parameter for beta family: 1.57					

^a Base level is Graphic type = Separate

In addition to the interaction effect above, there was also an interaction effect between the format of the avalanche problem graphics and a participant's completed level of avalanche awareness training (Figure 2.4). The ratings of the Aspect-Elevation Rose tended to increase with increasing levels of training. For participants who completed professional level training, the Aspect-Elevation Rose was rated 79.2 versus the Separate graphic at 71.1 (significantly different, p -value < 0.001) and for the Combined graphic it was 68.3 (significantly different from Aspect-Elevation Rose at p -value < 0.001, not significantly different than Separate style p -value = 0.18). The difference in rating between the Aspect-Elevation Rose and other styles decreases at lower levels of training, showing that at lower levels of training the effect of the Aspect-Elevation Rose graphic is not as preferred over other formats. Among participants with no training, the difference between the Aspect-Elevation Rose and the Separate graphic was the smallest (77.4 versus 73.1; p -value 0.005), and no other differences were significant among this group

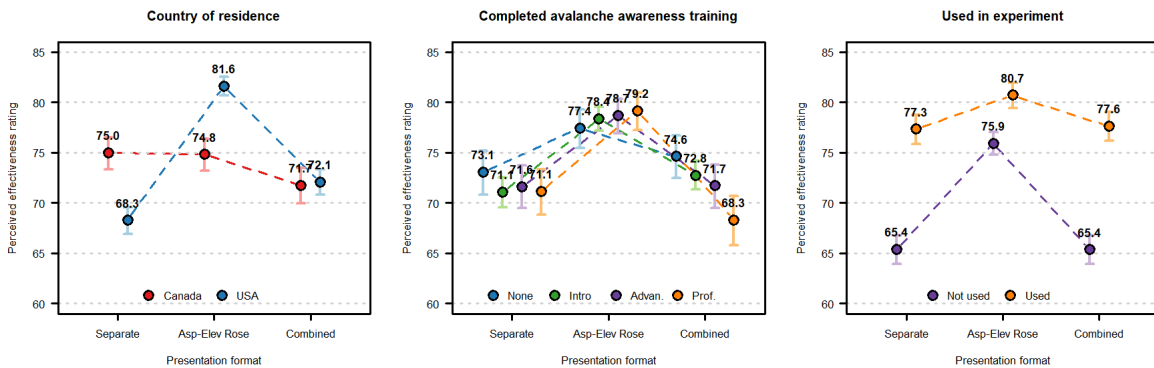


Figure 2.4. Effects plots illustrating the interaction effects with presentation format in the perceived effectiveness rating model. Error bars represent 95% confidence intervals for perceived effectiveness calculated from the subsample for the particular parameter level.

Another interaction effect was observed between the information presentation and whether a participant used it during the task exercises. Participant rated graphics they used during the task section of the survey higher than graphics they did not use during the survey (Figure 2.4). However, the difference in the rating for the graphics between participants who had not and who had used them was lower for the Aspect-Elevation Rose than for the Separate or Combined graphics. This shows that the Aspect-Elevation Rose

graphic was rated higher than the other two graphics even when participants had no familiarity with the icon from previous use in the survey.

There was also an interaction effect between the format of the graphics and how well a participant performed during the task exercises. For the Aspect-Elevation Rose and Combined graphic, participants' ratings of the graphics tended to increase with the number of tasks they completed correctly. In contrast, ratings of the Separate graphic tended to decrease with the number of tasks a participant completed correctly.

Unlike the other models, only one additional explanatory factor contributed to explaining the variation ratings. Participants who used their phone overall rated all of the graphics just slightly more favourably (75.3 versus 73.0, p -value < 0.001).

2.4. Discussion

We defined the success of an avalanche problem location information graphic based on whether participants completed the ranking task exercises correctly, how long it took them to complete the task, and how highly they rated the perceived effectiveness of the graphics. The use of regression analysis allowed us to isolate the influence of the graphics on each of these three metrics by controlling for the other influencing factors.

We can present an overall picture of user experience with each graphic by looking at a combination of the three metrics described above. The Separate graphic led to lower rates of correct task completion, slower task completion times, and was given relatively low ratings by all levels of training. Canadian residents rated the Separate graphic as about equivalently useful to the Aspect-Elevation Rose diagram, but US residents rated it the lowest of all the graphics. The Separate graphic received low ratings when compared to the Aspect-Elevation Rose regardless of whether it was used in the task exercises or not. These results indicate that the Separate graphic has challenges communicating avalanche problem information and we suspect that its popularity among Canadian residents is likely due to familiarity.

The Aspect-Elevation Rose graphic led to the highest rate of correct task completion, fast completion times, and was given the highest rating by all levels of training. It received the highest ratings regardless of whether or not survey participants used it during the task exercises, was rated by far the highest graphic by US residents and was

considered equivalent to the Separate graphic by Canadian residents. These results indicate the Aspect-Elevation Rose diagram is an effective graphic for communicating avalanche problem information and is likely to be accepted by many users.

The Combined graphic led to lower rates of correct task completion, on par with the Separate graphic, but fast completion times. The Combined graphic received relatively low ratings by both Canadian and US residents, regardless of whether or not it was used in the task. It received low ratings across all training levels, with ratings decreasing as training increased. These results indicated that the Combined graphic is not effective for communicating avalanche problem information, and not likely to be accepted by users.

2.4.1. Cognitive Load Perspective on Results

Our results are consistent with existing research on the effect of cognitive load on task performance. According to cognitive load theory, individuals have limited memory resources to apply to processing information, and that cognitive load increases with an increase in working memory use. Higher levels of cognitive load often lead to poor learning outcomes, lower task success, or trouble applying information (Allen et al., 2014; Dindar et al., 2015; Martin-Michiellot & Mendelsohn, 2000). Sweller et al. (2011) describe how cognitive load is altered by “interactivity”, which refers to the elements that must be processed simultaneously to be understood. Higher levels of interactivity generally lead to higher cognitive load. The authors further highlight that more information can be processed simultaneously when the information is broken down into meaningful “chunks” known as schema. Cognitive load can also be described as either intrinsic or extrinsic. Intrinsic cognitive load refers to the challenge inherent in understanding information or completing a task, whereas extrinsic cognitive load emerges from how the material is presented (Sweller et al., 2011). These two types of cognitive load are additive, with both competing for working memory capacity. If a task has a high intrinsic cognitive load, it is advised to reduce the extrinsic cognitive load as much as possible, as studies have found that people struggle with making behavioral choices when information is presented in a cognitively demanding format (Allen et al., 2014). There are multiple strategies for estimating cognitive load that include performance on tasks, efficiency of task completion, and self-reported ratings of cognitive load, often in combination although the relationship between measurements varies under different conditions (Dindar et al., 2015; Sweller et al., 2011). In the avalanche safety context of this study, interpreting the avalanche problem

graphics and making the route choice selection both demand cognitive resources from participants. Based on this, we can think of the metrics used to evaluate the problem graphics in this study as reflective of the cognitive load experienced during the task exercises. Completion of the route-ranking exercise is in itself an intrinsically challenging activity but did not vary between treatments, so it is expected that differences in outcome reflect the extrinsic cognitive load of the graphics.

The concept of extrinsic cognitive load helps explain the poor success of the Separate and Combined presentation formats. The Separate graphic is distinguished by a low success rate on the route ranking exercise, slow completion time, and low ratings for the graphic's perceived effectiveness. All of these indicators together suggest that the route-ranking exercise with this presentation format for the avalanche problem location information produced a high cognitive load that led to poor performance. In this presentation format, users had to combine the aspect and elevation information for multiple avalanche problems. Each individual component of the graphic could only be applied to terrain once combined with the others, which means that had graphic had high element interactivity. We hypothesize that this high element interactivity led participants to focus their cognitive resources on interpreting the graphic and lowering the resources available for actually applying the information to the terrain and ranking the routes. Additionally, to integrate the information, users had to direct their attention to multiple locations in the graphic to make sense of the information. There is evidence that this kind of attention splitting also leads to a higher cognitive load on individuals (Martin-Michiellot & Mendelsohn, 2000; Sweller et al., 2011).

With evidence that integrated information should lead to reduced cognitive load, it would be expected that the Combined graphic would lead to the least cognitive load because it integrated the most information into a single graphic. However, our results show that users also had a high amount of difficulty applying the information from this presentation format to the route-ranking exercise as demonstrated by the low correctness scores despite faster completion times. This result may be due to the high visual complexity of the Combined graphic leading to a high extrinsic cognitive load for the graphic. The Combined graphic uses multiple colours to represent avalanche problems, and the meaning of the colours must be distinguished and interpreted to understand the information presented in the graphic. Complex visuals have been shown to be difficult to interpret as they increase users' extrinsic cognitive load (Anderson et al., 2011; Harold et

al., 2020; Masri et al., 2008). Therefore, we suggest that that the extrinsic load from the complex visuals was high enough to reduce performance on the route-ranking exercise. Our results also mirror the result of studies on website complexity and hospital signage showing that visuals with medium levels of complexity performed most successfully with users (Rousek et al., 2011; Wang et al., 2014).

From a cognitive load perspective, the finding that the Aspect-Elevation Rose diagram performs best is not surprising. This presentation format mitigates the cognitive load required to integrate the avalanche problem aspect and elevation information by combining those elements into a single graphic, thereby lowering element interactivity. However, it keeps the avalanche problems separate. This degree of integrating information may correspond well to users existing schema or mental model about avalanche danger. In North America, the conceptual model of avalanche hazard uses “avalanche problems” as a framework to organize information about avalanche hazard. In the conceptual model, “location” is identified as one of four main characteristics of avalanche problems and, at the bulletin scale, “location” is described by aspect and elevation (Statham et al., 2018a). The success of the Aspect-Elevation-Rose graphic may be in part because it taps into this existing conceptual framework for thinking about “location” as a single characteristic defining avalanche problems. The Aspect-Elevation-Rose graphic is the only graphic that represents “location” for each avalanche problem, and therefore most closely represents aspect and elevation as they are included in the conceptual model. In contrast, the Combined graphic, which combines avalanche problems into a single graphic, aggregates location information at a higher level than is used in the conceptual model of avalanche hazard.

2.4.2. Implications for Avalanche Warning Services

The results of this study offer valuable insights for avalanche warning services seeking to communicate avalanche problem information to users more effectively. Our findings indicate that the Aspect-Elevation Rose diagram leads to the best performance in the route-ranking task, indicating that this presentation format may be best suited towards helping recreationists use the information as part of the avalanche bulletin. The Aspect-Elevation Rose was the most effective across all groups, and even users who are accustomed to the Canadian-style graphic can benefit from the US-style graphic.

Our results show that avalanche warning services interested in changing their information presentation might initially find resistance from their users as users prefer graphics that they are already familiar with. The interaction between country of residence and preference rating for the graphics suggests that users hold favourable perceptions of whichever graphic they are most familiar with. However, users may be flexible and willing to accept new graphics after experience with the graphics. Comparing the preferences of users on a per-graphic basis, participants who saw the Combined graphic during the task exercises exhibited the greatest increase in rating compared to those who did not use it. This boost to the preference of the Combined graphics by participants who used it in the tasks suggests that it may take relatively little time for users to become accustomed to a change in avalanche problem information graphics. This suggests any resistance to changing graphics used in the bulletin may be short lived.

Other results from this study that may be of interest to avalanche warning services is the finding that avalanche education was a strong predictor of how successfully people completed the ranking task. We found that participants with recreational level avalanche awareness training performed similarly to those with professional level training regardless of which graphics they used, which indicates that recreational training is successfully helping users interpret avalanche bulletins. This is consistent with prior research demonstrating that avalanche education is a significant factor influencing avalanche bulletin literacy (Finn, 2020). More importantly in the context of the objective of this study, however, our results show that the Aspect-Elevation Rose is the best presentation format for all training levels. Hence, there is no need to design different sets of graphics for beginners.

Additionally, this study found that participants with different primary backcountry activities performed differently on the task exercises even after controlling for avalanche awareness training. However, there was no interaction effect between the type of avalanche problem graphic used and participants' primary backcountry activity, indicating that the graphic use was not a factor in this variation of performance. Avalanche warning services can use this as evidence that changing avalanche problem graphics will not disadvantage backcountry recreationists of any sport. However, the route-ranking exercise may have been optimized for backcountry skiers based on the route design, and further research is needed to determine if the effect of backcountry activity on the results could be eliminated by optimizing the route-ranking exercise for different activities.

Additional research is also needed to determine if the effects observed for during this desktop exercise can be translated into increased recognition of hazardous aspect and elevation combinations in the field.

Finally, the success of combining avalanche problem aspect and elevation into the Aspect-Elevation-Rose graphic opens new doors for further improvements to the avalanche bulletin. In addition to aspect and elevation, likelihood and size are two additional avalanche problem characteristics that are presented graphically in North American avalanche bulletins. While likelihood and size are assessed and presented in a single chart in the conceptual model of avalanche hazard (Statham et al., 2018a), the two characteristics are presented in separate graphics in North American bulletins. Since this study has demonstrated that there are benefits to linking conceptually related avalanche hazard information into a single graphic for public use in avalanche bulletins, future research should seek to identify if this principle could also be extended to present likelihood and size in a single graphic or if it would disadvantage users with low graphical literacy.

2.4.3. Limitations

The participant sample in this study demonstrates trends consistent with previous surveys of backcountry recreation users. A high proportion of university educated, male, backcountry skiers, between 25 and 34 years of age with basic avalanche education engage in online surveys about avalanche safety (Finn, 2020; Haegeli & Strong-Cvetich, 2020; Haegeli et al. 2012). The similarity in sample demographics may be drawn from the similar survey promotion techniques used between this study and Finn (2020). Although this study and Finn (2020) did reach a wider range of users than previous studies, it only captures the behaviour of the demographic that responds to an online survey and may underrepresent non-English speaking participants or other demographics. Additionally, though the survey was open to all winter backcountry recreationists, the majority of the participants were backcountry skiers, and the tasks were optimized to show routes that would be realistic from the perspective of backcountry skiers. That means that the tasks exercises may not fully capture how other activity groups, such as snowmobilers, snowshoers, or ice climbers, think about terrain exposure and may not reflect how they apply avalanche problem location information to terrain when planning a travel route.

Future studies should seek to create hypothetical terrain scenarios tailored for the type of backcountry recreation the survey participant engages in.

2.5. Conclusion

To make informed decisions about when and where to travel in the backcountry, winter backcountry recreationists need to manage their risk from avalanches by monitoring the hazard conditions and relating this information to the terrain characteristics of their intended trips. The daily avalanche bulletins published by local avalanche warning services provide critical information about the existing conditions when recreationists are planning their trips from home. We used an online survey to evaluate the impact of avalanche bulletin information graphics on participants ability to apply the information to a route-ranking exercise that simulated the planning process for a backcountry trip. We evaluated the graphics on the correctness and completion times of user responses during the exercise, as well as useability ratings provided by users. Our study identified that combining aspect and elevation information into a single graphic leads to improved success on the route-ranking exercise, quicker completion times, and is favored by users regardless of avalanche training experience or country of origin. These results can be used by avalanche warning services seeking to maximize useability of their bulletins.

This study highlights that simply changing the graphic presentation of the aspect and elevation information can lead to greater success in applying the information to a route-finding task. These research results also provide valuable insight for the presentation of hazard information beyond avalanches by demonstrating that linking graphical hazard information to existing mental models about the hazard can lead to better application of the information. This lesson may help to improve communication of any natural hazard warning information where applying graphic information is necessary to make safe decisions

Chapter 3.

Exploring the avalanche bulletin as an avenue for continuing education by including learning interventions

This chapter is in preparation for publication in a peer-reviewed journal as Fisher, K., Haegeli, P., and Mair, P. "Exploring the avalanche bulletin as an avenue for continuing education by including learning interventions". As co-author I designed and executed the study and prepared the original draft with Pascal Haegeli. Patrick Mair provided support with statistical analysis and review.

Abstract

Snow avalanches pose a serious threat to people recreating in the mountainous backcountry during the wintertime. Assessing avalanche conditions and developing a risk management plan for travelling in avalanche terrain is a complex task with few opportunities for meaningful feedback. However, avalanche warning services publish daily condition reports that may be able to help guide recreationists by including interactive self-assessment opportunities for recreationists to check their understanding of daily hazard conditions.

We conducted an online survey to examine how adding interactive exercises coupled with feedback could enhance the educational value of avalanche forecasts in helping recreationists apply avalanche hazard information. Our results highlight that including interactive self-assessment exercises in avalanche forecasts has potential for enhancing their value and effectiveness, especially for individuals who might not have the skills to properly understand the hazard information well enough to make an informed decision about personal risk. This enhancement would turn forecasts from pure condition reports into a critical component of the overall avalanche awareness education system and help users develop appropriate risk management plans for recreating in avalanche terrain.

3.1. Introduction

Winter backcountry travel is growing in popularity, leading increasing numbers of recreationists to enter avalanche terrain in pursuit of recreational objectives. Recreating in avalanche terrain is an inherently risky activity that has resulted in 334 deaths in North America between 2011 and 2020 (Avalanche Canada, 2019; CAIC, 2020). Fortunately, avalanche deaths have not been increasing at the same rate as travel in the backcountry (Birkeland et al., 2017), but the rate of close-calls and near-misses that could have resulted in fatal accidents is unknown. To stay safe, recreationists must develop a risk management plan to minimize unnecessary exposure to avalanche risk by making decisions about when and where to travel. The development of avalanche risk management expertise is complicated by the fact that travelling in avalanche terrain is a wicked learning environment (Hogarth, 2015), where the system feedback about the consequences of key decisions is often unreliable, and the acquisition and application of knowledge are mismatched. Even under hazardous conditions, recreationists may be able to cross slopes that have high avalanche hazard without triggering an avalanche. However, such unreliable environmental feedback may reinforce incorrect understanding of what safe slopes look like, inaccurate self-perception of one's avalanche risk management skills and may hinder a meaningful development of these skills. As a result, there have traditionally been few opportunities for recreationists to get timely feedback about avalanche conditions.

Attempts to help recreationists learn about avalanche hazard include the development of recreational avalanche awareness courses, online tutorials and applications, and public avalanche bulletins. In North America, organizations such as Avalanche Canada and the American Institute for Avalanche Research and Education (AIARE) have developed curricula and classes teaching the skills and knowledge needed to travel safely in avalanche terrain. These courses offer recreationists the chance to learn from avalanche professionals about how to recognize and assess avalanche hazard, how to identify avalanche terrain, and crucial avalanche rescue skills. However, these courses require an investment of time and money, and not all backcountry recreationists have taken a training course (Finn, 2020). Moreover, a backcountry recreationist may only take a few such courses over their lifetime, thereby limiting opportunities for recreationists to validate their understanding of avalanche hazard with avalanche safety professionals.

Online tutorials, such as “AvySavvy” (avysavvy.avalanche.ca), “White risk” (whiterisk.ch) and “Backcountry Ascender” (Mayer, 2018) have attempted to bridge this education gap by providing easy to use or “gamified” avalanche education resources. These platforms offer opportunities to return to a trusted information source to review or learn concepts about avalanche safety and are available online and for no cost. However, the effectiveness of these platforms on avalanche education is unknown, they still require additional motivation to seek out the platform in for the purpose of knowledge development or practice, and they may not be regularly updated to reflect current conditions.

In contrast, public avalanche bulletins are updated daily with information about current avalanche conditions. Avalanche bulletins provide this information in a tiered structure with increasing levels of information complexity. The top of the tier is a danger rating describing the overall severity of the hazard, and lower tiers present more detailed information such as the location of avalanche problems and detailed snowpack observations as readers move through the bulletin (EAWS, n.d). In contrast to specialized classes or online tutorials, avalanche bulletins offer regular updates about avalanche hazard and timely suggestions on managing the terrain. However, the current format of the bulletin makes it a one-way condition report that does not offer ways for users to validate their understanding of the information. This is problematic, because as Finn (2020) demonstrated via a large-scale survey, many users lack the necessary skills to properly use the avalanche bulletin. Similarly, Hallandvik et al. (2017) found that novice users and experts read the avalanche bulletin differently and according to what information they understand. Additionally, Engeset et al. (2018) indicated that users’ comprehension of avalanche bulletin information can vary highly depending on what avalanche problem types are present. These findings indicate the existing form of avalanche bulletins may not be meeting the needs of recreationists desiring to further develop their risk management skills for travelling in avalanche terrain.

Increasing personal risk management competency in these challenging environments without access to expert guidance remains a challenge for the avalanche safety community and requires an innovative approach to avalanche safety education. A proposed solution has been to incorporate additional opportunities for recreationists to check their understanding of avalanche hazard conditions directly into public avalanche bulletins (St. Clair, 2019; St. Clair et al., under review), and there is strong support among

recreationists for the development of interactive components in avalanche bulletins (St. Clair, 2019; Finn, 2020).

There are multiple possibilities for how to integrate a 'self-check' component into the avalanche bulletin, among which are the inclusion of application exercises, opportunities for prompting reflection on the information, and opportunities for expert feedback. Practice with applying information is an important component of preparing to manage natural hazards. Applied simulations have been used to help decision makers practice working with information to improve hurricane preparedness (Regnier & Mackenzie, 2018), and other tools where users interact with the information have been shown to be successful in improving information comprehension in fields as diverse as health communication, flood preparation, and science education (Stretcher et al. 1999, Ancker & Kukafka 2007, Kuser-Olsen et al 2018, Stephens et al., 2017). Additionally, self-reflection has emerged as a viable educational strategy to enhance learning, and the importance of debriefing decisions is well-accepted within the field of operational safety (Chen et al., 2017; McCrindle & Christensen, 1995; Tannenbaum & Cerasoli, 2013). Chen et al. (2017), for example, observed that when students were asked to reflect on how they would use education resources prior to studying for an exam, they used resources more effectively and outperformed students in the control condition on exams, whereas McCrindle and Christensen (1995) observed more sophisticated cognitive strategies as well as increased performance on exams among biology students who wrote a self-reflection journal instead of a traditional report as part of required coursework. Finally, clear feedback on performance can also influence learning outcomes. In a study testing the diagnostic competence of medical students, feedback on examples was shown to be an important tool to improve performance (Heitzmann et al., 2015). In particular, feedback composed of both validation of results and elaboration on results is considered one of the most effective forms of feedback (Schute, 2008).

In this study, our first goal was to better understand whether adding learning interventions into the avalanche bulletin can strengthen bulletin users' skills in applying the presented information. We created an assessment exercise that simulated choices recreationists must face when planning a backcountry trip and included three learning intervention treatments. Our second goal was to determine if providing interactive exercises as part of avalanche warning service websites would be beneficial to users by asking users to reflect on the assessment exercise. The results of this study may be useful

to avalanche warning services seeking to connect more deeply with their users and enhance the educational value of their avalanche bulletins.

3.2. Methods

In the spring of 2020, we conducted a large-scale online survey to empirically examine different options for improving avalanche bulletin information in Canada. The survey was designed to elicit information about three different research themes within the avalanche bulletin. The first theme was testing how the presentation format of the avalanche problem location information (i.e., aspect and elevation) affects users' ability to apply this information when assessing the exposure of route to avalanche hazard. The second theme was understanding how learning interventions and interactive exercises impact user experience of the bulletin. The third theme involved investigating how users relate to the travel and terrain advice section of the bulletin.

The focus on this paper is to present the insight we have gained about the second research theme. The results that relate to the other two themes are described in separate manuscripts (Fisher, Haegeli & Mair, under review; Fisher, Haegeli & Mair, in preparation).

3.2.1. Survey Design

The primary focus of the survey was an application exercise where users completed a series of route-ranking exercises after seeing an avalanche hazard information scenario similar to how it is presented in an avalanche bulletin. A custom-built terrain map depicted three sample routes of travel on a simplified mountainscape with slopes of consistent incline on all aspects and elevation bands. The task of participants was to study the avalanche bulletin information and then rank the three depicted routes according to their exposure to the described avalanche problems. The correct solution for the ranking task could be determined by counting the number of aspect and elevation segments each route crossed where avalanche problems were present (Figure 3.1). The more avalanche problem aspect and elevation segments a route crossed, the more exposed it was to avalanche hazard. This approach allowed a targeted analysis of how participants understand terrain exposure, whereas approaches that required a more comprehensive assessment of avalanche hazard would also have to account for participants' perception of the danger scale and individual risk propensity. Additionally,

adjusting the weighting of exposure based on the nature of the avalanche problem would have required an objective assessment which types of avalanche problems are the more hazardous, which is difficult to quantify. Participants were explicitly alerted that overhead hazard and terrain traps should not be included in their assessment. To examine the effect of different presentation format, the aspect and elevation information of avalanche problems was presented in one of three different ways: a) separate graphics for aspect and elevation for each problem, b) separate aspect-elevation rose diagrams for each problem, and c) a single aspect-elevation rose diagram that shows the combined information from all problems in a single graphic (see Chapter 2 for details). To prevent the specifics of the avalanche bulletin information to affect our results in unintended ways, our experiment included six different avalanche bulletin scenarios (see Supplementary Material), all of which were developed in conjunction with avalanche industry experts to ensure they represent realistic real-world conditions.

Route Ranking Task (1 of 4)

Consider the avalanche hazard information provided to you below and rank the described backcountry routes according to their exposure to the mentioned avalanche problems. **Remember** that it is not necessary to consider **overhead hazard**, assume the **worst time of day**, and **flat terrain** is not exposed to avalanche hazard.

AVALANCHE BULLETIN

Avalanche Danger Rating		Avalanche Problems	
Elevation	Today	Wet Loose	Persistent Slab
What locations?	What locations?	What locations?	What locations?
Alpine	Moderate	Wet Loose	Persistent Slab
Treeline	Considerable	Wet Loose	Persistent Slab
Below treeline	Considerable	Wet Loose	Persistent Slab

• Please rank the three routes presented on the map below according to their exposure to mentioned avalanche problems from least to most exposed. *
You must rank all routes, and every rank can only have a single route.

Your exposure ranking

Routes

Least exposed - 1

2

Most exposed - 3

Route Ranking Task (2 of 4)

Consider the avalanche hazard information provided to you below and rank the described backcountry routes according to their exposure to the mentioned avalanche problems. **Remember** that it is not necessary to consider **overhead hazard**, assume the **worst time of day**, and **flat terrain** is not exposed to avalanche hazard.

AVALANCHE BULLETIN

Avalanche Danger Rating		Avalanche Problems	
Elevation	Today	Wet Loose	Persistent Slab
What locations?	What locations?	What locations?	What locations?
Alpine	Moderate	Wet Loose	Persistent Slab
Treeline	Considerable	Wet Loose	Persistent Slab
Below treeline	Considerable	Wet Loose	Persistent Slab

• Please rank the three routes presented on the map below according to their exposure to mentioned avalanche problems from least to most exposed. *
You must rank all routes, and every rank can only have a single route.

Your exposure ranking

Routes

Least exposed - 1

2

Most exposed - 3

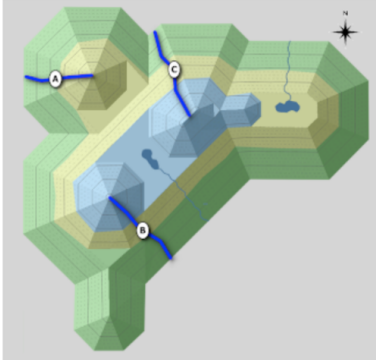
Figure 3.1. Example of route-ranking exercises with avalanche bulletin scenario and custom-built topographic map with three simple routes and three complex routes.

All participants completed two exercises for the first avalanche hazard condition scenario, one with “simple” routes that crossed only one aspect and one exercise with “complex” routes that crossed multiple aspects. After the two exercises participants were stratified into three treatment groups and presented with either an opportunity to reflect on the exercises by describing their approach or given one of two levels of feedback on their responses (Figure 3.2). The first feedback option was showing participants the correct exposure ranking of the routes alone, while the second was to show the correct rankings as well as detailed notes explaining the rationale for the rankings. After the opportunity to reflect on their process or see feedback, all participants were shown a second different avalanche scenario and had to complete two route ranking exercises, one simple and one complex, using the same instructions as the first scenario but with new bulletin information.

After the second scenario, all participants were shown the correct route rankings with the rationale of the exposure ranking. To debrief the exercise, participants were asked to rate how useful they found their treatment in helping them interpret the avalanche bulletin information, as well as how useful the route ranking exercises themselves were in helping to interpret the bulletin information. Both responses were rated on a four-level ordinal Likert scale that ranged from “not at all useful” to “somewhat useful”, “fairly useful” and “very useful”. At the very end, we also asked participants if they would like to see similar exercises included on avalanche forecasting websites, with “yes” and “no” as possible responses.

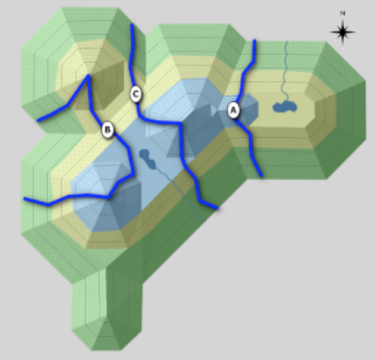
A) Please describe your approach for ranking these routes in a few sentences.
It is not necessary to describe your reasoning for each route individually. Please just describe your steps in general.

B) Ranking Task 1 **Ranking Task 2**



There are some differences between your and our rankings.

Least exposed	Your ranking	Our ranking
Rank 1	A X	C
Rank 2	B X	A
Rank 3	C X	B
Most exposed		

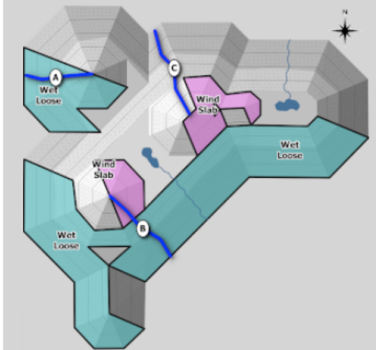


There are some differences between your and our rankings.

Least exposed	Your ranking	Our ranking
Rank 1	A X	C
Rank 2	B X	A
Rank 3	C X	B
Most exposed		

C) The reasons for our ranking
 See below for maps that overlay the routes with the problem areas.

Here, **Route B** is the **most exposed** since it is exposed to the wet loose avalanche problem at treeline and below, and the wind slab problem in the alpine. **Route A** is the **second most exposed**. This route avoids the alpine and is therefore only exposed to the wet loose avalanche problem. **Route C** is the **least exposed** as it avoids all avalanche problems.



All of these routes are exposed to the wet loose avalanche problem at treeline and below at least once. However, **Route C** is the **least exposed** as it does not cross any other areas with avalanche problems. **Route A** is the **second most exposed** because it is exposed to the wind slab problem on the north facing slope in the alpine. **Route B** is the **most exposed** route. In addition to being exposed to the wind slab in the alpine, it also crossed the wet loose avalanche problem a second time.

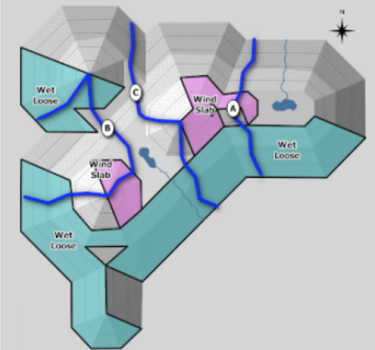


Figure 3.2. Three learning interventions tested in the study. A) Reflection exercise B) Answers only C) Detailed explanations. Panels B and C were presented together for the ‘Detailed explanation’ treatment.

In summary, the experimental portion of the survey included four route-ranking tasks that were complete in the following sequence:

1. First set of exercises (simple and complex)
2. Learning intervention (answers, detailed explanation, reflection)
3. Second set of exercises (simple and complex)
4. Presentation of detailed explanation of solutions of final second set of scenarios
5. Follow-up questions eliciting user opinion on the feedback and exercises

Our survey included a wide range of background questions to contextualize the results of the route-ranking exercise and the effectiveness ratings. We drew from questions included in Finn's (2020) survey and asked participants to indicate their primary modes of winter recreating in the backcountry, which avalanche bulletin region they recreate in, how often they check the bulletin, how many years and days per year of experience they had, what their overall attitude towards avalanches is, the level of avalanche training they had completed, and their bulletin user type as described by St. Clair (2019). Additional questions asked participants to identify how much weight they ascribe to different avalanche bulletin sections and rate their confidence in their abilities to understand the bulletin, recognize hazardous conditions in the field, make safe choices, and read topographic maps. Also included in the survey was a question explicitly testing users topographic map reading skills, as well as basic sociodemographic questions including self-identified gender, age, education level, location of residence, and colorblindness.

The survey was developed during the early part of the 2019/20 winter season and tested in February and March 2020 prior to release. Survey testing began with an initial round of testers with moderate to high levels of winter backcountry recreation experience and avalanche industry experts. A second round of testing included users from novice to expert participants. The survey was also reviewed and approved by the Office for Research Ethics of Simon Fraser University (SFU ethics approval 2020s0074).

3.2.2. Recruitment and Survey Development

The primary target audience for our survey was North American avalanche bulletin users, which we recruited in a variety of ways. The foundation of our recruitment were 3047 bulletin users who participated in previous avalanche bulletin surveys conducted by our research program and indicated that they were interested in participating in future studies. The survey was officially launched on March 23, 2020 by sending invitation emails to 300 individuals from this existing panel of prospective participants. This soft launch allowed us to monitor the initial responses and address any survey issues if necessary. However, the survey worked as designed and no modifications were required. On March 26, 2020, we sent invitation emails to the rest of our panel of prospective participants (2747 individuals) and between March 26 and April 1, 2020 the survey was also actively promoted by our partnering avalanche warning services (Avalanche Canada, Parks Canada, Colorado Avalanche Information Centre, Northwest Avalanche Center). Each of these warning services helped us recruit participants by including a banner on their bulletin website and promoting the survey through their social media channels. We also advertised our study by posting on various social media sites popular among winter backcountry users, such as *South Coast Touring* and *Backcountry YYC* on Facebook, and by reaching out to community leaders to distribute the survey among their followers.

To ensure meaningful and even samples for each of the experimental treatments included in our survey (type of location information graphic, type of feedback), participants were stratified according to their preferred winter backcountry activity and bulletin user type before being assigned to one of the experimental treatments. This guaranteed that all treatment combinations had representation from each winter backcountry activity and bulletin user type even if they were relatively small.

The survey sample for the present analysis was drawn on May 31, 2020, after which no additional surveys were included in analysis. At the close of the survey, 6789 individuals had visited our survey and 3668 (55.3%) completed it. The vast majority of the dropouts (1829, 27.6%) did not continue after looking at the first page of the survey that described the objective of the study and the structure of the survey. The dropout rate for individual survey pages was 1% or less except the page that introduced the route-ranking task (57, 3.4%). Of the individuals who completed the survey, 1600 (44.6%) were participants of previous survey studies of our research group who received an invitation

email. Other substantial recruitment sources included announcements on avalanche bulletin websites (17.5% of participants who completed survey), social media posts by collaborating avalanche warning services (9.2%), and other posts in social media groups (e.g., Facebook, Instagram) focused on winter backcountry recreation (21.5%).

3.2.3. Data Analysis

We conducted our entire analysis in R (Version 3.6.1; R Core Team, 2019). Our analysis approach started with the use of standard descriptive statistics to describe the nature of the analysis dataset and explore the relationships between different variables. To assess the effectiveness of the learning interventions and application exercise in detail, we computed two generalized linear mixed effects models and two conditional inference trees:

- ‘Correctness’ of answers in the route-ranking exercises,
- Derived ‘relative engagement in learning intervention’,
- Participants’ ‘Intervention usefulness’ ratings of how useful they found the interventions between the two bulletin scenarios, and
- ‘Completion time’ for the route-ranking exercises.

Furthermore, we calculated two additional conditional inference trees to assess how the application exercise itself might affected users’ experience with the bulletin:

- ‘Exercise usefulness’ ratings of how useful participants found the exercises overall, and
- ‘Include exercise’ request for avalanche warning services’ webpages.

In addition to variables directly representing survey responses (e.g., usefulness ratings, background variables on experience and training), our models also included several derived variables. First, participants’ correctness scores were calculated as follows: participants who ordered all three routes correctly received a passing grade whereas all other responses were assigned a failing grade. Second, we used ‘dwell time’ (i.e., how much time participants spend on a specific survey page) as a simple measure for how engaged participants were with either the route ranking exercise or the learning intervention. This approach follows the research of Baltierra et al. (2016), Lalmas et al. (2015), and Tian et al. (2021) who employed dwell time a simple metric measure for

assessing engagement. However, the inherent differences in the nature of the three intervention types prevent the absolute dwell time from being a meaningful measure of engagement in the learning intervention. To address this issue, we calculated the terciles of dwell time for the three interventions independently, and participants were given an ordinal relative engagement rating of “low”, “medium”, or “high” relative to the other participants viewing the same intervention type. The resulting ‘relative engagement in the learning intervention’ provides a consistent measure for how involved participants were in the intervention across the entire sample. For consistency, we used the same approach for describing participants’ engagement in the route ranking exercise in general. Here, we calculated the terciles for the average completion time of the two pre-intervention route ranking exercises and assigned all participants a relative engagement rating for the exercise of “low”, “medium”, or “high”.

Generalized linear mixed effects models (GLMM) are a suitable approach for exploring how the different intervention treatments influenced participants’ ability to complete the task correctly and their completion times because they properly account for the correlations that emerges from repeated measure designs or nested data structures (Harrison et al., 2018; Zuur et al., 2009). To accommodate these data structure, GLMMs include both fixed and random effects in their regression equation. The fixed effects, which are equivalent to the intercept and slope estimates in traditional regression models, capture the relationship between the predictor and response variables for the entire dataset. While traditional regression models assign the remaining unexplained variance in the data (i.e., randomness) entirely to the global error term, mixed-effect models partition the unexplained variance that originates from groupings within the dataset into random effects. Thus, random effects highlight how groups within the dataset deviate from the overall pattern described by the fixed effects included in the model. While there is some judgment involved in deciding what predictors are included in a GLMM as a fixed or random effect, it is generally the grouping variables that are not explicitly of interest that enter the analysis as random effects. In our analysis, this includes the participants as they completed multiple tasks, and the six avalanche bulletin scenarios that were repeatedly assessed by participants.

We implemented our GLMM analyses using the `glmmTMB` package (Brooks et al., 2017). The binary correctness response variable was modelled with a logistic mixed effects regression model, and the completion time was examined with a gamma mixed

effects regression model, which is suitable for a continuous, positive response variable. To integrate the three-way interaction between the set of the route ranking exercise (set 1: pre-intervention; set 2: post-intervention), the type of learning intervention (correct answers, detailed explanation, reflection) and the relative engagement in the learning intervention (low, medium, high) in an interpretable way, we combined the set and intervention type variables into a single variable, which we then interacted in the model with the relative engagement variable. In addition to these three variables, both GLMMs included participants' level of formal avalanche training, the complexity of the route options, and the type of information graphic as fixed main effects by default. The effects of other participant characteristics (e.g., primary winter backcountry activity, whether survey was completed on a smartphone, score on the map reading test) and relevant route ranking task attributes (e.g., the number of correctly completed ranking tasks) were explored during the model building process. However, these predictors were only kept in the models if the parameter estimates of any of their levels exhibited a p-value smaller than 0.050 and the effect size was meaningful. Differences between model variants were assessed with likelihood ratio tests and BIC (Schwarz, 1978), and model interpretability were used to guide final model selection. To account for the repeated measures included in the dataset, we added participant id and ranking task scenario id as random effects in both GLMMs.

The logit link function, and the presence of both main and interaction effects, make the parameter estimates emerging from the GLMMs in this study difficult to interpret directly. To make the results more tangible, we used the parameter estimates from the regression analyses to calculate estimated marginal means of the response variables (i.e., correctness, completion time) for the levels of different predictor variables and followed up with post-hoc pairwise comparisons to assess whether these estimates were significantly different from each other. We performed this part of the analysis using the emmeans function of the emmeans package (Lenth, 2019). To counteract the issue of Type I error inflation from multiple comparisons, we calculated Holm-corrected p-values. The results of these analyses are presented in so-called effects plots, which display the differences between levels of a predictor variable of interest while holding all other predictor variables constant at their base levels (ordinal, nominal variables) or at their average (interval variables).

We used conditional inference trees (CIT) to explore factors that affected participants 'relative engagement with the learning interventions', 'intervention usefulness', 'exercise usefulness', and if they would appreciate if avalanche warning services would 'include exercises' on their websites. We chose CITs for these analyses because they allow for an efficient simultaneous exploration of large numbers of potential predictor variables, naturally support interactions between predictors, produce visual outputs that are easy to interpret, and are less likely to overfit a model than traditional classification and regression trees (Hothorn & Zeileis, 2015; Hothorn, Hornik, & Zeileis, 2006). Using a statistical testing approach, CITs recursively split the analysis data set into smaller and smaller groups along splits of the predictor variables that result in subgroups whose distribution of the dependent variable are most different from each other. Our CIT analyses included a wide variety of predictor variables that described participants' personal experience, experimental conditions, performance on survey components, and participants' derived 'relative engagement in the exercise'. We used the `ctree` function of the `party` package (Hothorn & Zeiss, 2015; Hothorn et al. 2006) to identify which predictors significantly influenced the dependent variables of interest and did not manually remove any predictors.

3.3. Results

3.3.1. Participant Demographics

To ensure meaningful results, we only included participants in our analysis dataset who completed all pages of the survey, whose reported residence was in Canada or the United States, who were over the age of 20, and whose choices for primary activity and avalanche awareness training aligned with the predefined options. In addition, we excluded participants who took less than 10 minutes or more than 2 hours to complete the survey, or who spent longer than 10 minutes completing the route ranking tasks or reading feedback between the tasks. These cut-offs were chosen after a visual inspection of the distribution of page viewing times and are expected to exclude participants from the final analysis dataset who either did not properly engage with the survey or got interrupted. The final analysis dataset consisted of 2,278 participants, which represented 62.1% of the 3668 individuals who completed the survey. The median completion time of the survey was 24.6 minutes with an interquartile range of 18.5 to 32.6 minutes.

Of the 2,278 participants 76.5% of the study identified as male (1,727 participants), 36.9% (839 participants) were between 25 and 34 years old, 79.4% had a university-or-higher education (1,802 participants) and 82.6% (1,880 participants) had completed at least an introductory avalanche safety training course. Backcountry skiers represented the highest proportion of recreationists in the study with 78.6% of the sample (1,790 participants) identifying backcountry skiing as their primary backcountry winter activity. Additional types of recreationists present in our sample included out-of-bounds skiers (7.4%, 168 participants), snowshoers (5.8%, 131 participants), snowmobilers (4.7%, 108 participants), and less than two percent ice climbers and snowmobile-accessed backcountry skiers. The largest group of participants (31.7%, 719 participants) were relatively new to their sport, with between 2 and 5 years of experience. However, the second largest group of participants (24.9%, 565 participants) had over 20 years of backcountry experience. Bulletin user types 'D- Distinguish Problem Conditions' and 'E— Extends Analysis' made up 75.7% of participants (1,724). Finally, 70.4% (1,603) of responses were from residents of the USA.

3.3.2. Relative Engagement with Learning Intervention

The largest determinant in the relative engagement of participants in reading the learning intervention page was their relative engagement with the exercise (Figure 3.3). Participants with low relative engagement in the exercise (i.e., the first tercile of completion times) were also likely to have lower than average relative engagement in the learning interventions ($p < 0.001$). Another predictor of the relative engagement of participants was whether they made any mistakes in the first set of task exercises. Participants who answered both of the first set of tasks correctly were less likely overall to have high engagement with the intervention page (i.e., fall into the upper tercile of viewing time) than participants who got at least one of the tasks wrong ($p < 0.001$). Furthermore, the type of learning intervention was a significant predictor of the relative engagement of users for all branches, but the influence of the type of intervention varied among the branches of the tree. For participants who were in the upper two terciles of completion time and got all of the first set of tasks correct (node 10), the 'correct answers' intervention was distinctly less engaging than the other two interventions ($p < 0.001$), whereas the reflection exercise emerged as a standalone node that was less engaging for participants who made at least one error in the first set of tasks exercises (node 17). However, the reflection exercise did

lead to higher relative engagement scores than the answers with explanations among participants who got both tasks in the first set correct and fell in the middle tercile of task completion times (node 12; $p = 0.016$) Overall, the highest relative engagement with the learning interventions was among participants who fell in the upper two terciles of completion times for the first set of tasks, did not complete the all tasks correctly, and saw the ‘correct answers’ learning intervention (node 21).

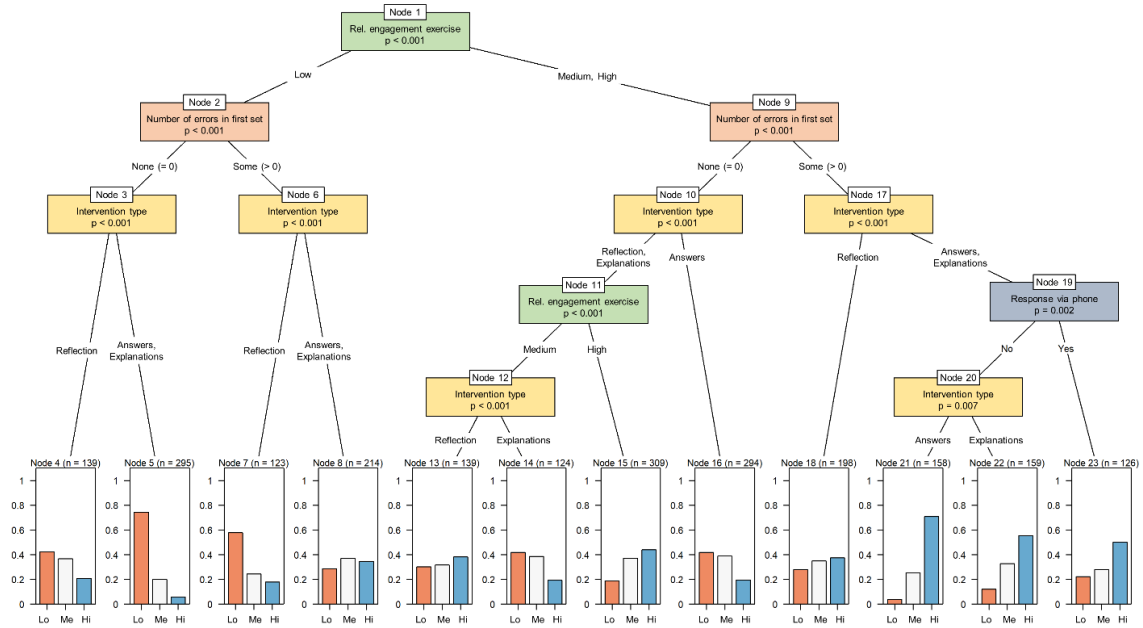


Figure 3.3. Conditional inference tree showing significant predictors of relative engagement in learning intervention. Labels for x-axis of bar charts are Low (Lo), Medium (Me), and High (Hi).

3.3.3. Correctness of Participants' Answers

Overall, our analysis dataset included 9,120 individual route-ranking tasks competed during the task exercises, of which 74.0% were completed correctly. The parameter estimates from the regression analysis are presented in Table 3.1.

Table 3.1. Parameter estimates of regression model examining the correctness of participants' responses in the route-ranking exercise. Dashes (-) indicate that the level represents the base level of the attribute (Number of obs = 9,120)

Fixed Effects		Parameter estimate	Standard error	p-value	p-value of Type II Wald Statistic
Main effects					
<i>Predictor</i>	<i>Level</i>				
Relative engagement in exercise	Linear trend	-1.1388	0.0971	<0.0001	<0.0001
Set / intervention type	Set 1 / Answers	-	-	-	0.0078
	Set 1 / Explanation	-0.0400	0.1076	0.7102	
	Set 1 / Reflection	-0.0559	0.1065	0.6000	
	Set 2 / Answers	0.0361	0.0986	0.7140	
	Set 2 / Explanation	0.1620	0.1080	0.1337	
	Set 2 / Reflection	-0.0560	0.1071	0.6012	
Avalanche training	None	-	-	-	<0.0001
	Introductory	0.3647	0.0926	0.0001	
	Advanced	0.4169	0.1118	0.0002	
	Professional	0.5520	0.1176	0.0000	
Route type	Simple	-	-	-	<0.0001
	Complex	-0.8767	0.0562	<0.0001	
Map literacy	Fail	-	-	-	<0.0001
	Pass	0.3978	0.0689	<0.0001	
Primary activity	Snowshoeing	-	-	-	0.0157
	Ice climbing	-0.0405	0.2594	0.8761	
	Out-of-bounds skiing	0.1059	0.1733	0.5412	
	Backcountry skiing	0.1023	0.1365	0.4537	
	Snowmobile-accessed backcountry skiing	-0.3118	0.2730	0.2533	
	Snowmobiling	-0.3716	0.1888	0.0491	
Graphic format	Separate				0.0495
	Aspect elevation rose	0.1741	0.0839	0.0380	
	Combined	0.0080	0.0838	0.9243	
Response via phone	No	-	-	-	0.0027

Fixed Effects		Parameter estimate	Standard error	p-value	p-value of Type II Wald Statistic
	Yes	-0.2101	0.0701	0.0027	
Intercept		1.1204	0.3063	0.0003	
Interaction effect					
<i>Predictor (levels)</i>		<i>Predictor (levels)</i>			
Set/ Intervention type	Relative engagement in learning intervention				<0.0001
Set 1/ Answers	Linear trend	-	-	-	
Set 2/ Answers		0.8408	0.1207	<0.0001	
Set 1/ Explanation		0.5963	0.1318	<0.0001	
Set 2/ Explanation		1.1181	0.1329	<0.0001	
Set 1/ Reflection		1.2811	0.1311	<0.0001	
Set 2/ Reflection		1.2972	0.1317	<0.0001	
Random effects		Number	Variance	Std. Dev	
Individual participant		2280	0.5795	0.7612	
Avalanche problem scenario		6	0.3874	0.6224	

Across the entire dataset and looking at the three learning interventions together, there was no significant difference in users' performance on the exercises between prior and after the learning interventions. However, a closer look at the interaction between the intervention type and how engaged participants were with the intervention reveals a more complex picture (Figure 3.4). For the reflection exercise, there was no significant difference between how well participants performed on the task exercise regardless of their level of engagement with the intervention page of the survey. The slightly increasing slope of both the before and after lines shown in the right section of Figure 3.4 are a reflection of the fact that participants who performed better in the first set of exercise tasks were more likely to engage with this leaning intervention. In contrast, participants who saw the answers were more likely to improve their performance on the second set of task exercises if they spent longer than the average participant on the intervention page of the survey (69.5% chance of correct completion v. 48.6 %, $p < 0.0001$). The dramatic negative slope of the before line in the middle section of Figure 3.4 indicate again that participants

who made errors in the first set of exercise tasks were more likely to engage with this type of learning intervention. Somewhat surprising, however, participants who engaged less than average with this type of feedback actually lowered their chances of completing the task exercises correctly after the learning intervention (90.2% v. 80.5%, $p < 0.0001$). Participants who received the answers together detailed explanations followed a similar pattern. Participants who paid less than the average amount of attention to the intervention page performed slightly worse on the second set of task exercises (83.0% v. 78.0%, $p = 0.0431$), whereas the other engagement tiers demonstrated improved performance after viewing the interventions (Average: 74.0% v. 77.7%, $p = 0.0345$; Higher: 62.3% v 77.3 %, $p < 0.0001$).

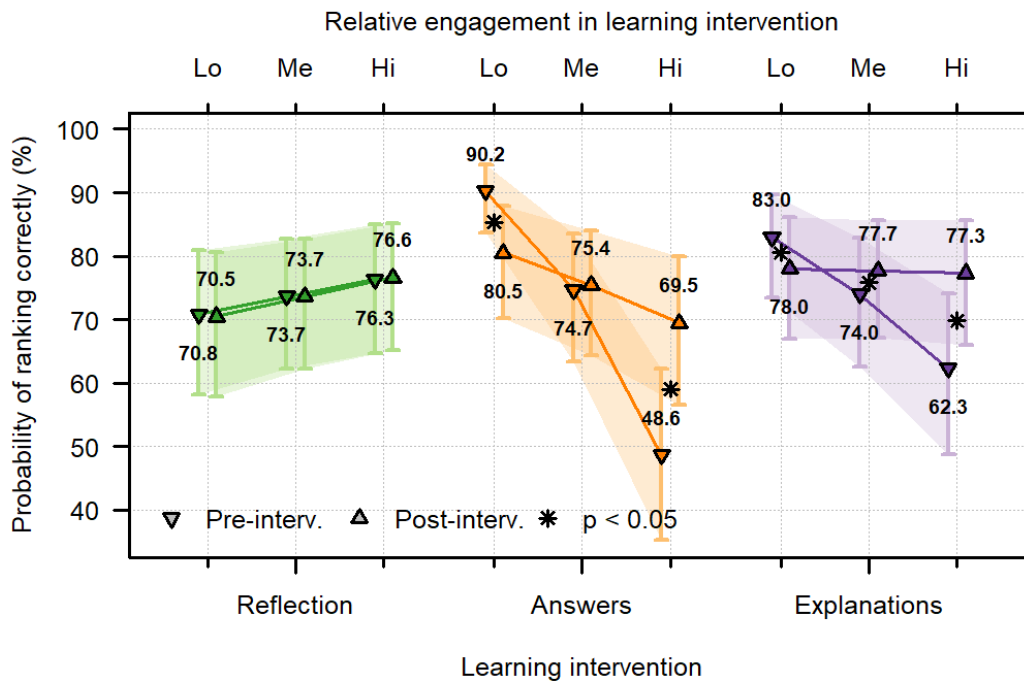


Figure 3.4. Effects plot illustrating the interactive effects of treatment type and relative engagement in the learning intervention (low, medium, high) on participants correctness scores. Downwards facing triangles represent participants' performance before the learning intervention, upward facing triangles represent participants' performance after the learning interventions, and asterisks indicate significant pairwise comparisons at the 5% level.

The parameter estimates presented in Table 1 also show that participants' probability of completing the tasks correctly was related to characteristics such as their level of avalanche training, primary backcountry activity, success on the map reading task, and whether the survey was completed on a phone. Participants with no formal training

had the lowest probability of completing the task correctly (68.1%²), which is significantly lower than participants with introductory training (75.5%, $p = 0.0002$). No significant differences were observed with additional levels of training (Advanced: 76.4%, $p = 0.8914$; Professional: 78.8%, $p = 0.4992$). Within our sample, snowmobilers and backcountry skiers who use snowmobiles for access had a lower probability of completing the tasks correctly than all other recreational activities. Individuals who identified snowmobiling as their primary activity were significantly less likely to complete the tasks correctly than backcountry skiers (69.1% v. 78.2%, p -value = 0.0121). Participants who passed the map test were more likely to complete the tasks correctly than those who failed it (78.4% versus 70.9%, p -value < 0.0001). Participants who did not use a phone to complete the survey were more likely to complete the tasks successfully than those who did (76.8% versus 72.8%, p -value = 0.0027). Finally, the probability of completing the tasks correctly was dependent on experimental conditions including the route type. Overall, participants were more likely to complete tasks correctly with the simple routes than the complex ones (82.2% v. 65.8%, p -value < 0.0001).

3.3.4. Completion Time of Exercises

Participants took a median of 88.0 s to complete the route-ranking task exercises and the interquartile range of completion times was from 60.0-134.0 s. Our final model describing completion time of the task exercises included seven main effects, and individual participants and bulletin scenarios were included as random effects (Table 3.2).

² Estimated marginal means for completing the ranking task correctly are calculated for the simple task in the first set of tasks and being in the central tercile for engagement. We used the based level for all other categorical or ordinal variables, and the average value for any numerical variables.

Table 3.2. Parameter estimates of regression model examining participants' completion time of the route-ranking exercise. Dashes (-) indicate that the level represents the base level of the attribute (Number of obs = 9,104).

Fixed Effects		Parameter estimate	Standard error	p-value	p-value of Type II Wald Statistic
Main effects					
<i>Predictor</i>	<i>Level</i>				
Relative engagement in learning intervention	Linear trend	0.1718	0.0107	<0.0001	<0.0001
Set / intervention type	Set 1 / Answers	-	-	-	<0.0001
	Set 1/ Explanation	0.0348	0.0242	0.1498	
	Set 1/ Reflection	-0.0191	0.0242	0.4310	
	Set 2/ Answers	-0.1942	0.0164	<0.0001	
	Set 2/ Explanation	-0.1493	0.0242	<0.0001	
	Set 2/ Reflection	-0.1321	0.0243	<0.0001	
Avalanche training	None	-	-	-	<0.0001
	Introductory	0.0826	0.0254	0.0012	
	Advanced	0.1206	0.0298	0.0001	
	Professional	0.1359	0.0310	<0.0001	
Route type	Simple	-	-	-	<0.0001
	Complex	0.1054	0.0096	<0.0001	
Map literacy	Fail	-	-	-	<0.0001
	Pass	0.0813	0.0189	<0.0001	
Age	Linear trend	0.0678	0.0070	<0.0001	<0.0001
Graphic format	Separate				<0.0001
	Aspect elevation rose	-0.1423	0.0224	<0.0001	
	Combined	-0.1586	0.0224	<0.0001	
Intercept		4.3859	0.0715	<0.0001	
Random effects		Number	Variance	Std. Dev	
Individual participant		2276	0.1172	0.3423	
Avalanche problem scenario		6	0.0210	0.1447	

The completion time of the tasks decreased overall from the first set of tasks to the second set of tasks with all learning intervention treatments. (Reflection: 104.5 s v 93.3 s, $p < 0.0001$; Answers: 106.5 s v. 87.7 s, $p < 0.0001$; Explanations: 110.3 s v. 91.7 s, $p < 0.0001$). There was no significant difference in how quickly the treatment groups completed the exercises prior to the feedback intervention, but after the feedback intervention the participants who received answers completed the tasks significantly faster than the participants asked to reflect on their process (87.7 s v. 93.3 s, $p = 0.0281$). Overall, however, the parameter spread of the relative engagement with the learning interventions indicates that it has the strongest association with the task completion time rather than the type of intervention viewed. This means participants with higher levels of engagement with the learning intervention also took longer to complete the task exercises in general (Figure 3.5). Furthermore, the lack of a significant interaction between the set of exercise tasks (i.e., pre- and post-intervention), the type of learning intervention, and participants' relative engagement in the intervention indicates that the type of intervention did not have an effect on participants' completion time in the second set of exercise tasks. In other words, the type of learning intervention and how much participants were engaged in that intervention did not determine whether they would take more time or less time to complete the second set of exercise tasks. Participants simply became more efficient across all treatments and levels of relative engagement. This further confirms and expands the results of the analysis that examined determinants for relative engagement in the learning intervention presented earlier. Participants who were more/less engaged in the exercises in general, were generally also more/less engaged in the learning intervention and stayed more/less engaged in the second set of exercise tasks.

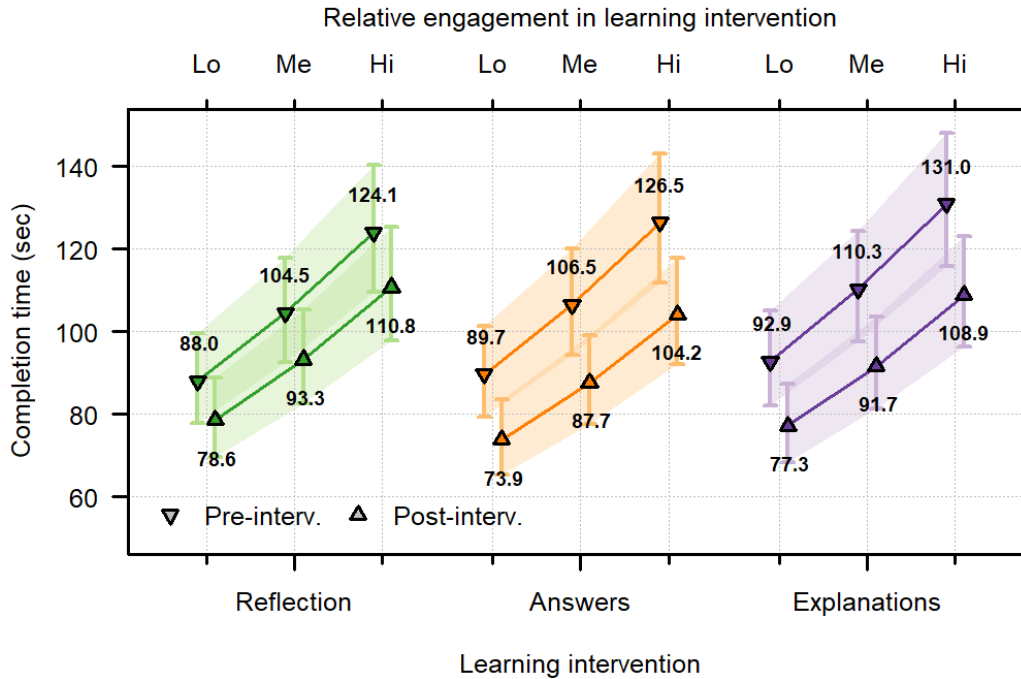


Figure 3.5. Effects plot illustrating the effects of treatment type and relative engagement in learning intervention (low, medium, high) on participants correctness scores, note there was no interaction between the learning intervention and the relative engagement. Downwards facing triangles represent participants' performance before the learning intervention, upward facing triangles represent participants' performance after the learning interventions, and asterisks indicate significant pairwise comparisons at the 5% level.

Avalanche training also emerged as a significant factor in the model for completion time. In general, the more training participants had completed, the longer they took to complete the task. Based on estimated marginal means calculated from the model parameters, participants with no training took 90.6 s to complete a task compared to 98.4 s for participants with introductory-level training ($p = 0.0033$). There were no significant differences in completion times among participants with introductory or advanced recreational training, or participants with professional level training. Participants who failed the map test completed the tasks more quickly than participants who passed it (94.7 s v. 102.8 s, $p < 0.0001$). Age was also a significant factor in completion time with participants in older age categories taking longer to complete the tasks everything else being the same.

Other factors that emerged as significant predictors of completion time include the experimental variables of avalanche problem graphic, and route type. Participants who

used the 'Separate' style graphics took significantly longer to complete the task exercises than those using either the 'Aspect Elevation Rose' or 'Combined' graphics. ('Separate': 109.1 s; 'Aspect Elevation Rose': 94.6 s, $p < 0.0001$; 'Combined': 93.1 s, $p < 0.0001$). Participants completing the 'Complex' tasks took significantly longer than participants completing the 'Simple' tasks (104.0 v 93.6 s, $p < 0.0001$).

3.3.5. Usefulness of Learning Interventions

The learning interventions were largely rated as useful by participants, with 42.9% reporting they were 'very useful'³ and only 5.3% indicating they did not find them useful at all. Our CIT analysis revealed that the format of the learning intervention a participant received was the greatest predictor of how likely they were to find it useful (Figure 3.6). Participants who received the reflection treatment formed the first split among participants ($p < 0.001$), and participants who had relatively low engagement in the learning intervention formed a distinct group that was less likely to find the intervention useful than other participants. The next distinct split between participants was between those who received the "correct answers" treatment and those who received the "detailed explanation" treatment, with a distinct node formed by the "correct answers" treatment ($p < 0.001$). Among participants who received the "detailed explanations" treatment, the number of days they participate in their recreational activity a year and their level of engagement in the learning intervention both were significant splits that formed distinct groups. Users in "detailed explanation" treatment group who spent less than 3-10 days in the backcountry and had an average or higher level of engagement in the intervention were significantly more likely to find the learning intervention useful than other groups. The highest usefulness ratings were provided by participants who saw the answers with the detailed explanations, spend less than 10 days in the backcountry each winter, and had an average or higher level of engagement in the education intervention (node 10).

³ The full four-level ordinal scale for the rating question was 'Not at all useful', 'Somewhat useful', 'Fairly useful' and 'Very useful'.

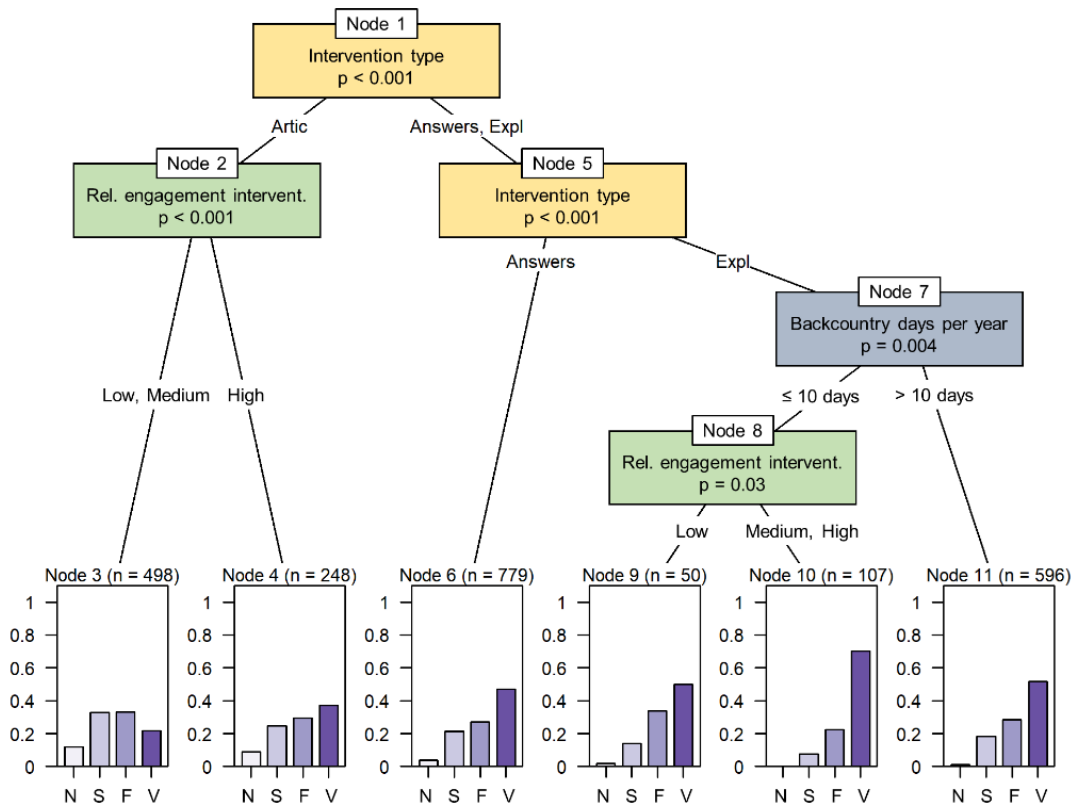


Figure 3.6. Conditional inference tree showing significant predictors of how useful participants found the learning interventions. The labels for the x axis of the bar charts are ‘Not at all useful’ (N), ‘Somewhat useful’ (S), ‘Fairly useful’ (F), and ‘Very useful’ (V).

3.3.6. Reactions to Route Ranking Exercise

We used the models for ‘exercise usefulness’ and ‘include exercise’ to gauge participants’ reactions to the exercise itself. Overall, participants found the route ranking exercises to be useful, with 56.7% of participants rating them as ‘very useful’ and less than a percentage rating them as ‘not at all useful’. In this analysis, the CIT algorithm found six significant nodes for how useful participants found the exercises (Figure 3.7). The first split was the number of days spent in the backcountry in the winter ($p < 0.001$). Among participants who spent 20 or fewer days in the backcountry, there was an additional split based on which tercile of time spent completing the first set of tasks they fell into ($p = 0.006$), and a second split among participants who were in the ‘low’ or ‘medium’ terciles of engagement in the intervention based on how many errors they made in the tasks ($p = 0.029$). Participants in this group who made errors, or who were in the ‘high’ tercile of engagement tended to find the exercises more useful. Among participants who spent more

than 20 days in the backcountry, the level of training a participant had completed emerged as a significant split with participants with professional level training forming a distinct node that was less likely to find the exercises to be ‘very useful’ ($p < 0.001$). Among participants without professional training, participants who had medium or higher relative engagement in the learning intervention were separated from the remaining participants ($p = 0.019$). Overall, the highest usefulness ratings were provided by i) participants with less than 20 backcountry days per winter and more than average engagement in the exercise in general (node 6), followed by ii) participants with more than 20 backcountry days per winter, recreational or no avalanche awareness training, and who had high engagement in the learning intervention (node 8).

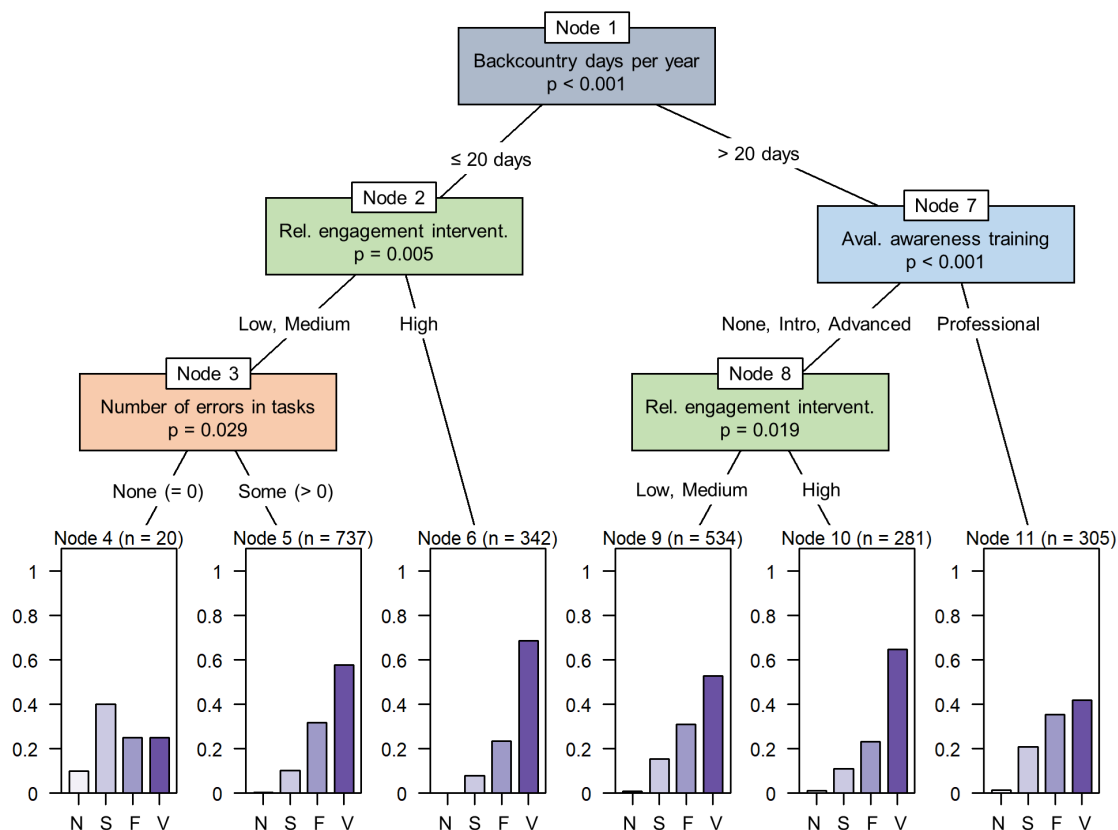


Figure 3.7. Conditional inference tree showing significant predictors of how useful participants found the application exercises. The labels for the x axis of the bar charts are ‘Not at all useful’ (N), ‘Somewhat useful’ (S), ‘Fairly useful’ (F), and ‘Very useful’ (V).

Overall, ninety five percent of participants indicated that they would like to see exercises similar to the route ranking exercise included in the bulletin. Our CIT analysis

only revealed one significant split in how participants responded to this question. Among participants with more than 50 days in the backcountry, only 90.6 % expressed that they would like to see similar exercises in the bulletin, whereas the approval rate was at 95.6% among participants spending less than 50 days per winter in the backcountry ($p < 0.001$).

3.4. Discussion

The two goals of this study were to test whether adding learning interventions into the avalanche bulletin can strengthen participant skills in applying the information, and to test if interactive exercises could be assets to avalanche warning service websites.

3.4.1. Learning Interventions

We looked at a combination of metrics to understand the educational potential of incorporating learning interventions into daily avalanche bulletins. First, we determined who was engaging with the learning interventions to better understand which users would benefit from the inclusion of learning interventions. We then determined whether the learning interventions were successful at helping participants to better apply the bulletin information to the application exercise. Finally, we used participants self-reported ratings of usefulness to assess how participants viewed the learning interventions.

The largest determinant of whether or not participants engaged with the learning interventions was whether or not they were engaging with the exercise itself. However, within this division, how well participants performed in the first half of the exercise was the largest driver of which feedback they engaged with. Users who got all of the tasks correct in the first half tended to engage more with the reflection intervention, while users who made mistakes tended to engage more with the interventions that provided feedback. This result makes sense, as users who were successful at the tasks were also able to articulate their process, and users who made mistakes had the opportunity to learn about their errors. This key difference in engagement demonstrates that if feedback is provided, users who need the feedback will be willing to engage with it. Interestingly, the level of avalanche training and bulletin user type did not predict how engaged participants were with the learning interventions. This shows that the interventions are engaging to participants regardless of other factors that typically explain their bulletin use, which we interpret to

mean that the learning intervention engaged a broader group than is typically served by existing bulletin products.

With the context that performance in the first half of the exercise led to differential engagement in the learning interventions, we also see that some of the interventions did produce positive change in participant performance. Our results showed that the learning interventions that provided participants with an opportunity to view feedback on their performance do increase participant success on subsequent tasks, but that increased success is predicated on their engagement with the feedback interventions. Taken together, these results show that the feedback interventions in this study can increase the ability of users to apply the bulletin information for users who were previously applying the information incorrectly and were motivated to engage with both the exercises and the feedback. While the feedback with the correct answers only resulted in an improvement among participants with a high level of engagement, the detailed explanation intervention produced improvements with both medium and high engagements. This relationship between engagement and performance has been documented in the educational community. Student engagement has been established as a predictor of student academic success with correlations emerging between how engaged they are with elements of online coursework and later performance on exams and final course grades and learning enjoyment has been shown to increase intentions for future engagement with educational material (Phan et al., 2016; Grey & Perkins 2019; Soffer & Cohen, 2018; Ainley & Ainley 2011). This relationship has been exploited by educators seeking to “gamify” educational materials, a trend which has started to enter the field of avalanche education with the ‘Backcountry Ascender’ (Mayer, 2018).

As well as increasing performance among users, both of the interventions that provided feedback were well regarded as useful among participants who viewed them regardless of their level of training or bulletin user type. In particular, the feedback with detailed explanations was favorably viewed by participants who spend a moderate amount of time in the backcountry each winter. We interpret these results as evidence that the value of feedback is not limited to one subset of users but is valuable to any users seeking guidance on applying bulletin information to terrain or looking to validate their interpretation of the information. These results should support avalanche warning services in including similar “application check” exercises into the bulletin, as a broad spectrum of users struggle to apply bulletin information to terrain (Finn 2020).

The potential benefit of feedback interventions may even be greater than observed in this study. A single experience with feedback has been noted to be less effective than repeated feedback over time. In a study of peer feedback on business school students, Donia et al. (2018) showed that one use of the system feedback system led to minimal improvement in performance, but after each repeated use of the feedback system cumulative performance increases were observed. A similar effect was observed in students by Butler (2010), who identified the importance of repeated testing in helping students apply previously learned information to a new knowledge domain. These studies are similar to the task exercises in this survey, because they focused on comparing participants' knowledge base in a test-like environment to determine the extent of their ability to interpret and apply information in a controlled context. The repetitive use of the bulletin over the course of a winter and evidence that ongoing interventions have greater impacts than single iteration interventions on learning outcomes, avalanche bulletins expanded with learning tools shows great potential for facilitate stage transitions among bulletin user types as described by St. Clair (2019).

Despite the potential benefits of feedback intervention treatments, our results also highlight that they can have negative effects on users who had the lowest relative engagement in the interventions. One possible explanation for this pattern is that users who were less engaged in the interventions may have also become tired of the survey and were rushing through. A second, and more concerning explanation is that participants who were told that they successfully completed the first set of tasks tended to engage less the feedback and may have become overconfident in their understanding of the task and confidently applied an incorrect assessment strategy. This interpretation is supported by the fact that the drop in performance was close to twice the size in the learning intervention that only provided the correct answers compared to the detailed explanation intervention that offers more insightful feedback (9.7 v. 5.0 percentage points). However, this finding requires further investigation to ensure that there will not be unintended negative outcomes of including feedback opportunities in the avalanche bulletin.

In contrast to the feedback treatments and despite documented evidence that reflection is a key element of learning (e.g., Chen et al., 2017; McCrindle & Christansen, 1995; Tannenbaum & Cerasoli, 2013), the reflection exercise in this study did not lead to improvements in applying the bulletin information to the task exercise. It was also rated as less useful overall by participants. This suggests that the daily avalanche bulletin may

not be an appropriate avenue for incorporating learning strategies that involve self-reflection. Our results mirror those of Lew and Schmidt (2011), who failed to identify an increase in academic performance among science students who kept a reflection journal as part of their curriculum. Despite the lack of strong correlation between reflection and academic performance, the authors noted a trend towards stronger correlation at the fourteen-week mark than at the three-week mark and hypothesized that the effects of the reflection journal may be subtle and potentially increase with additional reflection practice. Reflection has been shown to contribute to a strong safety culture among avalanche professionals (Johnson et al., 2016), so while this study indicates that interactive exercises in the avalanche bulletin are not an appropriate vehicle for encouraging this behavior, other mechanisms to promote reflective behavior among recreationists should be sought.

Interestingly, completion times decreased after viewing the interventions regardless of the learning intervention and the new combination of bulletin information and route options. Our original hypothesis had been that completion times would increase if the learning interventions increased engagement with the task exercises. However, while time is often used as a proxy for engagement, it is an imperfect metric and is typically combined with other measures such as click rates or visitation frequency (see, e.g., Dupret & Lalmas, 2013; Baltierra et al. 2016). Other estimations of engagement include combined indices of participants' perceptions and experiences with an intervention, as well as physiological metrics such as eye tracking or facial expressions (Lalmas et al., 2015). For this reason, we posit several interpretations of the finding that completion times decreased with the second set of task exercises (regardless of the learning intervention). 1) The learning interventions did not affect overall engagement with the task exercises 2) Familiarity with the nature of the exercise meant participants did not need to spend as much time on the exercises to complete them, regardless of engagement or 3) Completion time provides only an incomplete picture of how engaged participants were with the material. It is likely that several of these factors affected the completion times we observed. Uncovering the relationship between the learning interventions and participant engagement requires additional study.

3.4.2. User Perspectives on Application Exercise

In addition to the benefits of the learning interventions for users, we also were interested in understanding how participants would react to the application exercise. While

our study design was unable to assess if the route ranking exercise itself had direct benefits towards users' learning, we were still interested in participants' perspectives of the exercise itself, not just the learning interventions. The application exercise overall was well liked by users, especially among users who spent less time in the backcountry and who did not have professional level avalanche training. Users also overwhelmingly support the inclusion of application exercises into the webpages of avalanche warning services. We interpret these findings as evidence that users are eager for more practice with applying bulletin information.

3.4.3. Implications for Avalanche Warning Services

The results of this study demonstrate that application exercises are popular among recreationists, and that by including opportunities for feedback with the application these exercises can lead to educational benefits. We interpret our results as evidence that recreationists crave additional practice opportunities and feedback on applying bulletin information from trusted professionals. Therefore, avalanche warning services should consider integrating application exercises into daily avalanche bulletins to give users a chance to assess their understanding.

As this study only represents a one-time intervention, we are unable to determine if repeated interventions would lead to stronger educational benefits with repeated use, or conversely, if participants familiarity with the exercise would lead them into overconfidence or complacency in attempting the exercises. However, the integration of condition dependent, daily exercises for users to check their understanding of the bulletin could help to answer these questions, as well as be a useful continuous source of information on how users interpret the bulletin. The gained insight could provide valuable information for future bulletin improvements. It could also be used to develop target educational initiatives if certain combinations of problem conditions are repeatedly misunderstood.

3.4.4. Limitations

This study only reflects how participants applied the information as part of a desktop exercise, however users must be able to translate the bulletin information to field behaviors to make safe choices in avalanche terrain. While the learning interventions we tested did improve participants success at completing the task exercises, we are not able

to determine if these exercises could effect change in field behavior. Additionally, though the survey was open to all winter backcountry recreationists, the majority of the participants were backcountry skiers, and the tasks were optimized to show routes that would be realistic from the perspective of backcountry skiers. That means that the tasks exercises may not fully capture how other activity groups, such as snowmobilers, snowshoers, or ice climbers, think about terrain exposure and may not reflect how they apply avalanche problem location information to terrain when planning a travel route. Future studies should seek to create hypothetical terrain scenarios tailored for the type of backcountry recreation the survey participant engages in.

Finally, our survey sample included a high proportion of university educated, male, backcountry skiers, between 25 and 34 years of age with basic avalanche education. While this demographic is known to engage in online surveys about avalanche safety (Finn, 2020; Haegeli & Strong-Cvetich, 2020; Haegeli et al., 2012), it may not be fully representative of the backcountry user population, and only captures the behaviour of the demographic that responds to an online survey.

3.5. Conclusion

The avalanche bulletin is the primary source of avalanche hazard information for winter recreationists and includes information that changes on a daily basis. Ensuring that recreationists understand the avalanche bulletin is therefore of utmost importance to their backcountry safety. In this study, we tested if adding learning interventions to the avalanche bulletin could result in improvements to users' ability to apply the information. Our results showed that learning interventions that include feedback on an application exercise improved subsequent performance among users who engaged with the intervention. Additionally, learning interventions that included feedback were popular among users, as were the application exercises themselves. We recommend that avalanche warning services include opportunities for users to assess their knowledge of the avalanche bulletin content as part of their avalanche bulletins, and that future research should study the long-term impacts of adding these types of exercises into the avalanche bulletin especially among users under-represented in this study.

Chapter 4.

Travel and Terrain Advice: Understanding current use practices and modifications for increased useability among backcountry recreationists

This chapter is in preparation for publication in a peer-reviewed journal as Fisher, K., Haegeli, P., and Mair, P. "Travel and Terrain Advice: Understanding current use practices and modifications for increased useability among backcountry recreationists" As co-author I designed and executed the study and prepared the original draft with Pascal Haegeli, and Patrick Mair provided support with statistical analysis and review.

Abstract

Recreationists are responsible for developing their own risk management plan for travelling in avalanche terrain. In order to provide guidance for recreationists on mitigating exposure to avalanche hazard, avalanche warning services include a section known as 'Travel and Terrain Advice' alongside their publication of daily hazard information. However, the use and effectiveness of this advice has never been tested to ensure it is meeting the needs of recreationists developing their risk management approach for backcountry winter travel.

We released an online survey to determine which user groups are paying attention to the travel and terrain advice section of avalanche bulletins, and how useful users find the section, and if modifications to the phrasing of typical advice given would be able to improve the usefulness of the advice to users. We identified that reducing jargon used in the advice helped users understand the advice better, while providing increased context for the advice made the advice more useful for participants.

This study provides avalanche warning services with critical perspectives and recommendations for improving their travel and terrain advice so that they can better support recreationists in developing a risk management approach for travel in avalanche terrain.

4.1. Introduction

Mountainous areas with untracked powder slopes are popular destinations for winter backcountry recreationists including backcountry skiers and snowboarders, mountain snowmobile riders, and snowshoers. Even though detailed information on participation in winter backcountry recreation is sparse, there is strong anecdotal evidence that increasing numbers of people are taking to the mountains to pursue their mountain objectives, exercise, or simply enjoy nature (e.g., Birkeland et al., 2017). However, recreating in the backcountry comes with serious risks. In North America alone, avalanches were responsible for the deaths of 334 recreationists between 2011 and 2020, and an unknown number of injuries and near-misses (Avalanche Canada, 2019; CAIC, 2020). To safely recreate in avalanche terrain, recreationists must continuously monitor the severity of avalanche hazard and make informed decisions about what type of terrain is acceptable to travel in under the current conditions (Canadian Avalanche Association, 2016). While some recreationists hire certified mountain guides to manage the risk from avalanches for them, most make their own decisions about when, where, and how to travel in the backcountry.

Having a good understanding of the existing avalanche conditions is critical for putting together a meaningful avalanche risk management approach for a trip into the backcountry. To assist recreationists with this process, most western countries with mountainous regions have public avalanche warning services that publish daily avalanche condition reports, commonly known as ‘avalanche bulletins’ or ‘avalanche forecasts’. The main objective of these condition reports is to inform the reader about the severity of the existing avalanche hazard, which, in the context of public avalanche forecasting, is defined as the potential for avalanches to cause harm to backcountry recreationists (Statham, 2008). In North America, public avalanche forecasters assess avalanche hazard according to the conceptual model of avalanche hazard (Canadian Avalanche Association, 2016; Statham et al., 2018a). Based on the available weather, snowpack, and avalanche observations, forecasters develop a picture of the types of existing avalanche problems, the locations where these problems can be found in the terrain, the likelihood of associated avalanches, and their expected destructive size (Statham et al., 2018a). This information is then summarized into a set of three danger ratings that describe the overall severity of the conditions in the three elevation bands alpine, treeline

and below treeline according to the North American public avalanche danger scale (Statham et al, 2010). Reflecting this process, avalanche bulletins present the avalanche hazard information to their readers in a pyramid-like structure with the overall hazard rating given first, then details of avalanche problems, and finally additional details about snowpack structure, avalanche observations, and weather conditions (EAWS, n.d).

While avalanche bulletins provide an expert assessment of the existing hazard, recreationists must manage the associated risk associated by controlling their hazard exposure through their choices about when and where to go into the backcountry. These decisions can be made at different levels of sophistication, which were recently described in the bulletin user typology of St. Clair, Finn and Haegeli (under review). Bulletin User Type 'B's, for example, exclusively base their decision to go into the backcountry at all on the danger rating, whereas Type 'D's use the avalanche problem information to distinguish between suitable and unsuitable areas for travel. A follow-up survey study by Finn (2020) showed that while bulletin users generally have a decent understanding of the concepts presented in the bulletin, roughly half of his survey participants exhibited challenges applying the information in a hypothetical slope evaluation task. This highlights that there might be a considerable gap between understanding the hazard information and combining it with terrain selection to make good risk management decisions.

There are several existing avenues through which recreationists can develop skills in forming a risk management plan and learn about selecting terrain to reduce exposure. Avalanche awareness courses taught by mountain guides and avalanche educators offer an important resource for recreationists to learn about practical avalanche risk management skills that can be used to understand both avalanche hazard and how to control risk through terrain selection. This was confirmed by Finn (2020), who found a strong correlation between the avalanche awareness training level of survey participants and their performance at evaluating appropriate slopes for travel. To further assist recreationists in selecting appropriate terrain, various products have been developed including specialized maps, decision aids, and web applications. For example, Statham et al. (2006) developed the avalanche terrain exposure scale (ATES) to describe the severity of backcountry trips with respect their general exposure to avalanche hazard using the qualitative terms 'simple', 'challenging', and 'complex'. This expert terrain rating system has been used extensively to rate backcountry recreation areas in Canada (see <https://www.avalanche.ca/planning/trip-planner>), but ATES has also been applied in

Norway (Larsen et al., 2020), Spain (Gavalda et al., 2013) and Switzerland (Pielmeier et al., 2013). While the ATES system provides an expert assessment of the terrain, Harvey et al., (2016) took a more physical process-oriented approach to classifying terrain when developing avalanche terrain maps based on GIS algorithms that explicitly identify potential avalanche release areas, possible runout zones, areas with the potential for remote triggering, and areas where small or medium-sized avalanches might lead to serious injuries or deep burials due to terrain traps.

In addition to these terrain classifications, various decision frameworks have been developed to help recreationists combine the hazard information provided in avalanche bulletins with terrain characteristics of intended trips to manage avalanche risk. Examples include the ground-breaking Reduction Method developed by Munter (1997), which contrasts the published danger rating with several terrain characteristics and group factors to determine whether the associated risk is acceptable, and the Avaluator Trip Planner (Haegeli, 2010), which combines the danger rating of the bulletin and the ATES rating of an intended trip graphically to provide users with guidance about what level of training and experience is required to effectively manage avalanche risk under the given conditions. Most recently, some of the concepts presented by these decision aids have been implemented as web applications. Avalanche Canada has an online trip planner that displays Avaluator assessments for selected recreation areas based on their ATES ratings and the current avalanche danger rating (<https://www.avalanche.ca/planning/trip-planner>), and the Swiss skitourenguru.ch website has implemented a version of the reduction method to provide detailed daily risk assessments of backcountry routes in the central European Alps (Schmudlach & Köhler, 2016).

The terrain classification systems and decision aids described above exist separate from the hazard information in avalanche bulletins, provide only generic guidance, and their application requires some training and experience. However, avalanche bulletins also include travel and terrain advice (TTA) statements where avalanche forecasters directly communicate with their users to offer guidance about what specific terrain to avoid and what to favour under the existing hazard conditions. Avalanche warning services have taken a varied approach to including TTA statements in their bulletins. The Northwest Avalanche Center in Washington State, for example, presents the advice as part of their “bottom line” summary at the top of their bulletin webpage, while the Colorado Avalanche Information Center presents the information

below the avalanche danger rating (NWAC, n.d; CAIC, n.d). In contrast, Swiss avalanche bulletins include the information alongside specific avalanche problem descriptions (SLF, n.d). Avalanche Canada historically included the TTA statements on avalanche problem tab but has moved them below to the danger rating at the beginning of the 2020/2021 winter season. These statements are the primary source of information on appropriate terrain selection found in avalanche bulletins.

Despite the important potential that TTA statements have guiding users towards an appropriate risk management plan by linking daily hazard and terrain selection, and the large range of approaches taken by avalanche warning services, there have been no studies to-date that specifically examine how this section of advice is used by recreationists. In this study, we address this knowledge gap by identifying the segment of bulletin users who pay most attention to the TTA information, examining what contributes to the usefulness of a TTA statement, and studying how simple modifications could increase the usefulness of these statements.

4.2. Methods

In the spring of 2020, we conducted a large-scale online survey to empirically examine different options for improving communication of hazard and terrain information in avalanche bulletins. This paper focuses on the results pertaining to the travel and terrain advice (TTA) statements, whereas additional analyses investigating information graphics and bulletin interactivity are presented in Fisher, Haegeli and Mair (under review) and Fisher, Haegeli and Mair (in preparation) respectively.

4.2.1. Survey Design

Our first research question was to investigate the primary audience of the TTA section in the bulletin, so we asked all survey participants how much attention they generally pay to the TTA. This was to better understand which users are engaging with the TTA, as well as to target subsequent questions about the TTA towards participants who actually use it. Users were asked to rate their attention to the TTA on a four-level ordinal scale of 'None', 'A little', 'A considerable amount', and 'A large amount'. Users who selected any response other than 'None' were directed towards a section with more detailed questions about specific TTA statements.

We created a database of 18 TTA statements (Table 4.1) drawn from a larger database of statements provided by Avalanche Canada. The 18 statements selected covered a variety of snow conditions, terrain features, or behaviors participants should be mindful of while recreating in avalanche terrain. We also ensured the statements represented a mix of communication styles including direct recommendations for actions, mindsets to adopt while traveling, or simply bringing attention to certain key features ('statement type'). For each statement, the research team created a second statement that altered the original statement to vary the amount of jargon in the statement or add additional explanatory details about condition described in the statement. Additional details included the impacts of a condition or information on how to identify a feature into the statement. The end result was a database of 36 statements divided across four treatments: 'more jargon', 'less jargon', 'no explanation', and 'added explanation'. This structure allowed us to compare the impact of the statement treatment while controlling for the subject of the statement.

Table 4.1. Travel and terrain advice statements used

ID	Statement 1	Statement 2	Modification Treatment	Statement Type	Questions
1	Investigate the bond of the recent snow before committing to your line.	Check how well the recent snow sticks to the old snow surface before committing to your line.	Jargon	Action	Understanding, usefulness
2	Minimize exposure to steep, sun exposed slopes, especially when the solar radiation is strong.	Spend as little time as possible on or under steep, sun exposed slopes, especially when the sun feels strong.	Jargon	Action	Understanding, usefulness
3	Avoid lee and cross-loaded slopes at and above treeline.	Avoid slopes where blowing snow tends to deposit at and above treeline.	Jargon	Action	Understanding, recognition, usefulness
4	Choose gentle slopes without exposure to overhead hazard.	Choose gentle slopes without steep terrain above.	Jargon	Action	Understanding, recognition, usefulness
5	In areas where deep persistent slabs may exist, avoid shallow or variable depth snowpack areas.	In areas where deep persistent slabs may exist, avoid slopes that have areas where the snowpack is thinner.	Jargon	Action	Understanding, recognition, usefulness
6	Avoid freshly wind loaded features, especially near ridge crests, roll-overs and in steep terrain.	Avoid areas where blowing snow tends to deposit, especially near ridge crests, roll-overs and in steep terrain.	Jargon	Action	Understanding, recognition, usefulness
7	Watch for areas of hard wind slab on alpine features.	Watch for wind slabs in open areas at treeline and above.	Jargon	Attitude	Understanding, recognition, usefulness
8	Watch for areas of hard wind slab on alpine features.	Watch for areas of hard wind slab on alpine features. A good indicator is when travel suddenly gets easier because you do not sink in as much.	Explanation	Attitude	Understanding, recognition, usefulness
9	Be aware of the potential for remote triggering very large avalanches.	Be aware of the potential for triggering very large avalanches from flat areas that are typically not threatened by avalanches.	Jargon	Attitude	Understanding, usefulness
10	Use extra caution around cornices: they are large, fragile and can trigger slabs on slopes below	Use extra caution around cornices: these overhanging drifts of snow along ridge lines are large, fragile and can trigger slabs on slopes below.	Explanation	Attitude	Understanding, usefulness

11	Use caution when approaching steep and rocky terrain.	Use caution when approaching steep and rocky terrain where even small avalanches might have severe consequences.	Explanation	Attitude	Understanding, usefulness
12	Remember that in the spring strong solar radiation and warm temperatures can weaken the snow in a matter of minutes.	Remember that in the spring strong solar radiation and warm temperatures can weaken the snow in a matter of minutes and make avalanche more likely.	Explanation	Attitude	Usefulness
13	Watch out for changes in the weather and snow conditions.	Watch out for changes in the weather and snow conditions because they may increase avalanche hazard as the day progresses.	Explanation	Attitude	Understanding, usefulness
14	Firm cornices can pull back into flat terrain at ridgetop if they fail.	Firm cornices can pull back into flat terrain at ridgetop if they fail. Some clear signs that you are on solid ground include the presence of trees, rocks.	Explanation	Fact	Understanding, usefulness
15	Recent new snow may be hiding windslabs that were easily visible before the snow fell.	Recent new snow may be hiding windslabs that were easily visible before the snow fell making it more difficult to recognize and avoid the avalanche problem.	Explanation	Fact	Usefulness
16	When a thick melt-freeze surface crust is present, avalanche activity is unlikely.	A thick layer (15 cm or more) of frozen snow on the surface is a good sign that avalanches are unlikely.	Jargon	Fact	Understanding, recognition, usefulness
17	The trees are currently not a safe-haven .	Staying in the trees is currently not a good strategy for avoiding avalanches .	Jargon	Fact	Understanding, usefulness
18	If triggered, storm slabs in-motion may step down to deeper layers and result in very large avalanches.	If triggered, small storm slabs may trigger deeper layers and cause very large avalanches.	Jargon	Fact	Understanding, usefulness

Each participant was shown three TTA statements drawn semi-randomly from the database of 18 paired statements. Each participant saw a combination of original and modified statements, and participants did not see the original and modified versions of the same statement.

To comprehensively capture participants' perspective of the statements, we asked participants to rate each of the presented statements with respect to three different aspects. (Figure 4.1). First, if the TTA included a key phrase (e.g., 'minimize exposure', 'hard wind slab', 'thick melt-freeze surface crust'), the phrase was highlighted and participants were asked how easy it was to understand the phrases on a six-level scale including 'Very difficult', 'Difficult', 'Somewhat difficult', 'Somewhat easy', 'Easy', and 'Very easy'. All but two TTA statements included this question. Second, if the key phrase described a snow condition or terrain feature that users need to recognize in the field to apply the statement meaningfully, participants were asked how confident they were about recognizing the highlighted condition in the field on a five-level scale with response options including: 'not at all confident', 'somewhat confident', 'fairly confident', 'very confident', and 'extremely confident'. In total, this question was only included with six pairs of TTA statements. Finally, for all statements, participants were asked how useful they thought the statement was overall for their avalanche risk management practices, with five options including: 'Not at all useful', 'Somewhat useful', 'Fairly useful', 'Very useful', and 'Extremely useful'. The aim of this three-question setup was to provide deeper insight on why TTA statements are considered useful (or not) and how that perspective is affected by our statement alterations.

TRAVEL ADVICE STATEMENT 2

Watch for areas of **hard wind slab** on alpine features. A good indicator is when travel suddenly gets easier because you do not sink in as much.

- **How easy or difficult do you find the highlighted condition description to understand?**
Please select one of the following options.
 - Very difficult
 - Difficult
 - Somewhat difficult
 - Somewhat easy
 - Easy
 - Very easy

- **How confident are you in your ability to recognize this condition in the field?**
Please select one of the following options.
 - Not at all confident
 - Somewhat confident
 - Fairly confident
 - Very confident
 - Extremely confident

- **Overall, how useful do you find this travel advice statement for your decision-making in avalanche terrain?**
Please select one of the following options.
 - Not at all useful
 - Somewhat useful
 - Fairly useful
 - Very useful
 - Extremely useful

Figure 4.1. Screen shot of survey question for example statement

We included additional background questions so that we could contextualize and identify patterns among respondents. We drew from questions included in Finn’s (2020) survey and included questions about participants’ primary modes of winter recreating in the backcountry, how many years and days per year of experience they had, and their bulletin user type as described by St. Clair (2019). Further questions collected basic sociodemographic items including self-identified gender, age, education level, location of residence. Additional sections included to address additional research questions are described in separate manuscripts.

The survey was developed during the early part of the 2019/20 winter season and extensively tested in February and March 2020 prior to release. Survey testing began with an initial round of testers with moderate to high levels of winter backcountry recreation experience and avalanche industry experts. A second round of testing included users from

novice to expert participants. The survey was also reviewed and approved by the Office for Research Ethics of Simon Fraser University (SFU ethics approval 2020s0074).

4.2.2. Recruitment and Survey Deployment

The primary target audience for our survey was North American avalanche bulletin users, which we recruited in a variety of ways. The foundation of our recruitment were 3047 bulletin users who participated in previous avalanche bulletin surveys conducted by our research program and indicated that they were interested in participating in future studies. The survey was officially launched on March 23, 2020 by sending invitation emails to 300 individuals from this existing panel of prospective participants. This soft launch allowed us to monitor the initial responses and address any survey issues if necessary. However, the survey worked as designed and no modifications were required. On March 26, 2020, we sent invitation emails to the rest of our panel of prospective participants (2747 individuals) and between March 26 and April 1, 2020 the survey was also actively promoted by our partnering avalanche warning services (Avalanche Canada, Parks Canada, Colorado Avalanche Information Centre, Northwest Avalanche Center). Each of these warning services helped us recruit participants by including a banner on their bulletin website and promoting the survey through their social media channels. We also advertised our study by posting on various social media sites popular among winter backcountry users, such as *South Coast Touring* and *Backcountry YYC* on Facebook, and by reaching out to community leaders to distribute the survey among their followers.

The survey sample for the present analysis was drawn on May 31, 2020, after which no additional surveys were included in analysis. At the close of the survey, 6789 individuals had visited our survey and 3668 (55.3%) completed it. The vast majority of the dropouts (1829, 27.6%) did not continue after looking at the first page of the survey that described the objective of the study and structure of the survey. The dropout rate for individual survey pages was 1% or less except the page that introduced the route-ranking task (57, 3.4%). Of the individuals who completed the survey, 1600 (44.6%) were participants of previous survey studies of our research group who received an invitation email. Other substantial recruitment sources included announcements on avalanche bulletin websites (17.5% of participants who completed survey), social media posts by collaborating avalanche warning services (9.2%), and other posts in social media groups (e.g., Facebook, Instagram) focused on winter backcountry recreation (21.5%).

4.2.3. Data Analysis

Our analysis approach started with the use of standard descriptive statistics to describe the nature of the analysis dataset and explore the relationships between different variables. We used a standard ordinal regression model to evaluate how much attention users paid to the TTA in general, but since each of our participants evaluated multiple statements, we employed three ordinal mixed effects regression models to explore how participants rated their understanding of key phrases highlighted in the statements, how confident they felt recognizing those conditions in the field, and how useful they found the statements overall. Mixed effects models are a type of regression model that accounts for correlations that emerge from repeated measure designs or nested data structures (Harrison et al., 2018; Zuur et al., 2009). To accommodate these data structures, mixed effect models include both fixed and random effects in the regression equations. The fixed effects, which are equivalent to the intercept and slope estimates in traditional regression models, capture the relationship between the predictor and response variables for the entire dataset. While traditional regression models assign the remaining unexplained variance in the data (i.e., randomness) entirely to the global error term, mixed-effect models partition the unexplained variance that originates from groupings within the dataset into random effects. Thus, random effects highlight how groups within the dataset deviate from the overall pattern described by the fixed effects included in the model. While there is some judgment involved in deciding what predictors are included in the model as a fixed or random effect, it is generally the grouping variables that are not explicitly of interest that enter the analysis as random effects. In our analysis, this includes the participants as they assessed three TTA statements each, as well as the 18 pairs of original and modified versions of the statements.

We included the predictor variables of ‘modification type’ (original, less jargon, or more explanation) and ‘avalanche training’ (none, introductory, advanced, professional) as fixed effects in our regression analysis by default. Since we were interested in better understanding how the different statement modifications (less jargon, additional explanation) affect the responses of participants with different levels of training, we also included this interaction in the models for all three questions. We also by default included ‘statement type’, ‘years of experience’, ‘days per winter in backcountry’, ‘bulletin user type’, and ‘country of residence’ in the models for testing but removed them if their parameter estimates did not reveal a significant spread (i.e., p-values < 0.050). In addition, we took

the magnitude of the observed differences into account for deciding whether an observed difference was meaningful.

We conducted our entire analysis in R (Version 3.6.1; R Core Team, 2019). We used the `clmm` function of the 'ordinal' package (Christensen, 2019) to estimate our ordinal mixed effects models and the `pplr` function of the MASS package (Venables & Ripley 2002) to estimate our standard ordinal logistic regression models. Since parameter estimates of ordinal logistic regression models are notoriously difficult to interpret directly, we used effects plots that show the probabilities for selecting specific levels of the response variable to illustrate the results. We used the `ref_grid` and `emmeans` functions of the `emmeans` package (Lenth, 2019) to both estimate these probabilities and conduct post-hoc pairwise comparisons to explicitly test for significant differences between different combinations of predictor variables. To counteract the issue of Type I error inflation from multiple comparisons, we calculated Holm-corrected p-values. When reading about the results and examining the effects plots, it is important to remember that the shown probabilities are calculated for a specific combination of predictor values and cut point in the response variable to illustrate a particular pattern. Hence it is more important to look at the significance of the differences in these probabilities than their absolute values as they change depending on the chosen predictor values.

4.3. Results

4.3.1. Participant Demographics

To ensure meaningful results, we only included participants in our analysis dataset who completed all pages of the survey, whose reported residence was in Canada or the United States, who were over the age of 20, and whose choices for primary activity and avalanche awareness training aligned with the predefined options. In addition, we excluded participants who took less than 10 minutes or more than 2.5 hours to complete the survey, participants who did not respond to the question about how much attention they pay to the travel and terrain advice (TTA), and who did not include information on their years of experience or how often they visit the backcountry. We also disqualified participants who spent less than 30 seconds or more than 10 minutes viewing the travel advice page to remove participants who just clicked through it or got interrupted while completing the page. The final analysis dataset consisted of 3,185 participants, which

represented 86.8% of the 3668 individuals who completed the survey. However, not every participant responded to three questions so the datasets for the models rating individual statements vary.

Of the 3,185 participants, 76.7% identified as male (2,481 participants), 36.9% (1,174 participants) were between 25 and 34 years old, 79.4% had a university-or-higher education (2,526 participants) and 82.1% (2,617 participants) had completed at least an introductory avalanche safety training course. Backcountry skiers represented the highest proportion of recreationists in the study with 78.1% of the sample (2,487 participants) identifying backcountry skiing as their primary backcountry winter activity. Additional types of recreationists present in our sample included out-of-bounds skiers (7.5%, 239 participants), snowshoers (5.7%, 183 participants), and snowmobilers (5.1%, 162 participants), and less than two percent ice climbers and snowmobile-accessed backcountry skiers. The largest group of participants (31.0%, 982 participants) were relatively new to their sport, with between 2 and 5 years of experience. However, the second largest group of participants (25.0%, 791 participants) had over 20 years of backcountry experience. Bulletin user types ‘D—Distinguish and Integrate Avalanche Problem Conditions’ and ‘E—Extends Analysis’ made up 75.5% of participants (2,402). While we observed a significant correlation between avalanche training and bulletin user type (Spearman rank correlation: 0.407; p-value < 0.0001), the analysis sample included a range of training levels at each bulletin user type (Table 4.1). Finally, 69.4% (2,209) of responses were from residents of the USA.

Table 4.2. Distribution of avalanche training levels with respect to self-identified bulletin user type. Percentage values are row percentages except in the total column where they represent column percentages.

Bulletin user type	No training		Introductory level		Advanced level		Professional level		Total	
Type A	11	(73%)	4	(27%)	0	(0%)	0	(0%)	15	(1%)
Type B	87	(53%)	67	(41%)	8	(5%)	3	(2%)	165	(5%)
Type C	171	(35%)	241	(49%)	54	(11%)	24	(5%)	490	(16%)
Type D	122	(13%)	531	(58%)	176	(19%)	80	(9%)	909	(29%)
Type E	153	(11%)	591	(41%)	351	(25%)	339	(24%)	1434	(46%)
Type F ^a	0	(0%)	0	(0%)	0	(0%)	87	(100%)	87	(3%)
Total	544	(18%)	1434	(46%)	589	(19%)	533	(17%)	3100	(100%)

^a Type F was only available for survey participants who stated that they have completed professional level avalanche safety training.

4.3.2. Attention to Travel and Terrain Advice

Of the 3,100 participants included in the analysis dataset, 51.5% (1598) stated that they pay a large amount of attention to the TTA section of the avalanche bulletin (scale: ‘none’, ‘a little’, ‘a considerable amount’, and ‘a large amount’). Thirty-nine percent (1210) respondents stated that they pay a considerable amount of attention to the TTA, 8.8% (273) indicated that they only pay a little bit of attention to the TTA, and less than 1% (19) responded that they pay no attention to the TTA.

Our ordinal regression model for the probability of participants’ response selections revealed four significant predictors, which included the bulletin user type of the participant, the level of avalanche training they had completed, how many days they spend per year engaged in their preferred backcountry activity, and their country of residence (Table 4.2).

Table 4.3. Parameter estimates of regression model examining the attention paid to the TTA statements

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
<i>Predictor</i>	<i>Level</i>				
Bulletin user type	A	-	-	-	<0.0001
	B	2.1061	0.5406	0.0001	
	C	2.0720	0.5273	0.0001	
	D	2.6852	0.5272	< 0.0001	
	E	2.4905	0.5263	< 0.0001	
	F	2.1266	0.5730	0.0002	
Avalanche training	None	-	-	-	<0.0001
	Introductory	0.1195	0.1039	0.2502	
	Advanced	-0.0872	0.1260	0.4888	
	Professional	-0.5338	0.1399	0.0001	
Days in backcountry/winter	Linear trend	-0.1589	0.0382	< 0.0001	<0.0001
Country of residence	Canada	-	-	-	<0.0001
	USA	0.3320	0.0780	< 0.0001	

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Intercept	None Little	-3.1464	0.5661	< 0.0001	
	Little Considerable	-0.2784	0.5286	0.5984	
	Considerable Large	2.0170	0.5305	0.0001	

Participants who self-identified as bulletin user Type D were the most likely participants to pay attention to the TTA statements. The left panel of Figure 4.2 illustrates this effect by showing the estimated marginal probabilities selecting ‘A large amount’ for the different bulletin user types with avalanche training set at introductory, an average number of days in the backcountry per winter, and Canada as the country of residence. In this setting, the model estimates 57.7%⁴ chance that Type D users would respond that they pay ‘A Large amount’ of attention to the advice, followed by Type E users at 52.9%, though the difference is not significant ($p = 0.1079$). However, Type C and B users were significantly less likely to indicate that they pay a large amount of attention to the TTA than Type D users (42.5% and 43.3%, both $p < 0.0001$). The estimated probability for Type F users was at a similar level (43.8%), but the difference to Type E did not turn out to be significant due to the smaller number of survey participants who self-identified as Type F. Type A users were the least likely to indicate that they pay a large amount of attention to the travel and travel advice, and the difference was significantly lower than Type B [‘Base decision on danger rating’] users (8.5% vs. 43.3%, $p < 0.0001$).

⁴ Marginal probability estimates for the attention model were calculated using the following parameter default levels: Bulletin user type: D; Avalanche training: Introductory; Days in backcountry/winter: 11-20 days; and Country of residence: Canada.

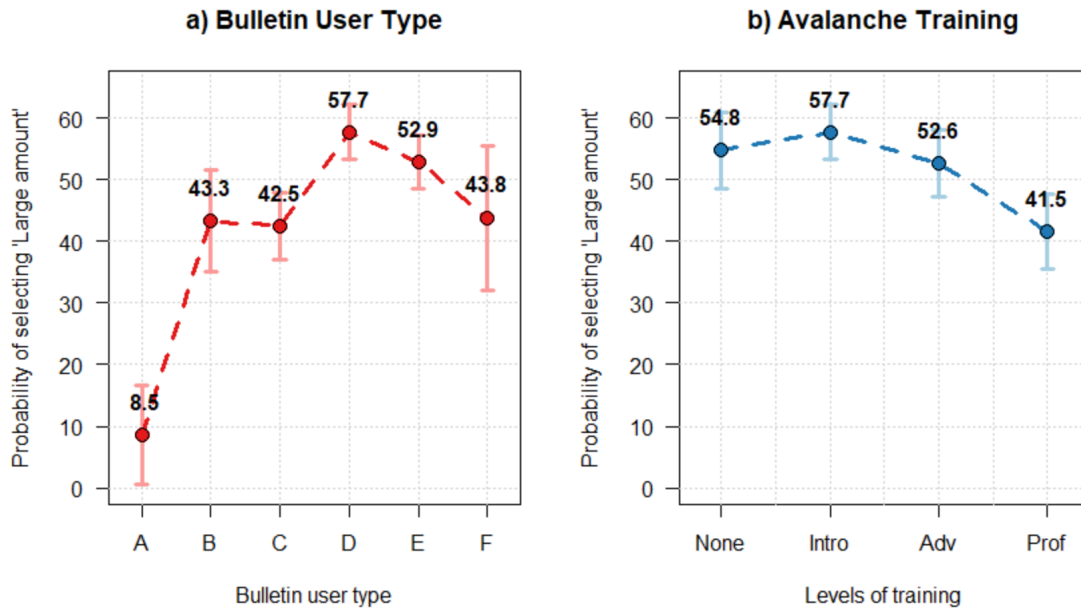


Figure 4.2. Estimated marginal probabilities for selecting 'A large amount' for a) different bulletin user types, and b) different avalanche training levels. Error bars represent 95% confidence intervals for probabilities calculated from the subsample for the particular parameter level.

In addition to the bulletin user type, the level of avalanche training a participant had completed was also a significant predictor of how much attention they pay to the TTA statements (Figure 4.2). Participants with professional level training were significantly less likely to report that they pay 'A large amount' of attention to the TTA statements (41.5%) than participants with advanced level training (52.6%, $p = 0.0007$), which was no different than participants with introductory training (57.7%, $p = 0.1014$) or no training (54.8%, $p = 0.5575$).

Another predictor of participants' attention to the TTA included the amount of time they spend in the backcountry during a typical winter, which we interpreted as their level of engagement in the activity. Participants who spend more days in the backcountry are more likely to indicate lower levels of attention to the TTA, while participants who spend fewer days in the backcountry are likely to state that they pay more attention to the TTA. Finally, participants residing in the US were more likely to indicate higher levels of attention to the TTA than Canadian residents.

4.3.3. Understanding of Key Phrase

Participants provided a total of 8079 understanding ratings, and overall, they found the key phrases highlighted within the travel and terrain statements easy to understand, with 70.7 % of the ratings at “easy” to “very easy” to understand (scale: ‘very difficult’, ‘difficult’, ‘somewhat difficult’, ‘somewhat easy’, ‘easy’, and ‘very easy’). We modeled the ratings of the key elements as an ordinal, mixed effects regression model with participant ID, statement ID, and statement version ID as random effects. The model included five significant predictors and one significant interaction (Table 4.3).

Table 4.4. Parameter estimates of regression model examining the ease of understanding of the TTA statements

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
<i>Predictor</i>	<i>Level</i>				
Bulletin user type	A	-	-	-	<0.0001
	B	0.8762	0.4984	0.0787	
	C	1.0841	0.4862	0.0258	
	D	1.533	0.4859	0.0016	
	E	1.7506	0.4853	0.0003	
	F	1.9576	0.5293	0.0002	
Avalanche training	None	-	-	-	0.0287
	Introductory	0.0353	0.1266	0.7801	
	Advanced	0.3480	0.1527	0.0226	
	Professional	0.6406	0.1665	0.0001	
Days in backcountry/winter	Linear trend	0.1485	0.0352	< 0.0001	<0.0001
Years of experience	First year	-	-	-	0.0065
	2-5	0.4768	0.1593	0.0028	
	6-10	0.5161	0.1681	0.0021	
	11-20	0.5028	0.1703	0.0031	
	20+	0.6291	0.1677	0.0002	
Attention to travel advice	Linear trend	0.2984	0.0501	< 0.0001	<0.0001
Statement treatment	More jargon	-	-	-	0.1548
	Less jargon	0.4773	0.2015	0.0179	
	No added explanation	-0.2855	0.3775	0.4494	
	More explanation	0.3354	0.3735	0.3692	

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Interaction effects					
<i>Predictor (level)</i>	<i>Predictor (level)</i>				
Statement treatment ^a	Avalanche Training				0.0065
Less Jargon	None	-	-	-	
	Introductory	-0.0161	0.1545	0.9170	
	Advanced	-0.3940	0.1852	0.0334	
	Professional	-0.5632	0.1907	0.0031	
No added explanation	None	-	-	-	
	Introductory	0.1246	0.2058	0.5450	
	Advanced	-0.1631	0.2474	0.5099	
	Professional	-0.0765	0.2606	0.7691	
More Explanation	None	-	-	-	
	Introductory	-0.2080	0.1978	0.2930	
	Advanced	-0.5453	0.2331	0.0193	
	Professional	-0.6979	0.2449	0.0044	
Threshold		Parameter Estimate	Standard Error	p-value	
VDiff Diff		-2.6244	0.57	< 0.0001	
Diff SWDiff		-0.7572	0.557	0.1740	
SWDiff SWEasy		0.7819	0.5555	0.1593	
SWEasy Easy		2.2755	0.556	< 0.0001	
Easy VEasy		4.4379	0.5586	< 0.0001	
Random Effects	Number of Groups	Variance	Standard Deviation		
Participant ID	3080	1.5285	1.2363		
Version Code : Statement ID	32	0.1274	0.357		
Statement ID	16	0.2559	0.5059		

^a Base level is 'more jargon' statement.

The bulletin user type of participants was the single largest predictor of how participants would rate their understanding of the TTA statement based on the spread of the parameter estimates (0-1.957). User with more advanced bulletin users tended to find the key phrases easier to understand. According to the model results, users of Types E and F had an 86.2% and 88.4% chance of rating the understandability of the key phrases

as either 'easy' or 'very easy', which were not significantly different from each other ($p = 0.8319$). However, users of type D were significantly less likely to find the key phrases at least 'easy' to understand than type 'E' (83.4%, $p = 0.0436$) but significantly more than type 'C' (76.2%, $p = 0.0009$). User types 'A' and 'B' was the least likely to find the phrases easy to understand (51.9%, 72.2%, $p = 0.4062$).

The statement treatments, that is, the presence or absence of jargon and an additional explanation, had a significant main effect on how participants rated their understanding of the highlighted phrases shown in in the TTA statements. However, this effect is modulated by the interaction effect with the level of avalanche training a participant received (Figure 4.3). Professionals and recreationists with advanced level training were overall the most likely to say they find the key phrases 'easy' or 'very easy' to understand, and it did not differ significantly between the version with less jargon or the version with more (Advanced: 82.4%⁵ vs. 81.2% $p = 0.6780$, Professional: 84.1.6% v. 85.3%, $p = 0.6761$) However, among participants with no training or introductory recreational training, it was significantly more likely that they would find the statements easy to understand if presented with a version that had less jargon than a version with more (No Training: 83.1% v. 75.3%, $p = 0.0230$, Introductory Training: 83.8% vs. 73.9%, $p = 0.0107$). Crucially, the post-hoc pairwise comparisons show that with the versions modified to include less jargon, there is no significant difference in the ease of understanding ratings across the different training levels. In other words, all training levels reported the same ease of understanding for the less jargony statements. In contrast, there were no significant effects of the added explanation at any of the training levels.

⁵ Marginal probability estimates for the ease of understanding model were calculated using the following parameter default levels: Bulletin user type: D; Avalanche training: Introductory; Year of experience in the backcountry: 6-10 years; Days in backcountry/winter: 11-20 days; and Attention to travel advice: Considerable amount.

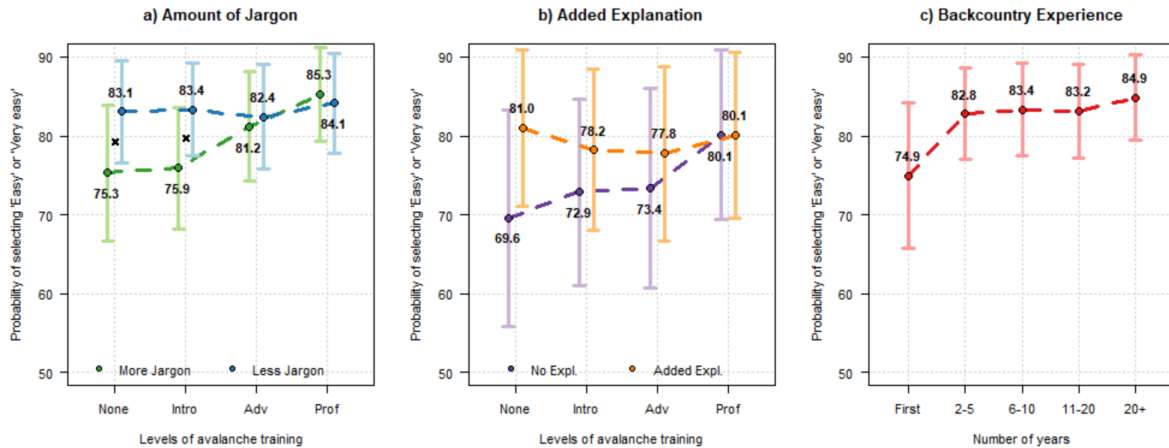


Figure 4.3. Estimated marginal probabilities for selecting ‘Easy’ or ‘Very Easy’ for understandability of statement as function of a) the interaction effect of avalanche training and amount of jargon, b) the interaction effect of avalanche training and added explanation, and c) the main effect of years of backcountry experience. Error bars represent 95% confidence intervals for probabilities calculated from the subsample for the particular parameter level. Significant post-hoc pairwise comparisons are indicated with asterisks (p -values < 0.01) or crosses ($0.01 \leq p$ -values < 0.05).

The number of years of experience a participant had in the backcountry was also a predictor of the chance of them finding the statements at least easy to understand (Fig. 4.3). Participants in their first year in the backcountry were significantly less likely to find the statements at least easy to understand than participants in the next cohort of 2-5 years (74.9% v. 82.8%, $p = 0.0374$). The other cohorts for backcountry experience responded similarly to the 2-5 years group and there were no significant differences between them (6-10 years: 83.4%, $p = 0.9832$, 11-20 years: 83.2%, $p = 0.9998$, 20+ years: 84.9%, $p = 0.5418$). Estimating the same model using linear and quadratic contrasts for experience instead of dummy coding confirms the significance of the curved trendline (i.e., flattening out at higher levels).

The number of days participants spent in the backcountry each winter was also included as a predictor, and the likelihood participant found the phrase easy to understand increased significantly with more time spent in the backcountry. The final significant predictor in the model was the how much attention participants generally pay to the TTA advice. Participants who pay higher amounts of attention to the TTA also tended to find the statements easier to understand.

There was greater variance associated with individual participants than with the statements used. This indicates that which specific statements participant saw did not have a large impact on their responses when compared to the nature of the individual, and it gives us confidence that the specific selection of statements used did not unduly impact our results. Additionally, statement type did not emerge as a significant predictor of participants' understanding and was therefore removed from the model during the development of the model.

4.3.4. Recognition Confidence of Key Features in the Field

Out of the eighteen pairs of statements included in the analysis, seven of them referenced a specific terrain feature or snow condition resulting in 3,442 ratings of confidence recognizing a condition in the field resulting in a dataset that is less than half the size of the dataset of the previous analysis. Approximately one third of participants who saw statements in this category reported that they would be fairly confident recognizing them in the field, and another third indicated that they would be very confident recognizing them in the field (scale: 'not at all confident', 'somewhat confident', 'fairly confident', 'very confident', and 'extremely confident'). To understand what factors contribute to the rating a statement received, we used an ordinal mixed regression model with participant ID, statement ID and version code as random effects. The model included four significant main effects and one interaction effect (Table 4.5).

Table 4.5. Parameter estimates of regression model examining participants confidence in recognizing the terrain or snowpack features described in the TTA statements.

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
<i>Predictor</i>	<i>Level</i>				
Bulletin user type	A	-	-	-	<0.0001
	B	1.0188	0.6799	0.1340	
	C	1.3794	0.6640	0.0378	
	D	2.0315	0.6633	0.0022	
	E	2.4911	0.6635	0.0002	
	F	2.8986	0.7183	0.0001	

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Avalanche training	None	-	-	-	<0.0001
	Introductory	-0.0306	0.1696	0.8570	
	Advanced	0.3938	0.2009	0.0500	
	Professional	1.4830	0.2270	< 0.0001	
Days in backcountry/winter	Linear trend				<0.0001
		0.4278	0.0468	< 0.0001	
Years of experience	First year	-	-	-	<0.0001
	2-5	0.8266	0.2091	0.0001	
	6-10	0.9923	0.2199	< 0.0001	
	11-20	1.3580	0.2254	< 0.0001	
	20+	1.4503	0.2213	< 0.0001	
Statement	More jargon	-	-	-	0.2968
	Less jargon	0.4059	0.2862	0.1561	
	No added explanation	-1.0428	0.9629	0.2788	
	More explanation	0.6499	0.9769	0.5058	
Interaction effects					
<i>Predictor (level)</i>	<i>Predictor (level)</i>				
Statement treatment ^a	Avalanche Training				0.0006
Less Jargon	None	-	-	-	
	Introductory	0.2274	0.2216	0.3048	
	Advanced	-0.1481	0.2584	0.5665	
	Professional	-0.6401	0.2734	0.0192	
No added explanation	None	-	-	-	
	Introductory	0.7493	0.4106	0.0680	
	Advanced	1.1975	0.4868	0.0139	
	Professional	1.6735	0.6564	0.0108	
More Explanation	None	-	-	-	
	Introductory	-0.1240	0.4479	0.7818	
	Advanced	-0.3439	0.5126	0.5023	
	Professional	-0.3642	0.5103	0.4753	
Threshold		Parameter Estimate	Standard Error	p-value	
Not at all Somewhat		0.3686	0.7791	0.6361	

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Somewhat Fairly		2.8416	0.781	0.0003	
Fairly Very		5.2495	0.7912	< 0.0001	
Very Extremely		7.8526	0.8069	< 0.0001	
Random Effects	Number of groups	Variance	Standard Deviation		
Participant ID	2448	1.1978	1.0945		
Version Code :	14				
Statement ID		0.1383	0.3719		
Statement ID	7	0.5567	0.7461		

^aBase level is 'more jargon' statement.

As with the model for the ratings of how easy it was for participants to understand the key phrases in the statements, bulletin user type of the participants was significant predictor of how confident they were in recognizing the subject in the field. Bulletin user Type F participants were the most confident at recognizing specific conditions in the field, with a 62.9% chance of indicating their confidence in recognizing the highlighted condition in the field as 'very' or 'extremely' confident. Confidence decreased with less advanced bulletin user types, though Type E (53.0%) was not significantly different than Type F ($p = 0.4849$). However, Type D (41.6%) was significantly less likely to have confidence identifying features in the field than Type E ($p < 0.0001$) but significantly higher than Type C (27.1%, $p < 0.0001$). Type C participants did not differ significantly from Type Bs (20.8%), which did not differ significantly from Type A (12.0%, $p = 0.3511$, $p=0.3014$).

The level of avalanche training a participant completed was also a significant predictor in the model with higher levels of training associated with higher chances of being 'very' or 'extremely' confident in recognizing conditions in the field. However, there was no significant main effect for the type of statement on how participants rated their recognition confidence. As in the model for understanding, a more complex pattern appears in the interaction of these predictors for participants with lower levels of training.

Participants with introductory level training only had a 27.4%⁶ chance of being ‘very’ or ‘extremely’ confident of identifying the feature described in the statement if they saw a statement with higher levels of jargon, but it rose to 41.6% when they saw the version of the statement with lower levels of jargon ($p=0.0115$). There were no other significant effects of the statement modifications for any levels of training.

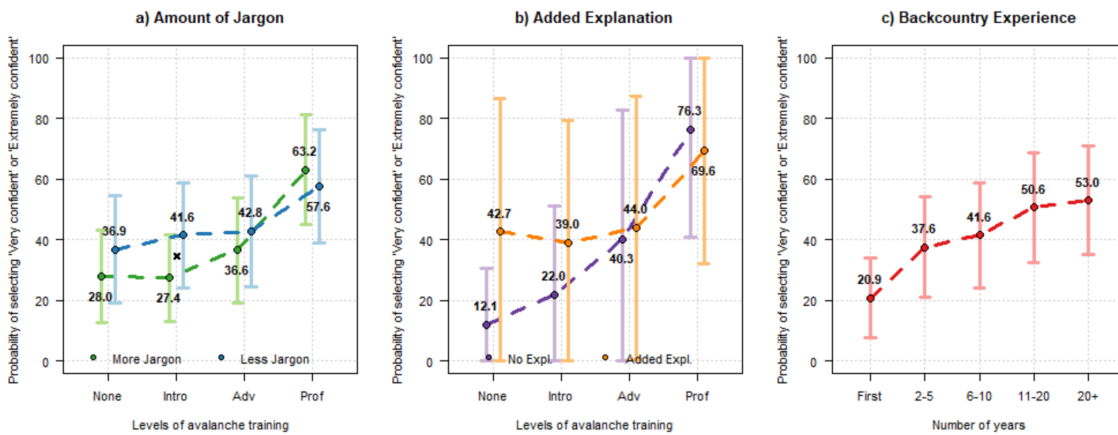


Figure 4.4. Estimated marginal probabilities for selecting ‘Very confident’ or ‘Extremely confident’ for recognizing condition in the field as function of a) the interaction effect of avalanche training and amount of jargon, b) the interaction effect of avalanche training and added explanation, and c) the main effect of years of backcountry experience. Error bars represent 95% confidence intervals for probabilities calculated from the subsample for the particular parameter level. Significant post-hoc pairwise comparisons are indicated with asterisks (p -values < 0.01) or crosses ($0.01 \leq p$ -values < 0.05).

Another predictor of how likely participants were to express that they were ‘very’ or ‘extremely’ confident in their ability to recognize a condition in the field was the number of years of experience they had (Figure 4.4). Overall, participants with more years of experience were more likely to express that they were at least ‘very’ confident. Participants in their first year were the least likely to report that they were at least ‘very’ confident, and the percent chance of that response was significantly lower than the next cohort of 2-5 years experience (20.9% vs. 37.6%, $p = 0.0005$). Unlike the question about understanding however, there remains further changes in confidence with additional years, with

⁶ Marginal probability estimates for the confidence in recognition model were calculated using the following parameter default levels: Bulletin user type: D; Avalanche training: Introductory; Year of experience in the backcountry: 6-10 years; Days in backcountry/winter: 11-20 days; and Attention to travel advice: Considerable amount.

participants who have 6-10 experience showing a 41.6% chance of responding that they are at least 'very' confident in their ability to recognize a condition in the field, which is significantly lower than participants who have 11-20 years of experience (50.6%, $p = 0.0194$).

A final predictor that increased the likelihood of participants being confident in their ability to recognize a highlighted condition in the field was how many days they spent in the backcountry each winter. As expected, more days tended to increase the likelihood that participants would have confidence in recognizing the condition.

There was greater variance associated with individual participants than with the statements used. This indicates that which specific statements participant saw did not have a large impact on their responses when compared to the nature of the individual and gives us confidence that the specific selection of statements used did not unduly impact our results. Additionally, statement type did not emerge as a significant predictor of participants' recognition confidence and was therefore removed from the model during the development of the model.

4.3.5. Overall Usefulness of Travel and Terrain Advice

In total, our dataset for this model consisted of 9196 usefulness ratings. Most participants found the TTA useful, with 49.0% of participants reporting that they found the statements either 'very' or 'extremely' useful (scale: 'not at all useful', 'somewhat useful', 'fairly useful', 'very useful', and 'extremely useful'). As in the other two models examining ratings of individual statements, we built an ordinal mixed regression model with participant ID, statement ID and statement version code as random effects. The model included four significant main effects and one interaction effect. The parameters for the regression are included in Table 4.6.

Table 4.6. Parameter estimates of regression model examining participants usefulness ratings for the TTA statements

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic	
Main effects						
<i>Predictor</i>	<i>Level</i>					
Ease of understanding	Not applicable	-	-	-	<0.0001	
	Very difficult	-5.2255	0.5231	< 0.0001		
	Difficult	-4.1911	0.3910	< 0.0001		
	Somewhat difficult	-2.6355	0.3638	< 0.0001		
	Somewhat easy	-1.3869	0.3572	0.0001		
	Easy	-0.3017	0.3546	0.3949		
	Very easy	0.8931	0.3555	0.0120		
Avalanche training	None	-	-	-	0.0024	
	Introductory	-0.1483	0.1265	0.2412		
	Advanced	-0.1552	0.1489	0.2974		
	Professional	-0.4799	0.1543	0.0019		
Recognition confidence	Not applicable	-	-	-	<0.0001	
	Not at all	-2.0964	0.3175	< 0.0001		
	Somewhat	-0.7085	0.2420	0.0034		
	Fairly	0.0990	0.2290	0.6654		
	Very	0.4176	0.2293	0.0686		
	Extremely	0.7625	0.2461	0.0019		
Attention to travel advice Statement	Linear trend	1.1301	0.0496	< 0.0001	<0.0001	
	More jargon	-	-	-		0.0022
	Less jargon	0.0346	0.1543	0.8224		
	No added explanation	-0.7633	0.2906	0.0086		
	More explanation	-0.4321	0.2854	0.1300		
Interaction effects						
<i>Predictor (level)</i>	<i>Predictor (level)</i>					
Statement treatment ^a	Avalanche Training				0.0456	
Less Jargon	None	-	-	-		
	Introductory	-0.0249	0.1566	0.8738		
	Advanced	0.0451	0.1857	0.8083		
	Professional	-0.0417	0.1893	0.8257		
No added explanation	None					
	Introductory	-0.0599	0.1869	0.7487		
	Advanced	-0.0520	0.2214	0.8144		
	Professional	0.4583	0.2305	0.0468		

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
More Explanation	None	-	-	-	
	Introductory	0.2783	0.1781	0.1182	
	Advanced	0.0038	0.2074	0.9854	
	Professional	0.140867	0.212642	0.5077	
Threshold		Parameter Estimate	Standard Error	p-value	
Not at all Somewhat		-3.3939	0.4192	< 0.0001	
Somewhat Fairly		-0.3203	0.4123	0.4372	
Fairly Very		1.7957	0.4128	< 0.0001	
Very Extremely		4.8271	0.4175	< 0.0001	
Random Effects	Number of groups	Variance	Standard Deviation		
Participant ID	3081	1.5054	1.2269		
Version Code : Statement ID	36	0.0321	0.1792		
Statement ID	18	0.1497	0.3869		

^a Base level is 'more jargon' statement.

Unlike in the other models, the main effect was that participants with higher levels of training tended to have lower ratings for how useful the statements were. Again, we see that this overall main effect masks the pattern that emerges as an interaction between the two predictors (Figure 4.5)⁷. Participants with both 'Introductory' and 'Advanced' level training were significantly more likely to find the statements with added explanation 'very' or 'extremely' useful when compared to the statements without the added explanation (Introductory: 50.1% v. 34.0%, $p < 0.0001$; Advanced, 43.1% v. 34.0%, $p = 0.0439$). No other significant differences among training and the statement treatment emerged.

⁷ Marginal probability estimates for the usefulness model were calculated using the following parameter default levels: Avalanche training: Introductory; Attention to travel advice: Considerable amount, Ease of understanding rating: Somewhat easy; Confidence in recognition rating: Fairly confident.

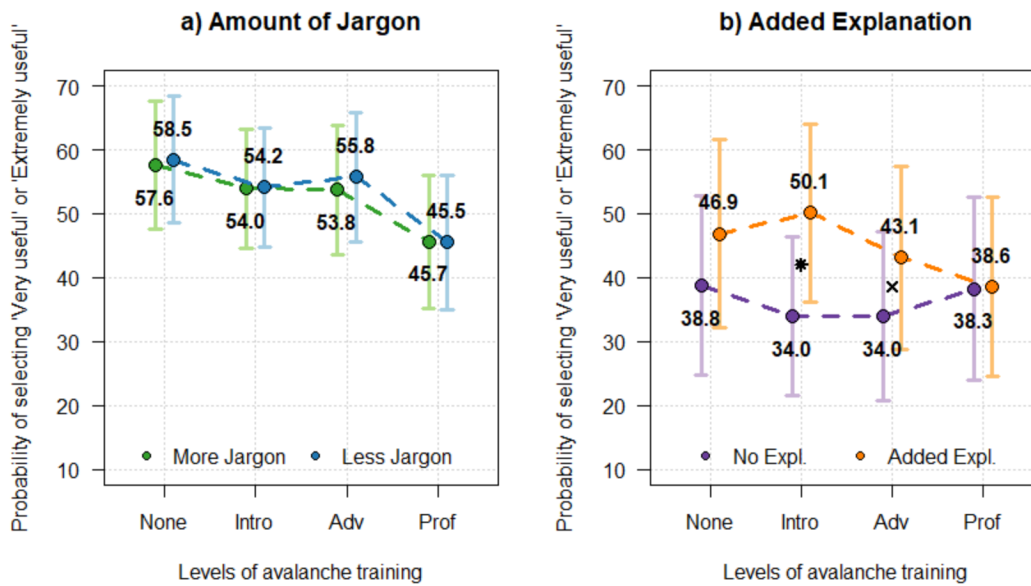


Figure 4.5: Estimated marginal probabilities for selecting ‘Very useful’ or ‘Extremely useful’ for usability of statement as function of a) the interaction effect of avalanche training and amount of jargon, and b) the interaction effect of avalanche training and added explanation. Error bars represent 95% confidence intervals for probabilities calculated from the subsample for the particular parameter level. Significant post-hoc pairwise comparisons are indicated with asterisks (p -values < 0.01) or crosses ($0.01 \leq p$ -values < 0.05).

Importantly, three other predictors emerged in this model. First, how well participants understand the statements emerged as a strong predictor of how useful they find it overall (Figure 4.6). Participants who found a statement ‘very difficult’ or ‘difficult’ to understand had the lowest percent chance of finding the statement ‘very’ or ‘extremely’ useful (2.5% and 6.7%, $p = 0.0252$). However, with every increase in rating of how easy it is to understand the statements the usefulness rating is significantly higher. Participants who rated the advice as ‘somewhat difficult’ have a 25.3% chance of finding the advice ‘very’ or ‘extremely’ useful ($p < 0.0001$), but the percent jumps to 54.2% for participants who found it ‘somewhat easy’ ($p < 0.0001$), and up to 77.8% ($p < 0.0001$) and 92.0% ($p < 0.0001$) for participants who found it ‘easy’ or ‘very easy’ to understand the statements.

Secondly, even while controlling for the above variables, how confident participants are at recognizing a condition in the field is also a significant predictor of how useful they find a statement (Figure 4.6). Participants who were ‘not at all’ confident in their ability to recognize a specific condition in the field only had an 11.6% chance of

finding the statement 'very' or 'extremely' useful, while participants who were 'somewhat confident had a 34.5% chance of the same responses ($p < 0.0001$). This effect continues for higher confidence levels, with the percentage chance of finding the statements 'very' or 'extremely' useful rising to 54.2% ($p < 0.0001$) for participants expressing that they were 'fairly' confident at recognizing a condition in the field, 61.9% ($p = 0.0020$) for those 'very' confident, and 69.7% ($p = 0.0201$) for those 'extremely confident'.

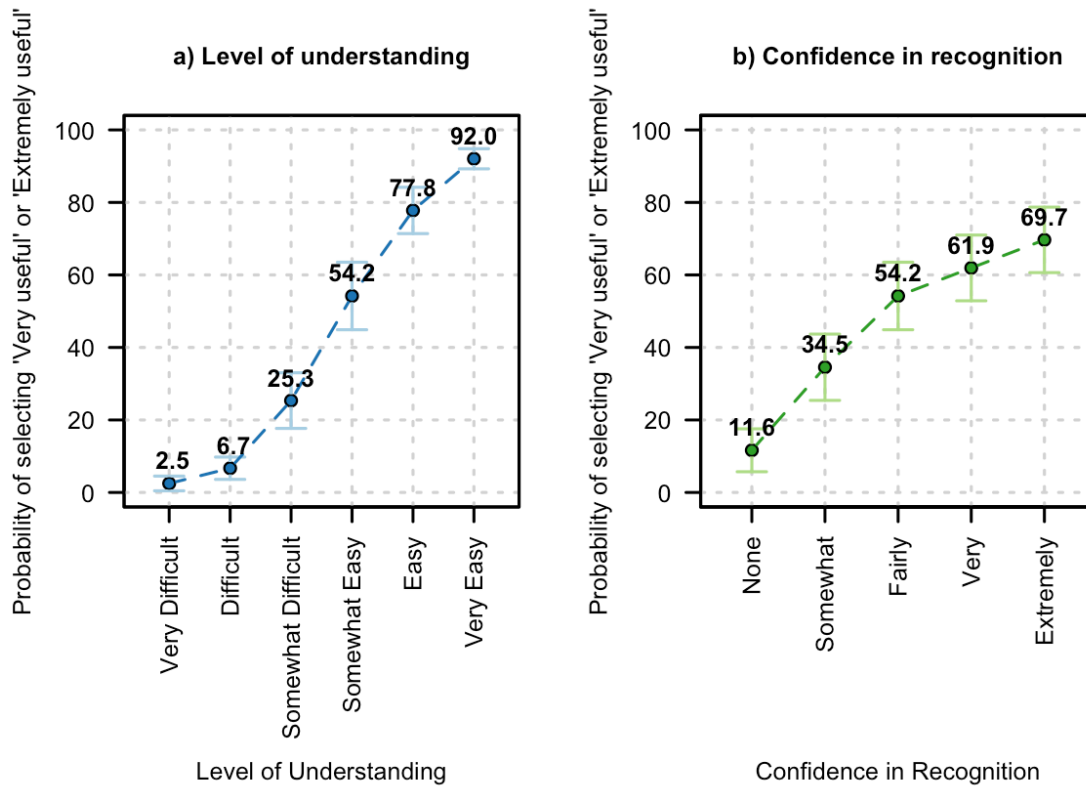


Figure 4.6: Estimated marginal probabilities for selecting 'Very useful' or 'Extremely useful' for usability of statement as function of a) participants' level of understanding, and b) their confidence in recognizing the condition or feature. Error bars represent 95% confidence intervals for probabilities calculated from the subsample for the particular parameter level.

Finally, the amount of attention participants pay to the travel advice in general also is a significant predictor of how useful they find the statements. As the attention increases, the percent chance a statement will be considered useful also increases.

There was greater variance associated with individual participants than with the statements used. This indicates that which specific statements participant saw did not have a large impact on their responses when compared to the nature of the individual and

gives us confidence that the specific selection of statements used did not unduly impact our results. Additionally, statement type did not emerge as a significant predictor of how useful the statements were and was removed from the model during the development of the model.

4.4. Discussion

In this study we examined who is paying attention to the travel and terrain advice (TTA) section of the bulletin, how useful participants find the advice, and if modifications to the advice could make it more useful for participants. We will describe key factors driving the responses to these questions and provide recommendations for avalanche warning services to optimize their TTA in avalanche bulletins.

4.4.1. Who is Paying Attention to the Travel and Terrain Advice?

The TTA section of an avalanche bulletin represents information that can help recreationists develop a risk management plan by guiding them towards appropriate terrain selection based on current avalanche hazard. Understanding who is using this section of the bulletin allows avalanche warning services to identify which users incorporate this advice as part of their risk management process.

Key Patterns among Travel and Terrain Advice Users

Significant patterns in who pays attention to the TTA emerged based on participants' bulletin user type, training, experience in the backcountry, and country of residence. Participants who indicated they are bulletin user Type 'D' reported paying the most attention to the TTA section of the avalanche bulletin, followed by Type 'E'. The remaining types 'B', 'C', and 'F' paid significantly less attention than types 'D' and 'E', and type 'A' paid the least attention by far. In the bulletin user typology, Type 'D' bulletin users are characterized by their use of the location and nature of specific avalanche problems as part of their risk management approach for determining their terrain objectives for the day (St. Clair, 2019; St. Clair et al., under review). It is therefore not surprising, that we see 'Type D' users paying the greatest amount of attention to the TTA, which is the section of the bulletin explicitly targeted towards helping users develop a plan for how to travel through the terrain under the daily avalanche conditions. In contrast, Type 'C' users make their travel decisions by 'opening and closing' avalanche terrain at a larger scale, and so

the drop in attention we observe in this group may be because they do not incorporate specific terrain features, such as those described in the TTA, into their approach to managing avalanche hazard (St. Clair, 2019). The alignment of our results with predictions based on the bulletin user typology show that the TTA section is being incorporated as expected as part of the risk management plan of users who incorporate specific terrain features into their analysis. To support these users, the information contained in the TTA should continue to highlight relevant slope-scale terrain features.

Additionally, after controlling for the bulletin user type, we also see a relationship between the personal experiences of participants and the level of attention they pay to the TTA statements. Both higher levels of avalanche training and more years of experience in the backcountry lead to lower levels of attention to the TTA section of the bulletin. Participants with professional level training are significantly less likely to pay attention to the TTA than participants with lower levels of training, and there is a decreasing linear trend between the years of experience a participant has and their attention to the TTA. This pattern is not surprising, because more advanced users are more likely to already know the information conveyed in the TTA based on their understanding of the avalanche problem information. These relationships demonstrate that it is less trained and less experienced users who are using the TTA advice, which makes it important to ensure that the advice is targeted towards these groups and is useful to them.

Finally, participants residing in the USA indicated higher levels of attention to the TTA than Canadian residents. While the results of our study are unable to provide specific insight on the reasons for this difference, but we hypothesize that it may be related to differences in avalanche bulletin format or outreach efforts. Many USA-based avalanche bulletins integrate TTA statements as part of a prominent “bottom line” section, whereas Canadian avalanche warning services have historically had the TTA advice in the avalanche problem section on a secondary tab of their bulletins. While Canadian bulletins have recently moved the TTA advice to the front page of the bulletin, it is possible that user habits have not caught up with the change. It is also possible that differences in presentation of the TTA statements, such as including explanatory photos in US-based bulletins, may lead to higher use by USA residents. Further study is necessary to properly identify reasons for the difference between user attention to the TTA advice between participants located in Canada versus the USA.

Implications

Our results demonstrate that users who are integrating terrain into their daily planning--but have lower levels of training or experience to support that integration--are the current users of the TTA statements in bulletins. Hence, avalanche warning services should target the messaging of the TTA to the needs of these groups. Our findings suggest that the TTA is underused by participants who do not integrate terrain as part of their bulletin use, as well as participants who take advanced risk management approaches. Avalanche warning services can use this information to determine if additional products or information could be developed to better fit the needs of these user groups. As well, the findings in differences between Canadian and USA based organizations should prompt additional communication between organizations to identify successful strategies for reaching more users in Canada.

4.4.2. What Determines the Usefulness of a Travel and Terrain Advice Statement?

With a better understanding of who is using the TTA section, we turned towards investigating what makes TTA statements useful for users. In this section, we describe the factors that predict the usefulness of the TTA statements and how we interpret these factors.

Understanding and Recognition Confidence drive Usefulness

Participants' level of understanding and their confidence in recognition of the TTA statements both had a strong influence on how useful participants found the TTA statements. Higher levels of understanding and recognition confidence both led to higher usefulness ratings, and the spread of the parameter estimates shows that participants' understanding of the advice is the more dominant of the two in determining the usefulness of the statements.

Our additional regression analyses allow us to further investigate what contributes to these two main factors determining the usefulness of TTA statements. The regression model for how well participants understood the statements indicated that increases in the bulletin user type, level of training, years of experience, days spent recreating in the backcountry, and how much attention they pay to the TTA all increased the chances that participants would find the statements easier to understand. These same factors predicted

how participants rated their recognition confidence, with the exception of how much attention they pay to TTA. The increase in both understanding and recognition confidence with additional training, experience, and a more sophisticated approach to the risk management is expected, as these are skills that develop over time and are taught as part of formal avalanche safety training courses. The absence of the attention to travel advice as a predictor for recognition confidence is also not surprising, as recognizing field conditions is not a bulletin-based skill and need to be developed through other channels.

Within these overall trends, there are some interesting differences in the predictors appeared in the models for both understanding and recognition confidence. The ratings of understanding increased quickly for participants with more than one year of experience but leveled off with no further differences between users with additional experience. In contrast, recognition confidence increased more gradually after the first year, and confidence continued to increase with additional years of experience. This suggests that confidence in recognizing conditions in the field develops more slowly than understanding does. Recognizing specific terrain features or hazardous conditions is more difficult than simply understanding the phrases in the bulletin. This finding echoes the gap between comprehension and application of avalanche safety information among recreationists that was identified by Finn (2020). Most importantly, it highlights a need for continued opportunities for improvements in application practice, both at the desktop and in field. Future research into strategies to develop better terrain feature recognition, such as the inclusion of visual aids along with the TTA, should be considered to help users build their confidence in recognizing field conditions mentioned in the TTA.

The strong influence of understanding and recognition confidence on overall usefulness of the statements is important because it means that variations in these factors will also indirectly influence how useful the TTA statements are. By understanding what drives these additional variables, we are able to see more clearly how participants relate to the TTA statements. Our analyses show that users with less training and less experience are more likely to struggle with both understanding TTA statements and at recognizing the specific conditions mentioned in these statements. This should highlight to avalanche warning services that more effort in education and skill building is needed for these groups of users.

Strong Links between Attention, Usefulness, and Understanding

In addition to ease of understanding and confidence in recognition, the amount of attention participants pay to the TTA section was a significant predictor of useful they find the statements, as well as how well they understand them. One possible way to interpret this result is that the amount of attention participants pay to the TTA section represents their bulletin use practice similar to the avalanche bulletin user types described by St Clair (2019). Bulletin users who pay more attention to the TTA section might become more familiar with the terminology and messages over time and therefore find them more useful. This interpretation of the attention to TTA may also explain why bulletin user type did not emerge as a predictor in the usefulness model. Furthermore, it is consistent with the absence of this predictor in the recognition confidence model since recognizing a condition is a field-based skill and less tightly related to bulletin use patterns.

Even though this interpretation seems intuitive, it is important to remember that regression analyses can only highlight association and not determine causation, and a reasonable alternative interpretation of the observed relationship could be that bulletin users pay more to the TTA section because they find the statements more useful. However, since our survey presented each participant with a different subset of TTA statements, the structure of our dataset does not allow us to integrate participants' statement-specific usefulness and understanding ratings into the regression analysis for how much attention people pay to the TTA. Despite this limitation, our analysis highlights that the relationships between attention-usefulness, attention-understanding, and understanding-usefulness are strong and work together to drive user engagement with the TTA.

The Opposing Effects of Avalanche Training

While higher levels of avalanche training indirectly affect the usefulness of the TTA positively by leading to increased understanding and recognition confidence, we see the direct effect of training on the usefulness ratings to be in the opposite direction. This means that at equal levels of understanding and recognition confidence, participants with higher levels of training perceive the TTA statements to be less useful, while participants with lower levels of training find the statements to be more useful. We interpret this result to indicate that while avalanche awareness training does increase one's understanding of the TTA statement and confidence to recognize the described conditions in the field,

participants with professional training may have the necessary avalanche risk management knowledge and skill to link avalanche hazard and terrain exposure without the explicit assistance provided by the TTA in the avalanche bulletin. This interpretation is consistent with the observation that the amount of attention to the TTA section of the bulletin decreases with increasing levels of avalanche awareness training. This highlights that the primary target audience for TTA statements are users with lower levels of training, and avalanche warning services should seek to make sure the statements are optimized for these types of bulletin users

4.4.3. Can Travel and Terrain Advice Statements Be Made More Accessible to Users?

After controlling for all other factors, participants with the lowest levels of training found the TTA statements to be the most useful, but also demonstrated the lowest levels of understanding of the advice and the least confidence in recognizing the conditions in the field. This suggests that there may be a potential gap that these participants could be falling into, relying on advice they do not completely understand. To close this gap, we tested two types of modifications to TTA statements to see if they could help to improve the understandability, recognition confidence, and overall usefulness of the statements.

Removal of Jargon

Simply removing the jargon from the TTA statements was enough to increase understanding of the statements among participants with no or introductory-level training to the same level as participants with advanced- or professional-level training reported it. Lowering jargon was also sufficient to boost the confidence in recognizing a condition in the field for participants with introductory-level training. As both understanding and recognition confidence are strong predictors of how useful participants find the TTA, it means that simply changing the phrasing of the statements will allow participants with low levels of training to make better use of the TTA without diminishing their clarity for users with more advanced training. This effect has been well documented in the science education and medical communities (e.g., Thomas et al., 2014; Bullock et al., 2019; Rau et al., 2020). Studies on both cardiac patients and parents undergoing pre-natal counselling have identified that terms commonly used by professionals are not widely understood by patients, despite having visited these professionals (Thomas et al. 2014, Rau et al. 2020). Furthermore, Bullock et al. (2019) demonstrated that jargon reduces the

ability to process scientific information and even impacts willingness to consider alternative perspectives or adopt new technologies. These studies are important for the avalanche community, because it is important that readers of TTA be able to both process the information as well as be open to adjusting their terrain exposure based on information within the TTA.

Interestingly, the lower levels of jargon did not affect the usefulness of the TTA statements beyond the indirect effects captured within the models for understanding and recognition confidence. We interpret this to mean that jargon is hard for users to interpret, but once the wording has been changed, it does not further affect the usefulness of the message of the advice given in the statement.

In this study, the removal of jargon had no effect on professional or advanced level users in any of the models. However, other studies express nuances in how jargon is perceived among laypeople. Zimmerman and Jucks (2018) showed that increased jargon impacts professional credibility both positively and negatively depending on the target audience for the communication. Their study emphasized that it is important to match the level of jargon to the intended audience of communication efforts. In the case of the avalanche bulletin, this supports our finding that jargon should be reduced in the TTA statements used by less advanced recreationists. However, it also implies that some jargon can still be used to communicate more precisely in messages targeted towards more advanced users, such as the snowpack and avalanche activity sections of the bulletin.

Added Explanation

In contrast to jargon, which only impacted usefulness via understanding and recognition confidence, adding additional explanations to the statements directly impacted how useful participants found the statements. Participants with introductory and advanced recreational training tended to find TTA statements with added explanations significantly more useful. The additional explanations provided information on context, how to identify the features, or the impacts of certain conditions. (E.g., The italicized phrases “Watch out for changes in the weather and snow conditions, *they may increase avalanche hazard as the day progresses*”, or “Use extra caution around cornices: they are large, fragile, *and can trigger slabs on slopes below.*”).

This increase in usefulness with the added explanation has also been observed in hurricane evacuation messaging research. The experimental study of Morss et al. (2016) demonstrated that warning messages that explained the potential impacts of an approaching hurricane have a bigger impact on participants' intentions to evacuate than messages without that added explanation. Additional work has refined the importance of these types of additions to forecasts by making the distinction between fear-based and impact-based messages. (Morss et al., 2018). In a study of individuals affected by Hurricane Sandy, four warning messages were trialed to determine how participants responded, including messages using non-personalized language to describe the impact of the storm, and messages using personalized language to trigger a fear-based reaction. In that study, high impact messages led to high evacuation intentions and higher risk perceptions than the fear-based message. Furthermore, the high-impact message was less likely to be perceived as overblown. From this, the authors concluded that adding impact messages that do not instill fear may have advantages. While our study did not investigate the role of fear-based messages, we suspect that the results of Morss et al. (2018) also apply to TTA statements. Given that backcountry recreationists voluntarily expose themselves to avalanche risk, including more information about the impacts of conditions in TTA statements is likely even more useful to participants than fear-based messaging, which may lead to warning fatigue and a loss of credibility.

Despite higher observed ratings among participants with no training or introductory training, added explanation did not significantly increase understanding or recognition confidence in participants. However, the effect was nearly significant, and a larger sample size may be sufficient to make the observed differences significant or allowed additional variables to emerge, particularly in the recognition confidence model where the sample size was reduced due to fewer questions.

4.4.4. Limitations

The participant sample in this study demonstrates trends consistent with previous surveys of backcountry recreation users. A high proportion of university educated, male, backcountry skiers, between 25 and 34 years of age with basic avalanche education engage in online surveys about avalanche safety (Finn, 2020; Haegeli & Strong-Cvetich, 2020; Haegeli et al. 2012). The similarity in sample demographics may be drawn from the similar survey promotion techniques used between this study and Finn (2020). Although

this study and Finn (2020) did reach a wider range of users than previous studies, it only captures the behaviour of the demographic that responds to an online survey and may underrepresent non-English speaking participants or other demographics. Additionally, though the survey was open to all winter backcountry recreationists, the majority of the participants were backcountry skiers, and the TTA statements were designed primarily from the perspective of backcountry skiers. Future studies should test if tailoring the statements for different activity groups, such as snowmobilers, snowshoers, or ice climbers, leads to improved usefulness of the statements for these users.

Our study also relies on self-reported metrics of understanding, recognition confidence, and usefulness. We did not include knowledge-based questions to test participant understanding and did not include field studies to determine if participants' confidence in their ability to recognize conditions in the field is warranted or not. The goal of this study was to understand how participants relate to the information provided in the bulletin, so while these self-reported metrics have limitations, we are confident that they are appropriate metrics for this study. Future research may seek to understand how participants' perceptions and self-reported ratings relate to their performance in field conditions.

Our study included a limited set of potential TTA statements and was intended to identify principles of communication via the TTA statements rather than suggest specific wording to warning services. Further research is needed to identify if additional trends in how the TTA is phrased, or if alternate coding of 'statement type', can lead to further increases in usefulness of the TTA. We recommend that warning services work with members of the intended target audience to explicitly test the clarity and usefulness of their own specific TTA statements.

4.5. Conclusion

Selecting appropriate terrain while exposed to avalanche hazard is necessary to mitigate the risk of avalanches while traveling in the winter backcountry. While avalanche bulletins mainly focus on describing the hazard conditions, some of them also provide travel and terrain advice (TTA) statements to help recreationists put the hazard information into action and navigate the backcountry safely. For this information to be effective, avalanche warning services need to understand who is using the advice, if the advice is

useful to participants, and if altering the phrasing of the advice could broaden the accessibility of the information for more users. In this study, we identified that the core audience of the TTA in avalanche bulletins is users introductory level avalanche awareness training who base their risk management decisions on slope-level factors (Type 'D' users). Our results also highlight that simple statement modifications can considerably enhance the value of the TTA statements for the identified target audience. First, reducing jargon helps increase participant levels of understanding, which in turn makes the statements more useful for a broader audience. Second, adding additional information to the TTA statements that gives additional context or explanation to help clarify the statements makes the statements more meaningful. Taken together these findings indicate that the TTA section is valuable for participants, and that making small changes to the presentation of the TTA advice can further increase the usefulness for a wider group of users.

Avalanche warning services can implement these findings by creating communication guidelines for forecasters writing TTA statements that reduce jargon and include additional context for the statements. By improving communication of the TTA, avalanche warnings services can strengthen their role in helping recreationists not only understand avalanche hazard, but also how to mitigate their exposure to the hazard.

Chapter 5.

Conclusion

This collection of studies was developed with the intent of providing Avalanche Canada with actionable data-driven advice and insights about the ways in which the design of avalanche bulletins could be improved for recreational users. Prior research and consultations with Avalanche Canada identified three research priorities for testing the effectiveness of bulletin components and modifications to improve useability:

1. Evaluating the effectiveness of graphic icons used to present avalanche problem information
2. Exploring opportunities to deepen user understanding of daily avalanche hazard through interactive exercises
3. Examining modifications to the phrasing of travel and terrain advice (TTA) statements to make them resonate better with bulletin users.

From this research, I present the following findings and recommendations to Avalanche Canada for their consideration.

The graphic used for the avalanche problem information does affect participants' ability to successfully apply the bulletin information. The graphic currently in use by Avalanche Canada—aspect and elevation information presented separately for each avalanche problem—is not as effective at helping users to apply the information as a version with the aspect and elevation presented in a single rose diagram for each avalanche problem ('Aspect-Elevation Rose'). This was true regardless of other factors such as a participants' level of avalanche training or country of residence. Additionally, the 'Aspect-Elevation Rose' is the most popular among recreationists with all levels of avalanche training and was rated similarly to the existing graphic among Canadian residents. These findings lead me to recommend that Avalanche Canada consider transitioning their avalanche problem graphics to a single Aspect-Elevation rose for each avalanche problem, similar in style to those used in many US-based avalanche centres.

These findings also suggest that there would be benefits to including opportunities for recreationists to check their understanding of the daily avalanche hazard conditions through interactive exercises that provide feedback. Recreationists who do engage with

such exercises, and who struggled to apply the hazard information, showed significant improvement in applying the information after receiving feedback. While Avalanche Canada has incorporated interactive exercises into an online curriculum (avvysavvy.ca) we further recommend searching for ways to incorporate an option that allows users to check their understanding of the daily avalanche hazard conditions, as well as continuing research examining the impact of such exercises over time. I believe there are additional promising and novel developments to be made in the incorporation of self-assessment and feedback tools within the avalanche bulletin. For example, additional self-assessment options for checking understanding of the daily conditions could include questions about specific terrain features, avalanche warning signs, and include photos or other imagery expected to be relevant for the hazard conditions of the day.

For the first time, my collaborators and I identified the primary users of the TTA section of the avalanche bulletin. Type 'D' users, and users with introductory level training, are the primary audience of the TTA section. Ensuring that the advice presented in the TTA section meets the needs of Type 'D' users and ensuring it is presented at a level understandable by participants with introductory training is important to ensure that the needs of these users are being met. The results also show that simple modifications can help participants with no training or introductory training understand the statements better, as well as increase their use. For this reason, I encourage a reduction in the level of jargon used in the TTA statements as well as providing more context for the statements where possible. In addition, I suggest further research using focus groups to develop a clearer picture of what concepts and terminology participants struggle with and ensuring that sufficient details are available for more advanced recreationists in additional sections of the bulletin to better express nuance that may typically be captured in jargon.

My research into TTA statements also highlighted a critical gap between how participants understand TTA and how confident they are at recognizing it in the field. One potential avenue to help reduce this gap could be the inclusion of photos to help illustrate concepts within the TTA statements, as well as the development of products, programs, or initiatives to help build field skills in avalanche bulletin users. I recommend that any initiatives created to develop these important field skills be accompanied by a research program to ensure they are effective and delivering long-term benefits for users.

It is my hope that this research will assist Avalanche Canada to make avalanche safety information more accessible to a wider range of users and refine their bulletin products to help recreationists better understand avalanche conditions and how to manage the associated risk. In addition, I hope that these studies inspire additional research projects that further expand the foundation for the development of evidence-based avalanche safety interventions.

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Appendix.

Survey Screenshots

Landing page

Avalanche Terrain Information Study

The **Avalanche Research Program** at Simon Fraser University, **Avalanche Canada** and several **U.S. Avalanche Centers** are conducting an online survey to examine how backcountry recreationists—skiers, mountain snowmobilers, snowshoers and ice climbers—use public avalanche safety information.

We are interested to hear from **backcountry users of all experience levels**. Our goal is to better understand how you process hazard and terrain information provided in public avalanche forecasts. The results of this study will offer important insight for **improving avalanche safety information products** in Canada and the United States.

As a token of our appreciation, participants who **complete the survey before May 15, 2020** will be entered in a draw for **several cash prizes**. Click [here](#) for more information.

Click the 'Start' button below to participate in our study.

[Start >>](#)


[Informed Consent](#) [Contact Information](#)

SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

Avalanche Canada

UAS NATIONAL AVALANCHE CENTER

Informed Consent Background



Informed Consent

By filling out this questionnaire, you are consenting to participate in our research. Your participation in this survey is voluntary, and you may choose not to respond to any question or terminate the survey at any time. While it is not possible for participants to withdraw previously submitted responses, responses of participants who did not complete the survey will be destroyed prior to analysis.


All information you provide in this survey will be kept strictly confidential in accordance with Simon Fraser University's research ethics guidelines. Any contact information you provide will only be used to contact prize winners. After the prize draw has been completed, all of the contact information will be stripped from the database, and the anonymized records will be moved to a separate secure research database server at Simon Fraser University. Individual records will be identified using a code for data analysis. Your responses will be analyzed in aggregate and will not be identifiable in any publications. While the anonymized raw data collected in this study will be stored indefinitely to facilitate longitudinal research on avalanche safety, it will never be shared outside of the avalanche research program at Simon Fraser University.

Please note that posting to comments sections on social media or other forums about this study may identify you as a participant. We therefore suggest that if this study was made available to you via a social media site or other online forums, you refrain from posting comments to protect your anonymity.

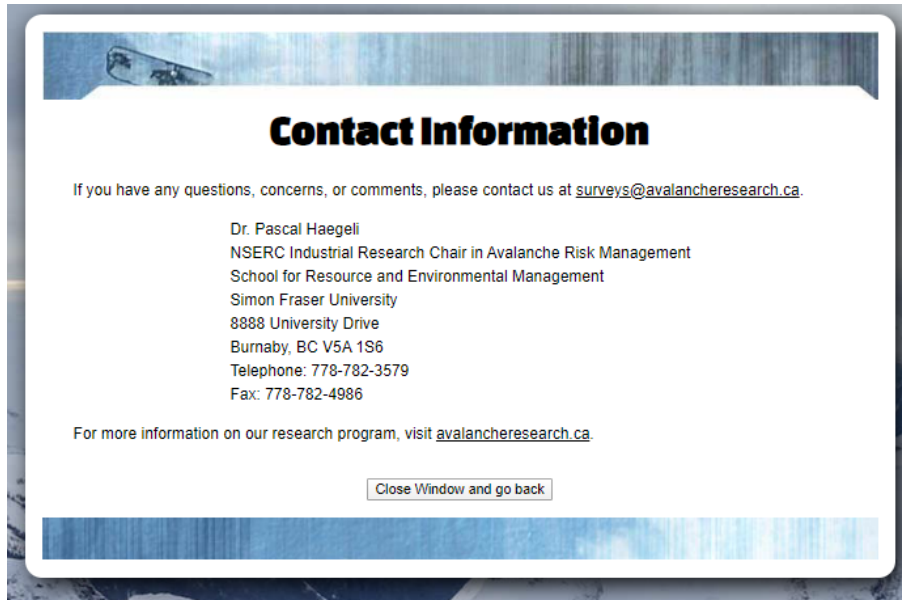
If you indicate interest in participating in future studies on avalanche risk communication, we will store your email address for contacting you in the future in a database separate from the database used for the current analysis.

The winter backcountry activities mentioned in this survey involve serious risks that can lead to severe injuries and/or death. Note that being associated with these activities might negatively affect your insurance benefits (e.g., travel insurance).

For any questions regarding this study, please contact Dr. Pascal Haegeli, NSERC Industrial Research Chair in Avalanche Risk Management, at pascal.haegeli@sfu.ca or 778-782-3579. If you have any concerns about your rights as a research participant and/or your experiences while participating in this study, you may contact Dr. Jeffrey Toward, Director, Office of Research Ethics at jtoward@sfu.ca or 778-782-6593.



Contact information



Contact Information

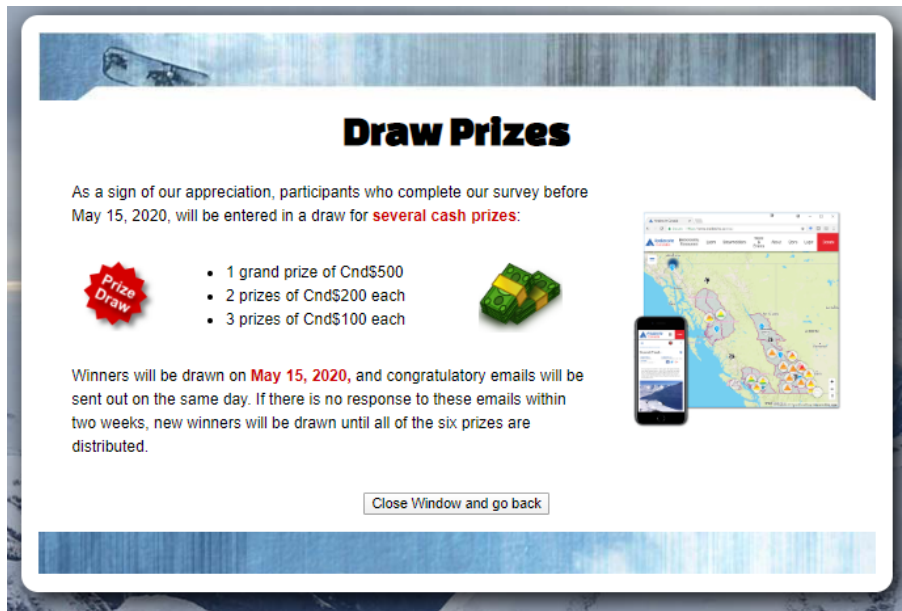
If you have any questions, concerns, or comments, please contact us at surveys@avalancheresearch.ca.

Dr. Pascal Haegeli
NSERC Industrial Research Chair in Avalanche Risk Management
School for Resource and Environmental Management
Simon Fraser University
8888 University Drive
Burnaby, BC V5A 1S6
Telephone: 778-782-3579
Fax: 778-782-4986

For more information on our research program, visit avalancheresearch.ca.

[Close Window and go back](#)

Draw prizes

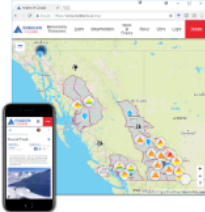




Draw Prizes

As a sign of our appreciation, participants who complete our survey before May 15, 2020, will be entered in a draw for **several cash prizes**:

- 1 grand prize of Cnd\$500
- 2 prizes of Cnd\$200 each
- 3 prizes of Cnd\$100 each

Winners will be drawn on **May 15, 2020**, and congratulatory emails will be sent out on the same day. If there is no response to these emails within two weeks, new winners will be drawn until all of the six prizes are distributed.



[Close Window and go back](#)

Welcome to our Study




2% Complete

Welcome to our Study

Thank you very much for your interest in our study on the use of terrain information provided in public avalanche bulletins.



This survey will take **up to 25 minutes** to complete and consists of the following sections:

- 1) Personal experience
- 2) Route ranking tasks
- 3) Travel advice
- 3) User feedback
- 4) Personal background



- **Please provide us with your contact information so we can enter your name in the prize draw.**
Click [here](#) for more information about the prize draw.
Email:

- **How did you hear about our survey?**
Please select one of the following options.
 - I was emailed a link to the survey.
 - Avalanche bulletin website
 - Avalanche awareness talk/event
 - Avalanche safety course (e.g., AST)
 - Backcountry club/organization
 - Social media (e.g., Facebook)
 - Information at a trailhead
 - Other:

 **Please do not use the Back and Forward buttons on your browser when completing the survey.** 

Personal Background

15% Complete

Personal Background

- **What winter backcountry activity or activities do you most associate with? ***
Please select at least one activity in the first column.

	First activity	Second activity	Third activity
Mountain snowmobile riding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Backcountry skiing/snowboarding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Snowmobile-access backcountry skiing/snowboarding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Out-of-bounds skiing/snowboarding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Snowshoeing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ice climbing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other: <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- **Overall, how much experience do you have in all your winter backcountry activities combined?**
Please select the appropriate option in each column.

Number of winters	Average number of days per winter
<input type="radio"/> This was my first winter	<input type="radio"/> 1-2 days per winter
<input type="radio"/> 2-5 winters	<input type="radio"/> 3-10 days per winter
<input type="radio"/> 6-10 winters	<input type="radio"/> 11-20 days per winter
<input type="radio"/> 11-20 winters	<input type="radio"/> 21-50 days per winter
<input type="radio"/> More than 20 winters	<input type="radio"/> More than 50 days per winter

Avalanches and You

25% Complete

Avalanches and You

• Which of the following statements best describes your thinking about avalanches? *

Please select one of the following options.

- I generally do not think about avalanches where I go.
- I know that avalanches can happen in some of the places I go, but avalanche danger generally does not affect my choices.
- I have not taken a formal avalanche safety course (e.g., Canadian AST1 or U.S. Level 1) since my personal backcountry experience has provided me with all the skills I need for managing avalanche danger where I go.
- I have not taken a formal avalanche safety course, but I would like to learn more about avalanche safety because I sometimes worry about being caught.
- I have taken a formal avalanche course with a field component, but I don't regularly apply what I learned.
- I have taken a formal avalanche course with a field component and I am practicing my skills whenever I can.
- 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 backcountry practice.

→ What is the highest level of formal avalanche awareness training you have completed?

Please select one of the following options.

- Free avalanche awareness seminar (approx. 3 hrs)
- Classroom component of an introductory avalanche awareness course (e.g., classroom component of Canadian AST 1; U.S. Awareness)
- Complete introductory avalanche awareness course with a field day (e.g., complete 2-day Canadian AST 1; U.S. Level 1 Avalanche)
- Advanced avalanche awareness course (e.g., complete 4-day Canadian AST 2, U.S. Level 2 Avalanche)
- Professional level avalanche training (e.g., CAAITP Level 1 or higher, U.S. Professional Avalanche 1 or higher)
- Other:

→ What year did you complete your most recent formal avalanche awareness training or refresher?

Please enter the approximate year.

Avalanche bulletin approach

15% Complete

Avalanche Forecast Use

Avalanche forecasts are published daily to inform the public about current avalanche conditions. In Canada, forecasts are available through the Avalanche Canada and Parks Canada websites (www.avalanche.ca and avalanche.pc.gc.ca) and the Avalanche Canada mobile app. In the U.S., see avalanche.org for an overview of all avalanche forecast regions.

- **Which avalanche forecast region or forecast center do you check most often? ***
*Please select one forecast region or forecast center.
Choose 'None' at the bottom of the list if you never use any.*
- **How often do you check the avalanche forecast for this region?**
Please check the appropriate option.
 - Rarely
 - Before most trips into the backcountry
 - Before every trip into the backcountry
 - Before every trip and occasionally in between
 - Every day
- **Which of the following statements best describes your use of avalanche forecasts when planning a backcountry trip? ***
Please select one of the following options.
 - It is not typical for me to consult the public avalanche forecast online (website or mobile app) when making backcountry travel plans.
 - I typically use the forecast to check the danger rating which informs my decision of whether or not it's safe to travel in the backcountry.
 - I typically combine the danger rating from the forecast with knowledge of how avalanche prone an area is to determine where to travel in the backcountry.
 - I typically make a decision about where or when to go based on the specific nature of the avalanche problem conditions reported in the forecast and whether I feel that I can manage my travel in the terrain given these conditions.
 - I typically use the available information about the specific nature of the avalanche problem conditions from the forecast as a starting point for my continuous assessment in the field to confirm or disconfirm the information where I am travelling.

Next >>

Personal confidence

20% Complete

Personal Confidence

- Please rate your confidence in your personal ability ...
Please rate your confidence on a scale from 0 (Cannot do at all) to 100 (Highly certain can do).

	Cannot do at all	Moderately can do	Highly certain can do
... to understand avalanche hazard and terrain information presented in the forecast.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
... to recognize the terrain that the forecast describes as being most hazardous in the field.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
... to make safe route choices under a variety of avalanche conditions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
... to read topographic maps.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

0 10 20 30 40 50 60 70 80 90 100

Next >>

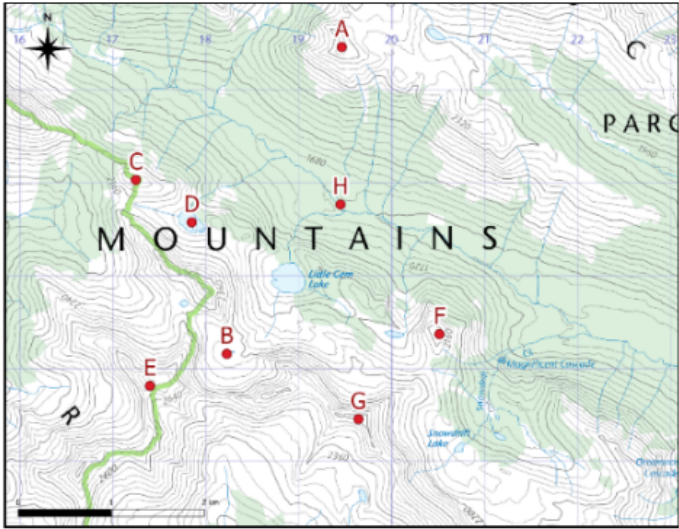
Map reading

55% Complete

Map Reading

- Which of the labelled points in the map below is the closest peak southwest of 'Little Gem Lake'?

Please select one of the following options.



Point A Point D Point G
 Point B Point E Point H
 Point C Point F None of these points

Next >>

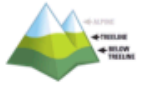



Avalanche Problem Info

30% Complete

Avalanche Problem Info

Canadian and American avalanche forecasts include detailed information about avalanche problems.

Avalanche Problem: Persistent Slabs

What Elevation?	Which Slopes?	Chances of Avalanches?	Expected Size?
			

- **When you read the forecast, how often do you check the avalanche problem information?**
Please check the appropriate option.
 - Never
 - Rarely
 - Occasionally
 - Most of the time
 - Always

- **When you check the avalanche problem information, how much weight do you generally give the elevation information in your assessment process?**
Please check the appropriate option.
 - None
 - A little amount
 - A considerable amount
 - A large amount
 - I only give a large amount of weight for certain avalanche problem types.

- **When you check the avalanche problem information, how much weight do you generally give the aspect information in your assessment process?**
Please check the appropriate option.
 - None
 - A little amount
 - A considerable amount
 - A large amount
 - I only give a large amount of weight for certain avalanche problem types.

- **When you check the avalanche problem information, how much weight do you generally give the chances of avalanches information in your assessment process?**
Please check the appropriate option.
 - None
 - A little amount
 - A considerable amount
 - A large amount
 - I only give a large amount of weight for certain avalanche problem types.

- **When you check the avalanche problem information, how much weight do you generally give the expected size information in your assessment process?**
Please check the appropriate option.
 - None
 - A little amount
 - A considerable amount
 - A large amount
 - I only give a large amount of weight for certain avalanche problem types.

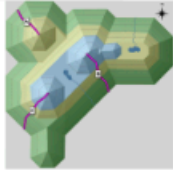

Route Ranking Scenario Intro

35% Complete

Route Ranking Task Intro

On the next pages, you will be presented **hypothetical forecasts** that include avalanche danger ratings for the three elevations band and the location information of the existing avalanche problems. In addition, you will be presented with **different route options** as shown in the image on the right.

Your task is to examine the available information and rank the available route options with respect to their exposure to avalanche hazard.



Next >>

Route Ranking Instructions

40% Complete

Route Ranking Task Instructions

The image below shows an example of the route ranking task with detailed instructions. Please familiarize yourself with the exercise before moving on to the first task.

AVALANCHE BULLETIN

Avalanche Danger Rating	Avalanche Problems	
	Persistent Slab	Wind Slab
Treeline	What locations?	What locations?
Considerable		
Moderate		

1. Avalanche danger rating for each elevation band.

2. Location information for avalanche problems.

• Please rank the three routes presented on the map below according to their exposure to mentioned avalanche problems from least to most exposed. *
You must rank all routes, and every rank can only have a single route.

3. Hypothetical mountain with different elevation bands.

4. Three route options.

5. Dropdown lists for ranking exposure of routes. All routes must be ranked.

Legend

- Alpine
- Treeline
- Below treeline

Your exposure ranking

Routes

Least exposed - 1

2

Most exposed - 3

For your assessments, note that

- It is not necessary to consider **overhead hazard**.
- Assume the **worst time of day** for avalanche hazard, and
- Flat terrain** is not exposed to avalanche hazard.

Avalanche problem location information

Note that in your scenarios, the location information of the avalanche problems will be presented like in **American avalanche forecasts** with the aspect and elevation information presented together in one graphic for each avalanche problem (see example below).

Avalanche Problems

Persistent Slab	Wind Slab
What locations?	What locations?

Next >>

Route Ranking Scenario

There are four of these route ranking exercises in total.

48% Complete

Route Ranking Task (1 of 4)

Consider the avalanche hazard information provided to you below and rank the described backcountry routes according to their exposure to the mentioned avalanche problems. **Remember** that it is not necessary to consider **overhead hazard**, assume the **worst time of day**, and **flat terrain** is not exposed to avalanche hazard.

AVALANCHE BULLETIN

Avalanche Danger Rating		Avalanche Problems	
		Storm Slab	Wet Loose
Elevation	Today	What locations?	What locations?
Alpine	Considerable		
Treeline	Considerable		
Below treeline	Moderate		

- Please rank the three routes presented on the map below according to their exposure to mentioned avalanche problems from least to most exposed. *
You must rank all routes, and every rank can only have a single route.

Legend

- Alpine
- Treeline
- Below treeline

Your exposure ranking

Routes

Least exposed - 1

2

Most exposed - 3

Route Ranking Debrief

Between the second and third route ranking exercise, participants will be presented with some feedback. They are randomly assigned to one of four treatments:

1. No feedback
2. Asked to describe their reasoning process
3. We provide them with our ranking
4. We provide them with our ranking and a detailed explanation

1. No feedback

Skips this page

2. Description of their reasoning process.

55% Complete

Route Ranking Task

We are curious to learn more about how you approached this ranking task. Below you see the avalanche forecast you were given with the two maps and your ranking of the routes.

AVALANCHE BULLETIN

Avalanche Danger Rating		Avalanche Problems	
		Storm Slab	Wet Loose
Elevation	Today	What locations?	What locations?
Alpine	Considerable		
Treeline	Considerable		
Below treeline	Moderate		

YOUR EXPOSURE RANKING

Ranking Task 1

Least exposed
Rank 1: **C**
Rank 2: **B**
Rank 3: **A**
Most exposed

Ranking Task 2

Least exposed
Rank 1: **B**
Rank 2: **A**
Rank 3: **C**
Most exposed

- **Please describe your approach for ranking these routes in a few sentences.**
*It is not necessary to describe your reasoning for each route individually.
 Please just describe your steps in general.*

Next >>

3. Our ranking

55% Complete

Route Ranking Task

We would like to give you some feedback on your ratings. Below you see the avalanche forecast you were given with the two maps and your route rankings compared to ours.

AVALANCHE BULLETIN

Avalanche Danger Rating		Avalanche Problems	
	Today	Storm Slab	Wet Loose
Elevation	Today	What locations?	What locations?
Alpine	Considerable		
Treeline	Considerable		
Below treeline	Moderate		

EXPOSURE RANKING WITH FEEDBACK

Ranking Task 1

Congratulations! You ranked the routes exactly the same way we did.

Least exposed	Your ranking	Our ranking
Rank 1	C ✓	C
Rank 2	B ✓	B
Rank 3	A ✓	A
Most exposed		

Ranking Task 2

There are some differences between your and our rankings.

Least exposed	Your ranking	Our ranking
Rank 1	B X	C
Rank 2	A ✓	A
Rank 3	C X	B
Most exposed		

Next >>

4. Our ranking with explanations

55% Complete

Route Ranking Task

We would like to give you some feedback on your ratings. Below you see the avalanche forecast you were given with the two maps and your route rankings compared to ours. We also provide you with the reasons for our rankings.

AVALANCHE BULLETIN

Avalanche Danger Rating		Avalanche Problems	
		Storm Slab	Wet Loose
Elevation	Today	What locations?	What locations?
Alpine	Considerable		
Treeline	Considerable		
Below treeline	Moderate		

EXPOSURE RANKING WITH FEEDBACK

Ranking Task 1

Congratulations! You ranked the routes exactly the same way we did.

Least exposed	Your ranking	Our ranking
Rank 1	C ✓	C
Rank 2	B ✓	B
Rank 3	A ✓	A
Most exposed		

Ranking Task 2

There are some differences between your and our rankings.

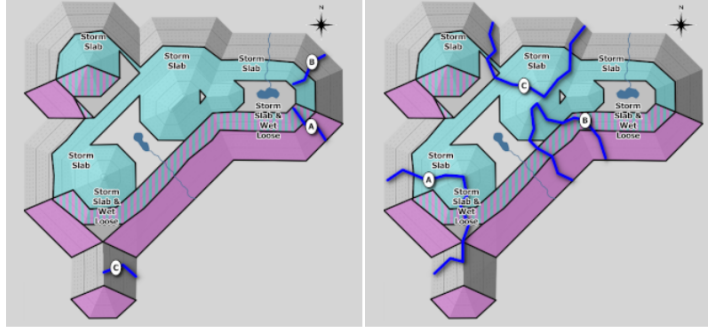
Least exposed	Your ranking	Our ranking
Rank 1	B X	C
Rank 2	A ✓	A
Rank 3	C X	B
Most exposed		

The reasons for our ranking

See below for maps that overlay the routes with the problem areas.

Among these short routes **Route C** is the least exposed because it is not exposed to any avalanche problems. **Route B** is the second most exposed as it is exposed to the storm slab problem at treeline. **Route A** is the most exposed since it is exposed to both the storm slab problem at treeline and the wet loose problem at treeline and below.

In this scenario, **Route B** is the most exposed since the entire route is exposed to avalanche problems: the storm slab problem in the alpine and at treeline, and the wet loose avalanche problems at treeline and below. **Route C** is the least exposed. While this route is still exposed to the storm slab problem in the alpine and at treeline, it completely avoids the wet loose problem. **Route A** is the second most exposed as it avoid the wet loose problem on the west facing slope, but no on the south facing slope at treeline.



Next >>

Interactive Exercises

75% Complete

Interactive Exercises

We are exploring the possibility of **adding interactive exercises** such as the route ranking exercise presented in this survey on avalanche forecast websites to enhance their educational value for our users.

- **How useful was the route ranking exercise for working through and absorbing the avalanche hazard information?**
Please check the appropriate option.
 - Not at all useful
 - Somewhat useful
 - Fairly useful
 - Very useful
- **How useful was the feedback information after the first two route ranking exercises for making the second set of assessments easier?**
Please check the appropriate option.
 - Not at all useful
 - Somewhat useful
 - Fairly useful
 - Very useful
- **How useful was the detailed feedback you received at the end of route ranking exercise for enhancing you avalanche forecast reading skills?**
Please check the appropriate option.
 - Not at all useful
 - Somewhat useful
 - Fairly useful
 - Very useful
- **Would you welcome interactive route exercises that relate to current conditions on avalanche forecast websites?**
Please select one of the following options.
 - Yes
 - No

Next >>

Location Information

80% Complete

Location Information

We are interested in learning more about how you link the terrain information you read in the forecast to the conditions in the field.

- When the forecast states that a **wet loose avalanche problem** is present from **SE to W** below treeline (see below), how surprised would you be to find evidence of wet loose avalanche activity on a **NE aspect in the below treeline** (red ●)?
Please rate the level of your surprise on a scale from 0 (Not at all surprised) to 100 (Extremely surprised).

Wet Loose

What locations?

Not at all surprised Moderately surprised Extremely surprised

0 10 20 30 40 50 60 70 80 90 100

- When the forecast states that a **wind slab avalanche problem** is present from **N to E** in the alpine (see below), how surprised would you be to find evidence of wind slab avalanche activity on a **NW aspect in the alpine** (red ●)?
Please rate the level of your surprise on a scale from 0 (Not at all surprised) to 100 (Extremely surprised).

Wind Slab

What locations?

Not at all surprised Moderately surprised Extremely surprised

0 10 20 30 40 50 60 70 80 90 100

Next >>

Location Graphics

85% Complete

Location Graphics

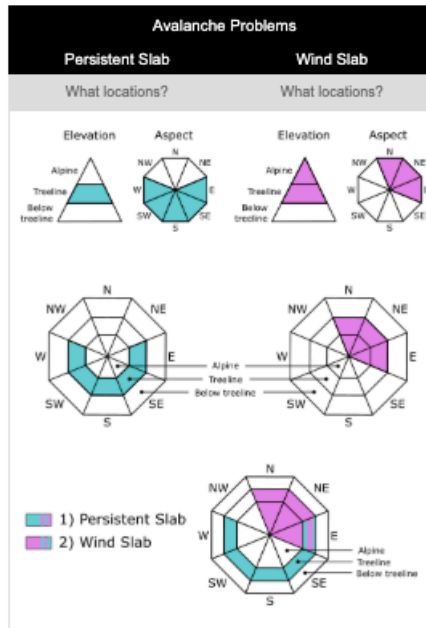
In this survey, participants are presented with different graphics for the elevation and aspect information of avalanche problems to evaluate their effectiveness for planning trips into avalanche terrain.

The three different formats included in the survey are:

a) Separate graphics
Present elevation and aspect in two separate icons for each avalanche problem.

b) Aspect-elevation rose diagrams
Presents elevation and aspect information in one graphic for each avalanche problem.

c) Combined graphic
Combines the elevation and aspect information of all problems into a single graphic. Solid colors are used when only a single avalanche problem is present in a sector. Stripes are used when multiple problems are present in the same sector.



- **For you personally, how effective do you find these graphics for getting a quick understanding of where the avalanche problem areas are in the terrain?**
Please rate the effectiveness of the graphics on a scale from 0 (Not at all effective) to 100 (Extremely effective).

	Not at all effective	Moderately effective	Extremely effective
Separate graphics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Aspect-elevation rose diagrams	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Combined graphic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

0 10 20 30 40 50 60 70 80 90 100

- **If you wish to comment on your choice, please enter your comments below.**

Next >>

Travel Advice Statements

Each participant will be given three statements similar to the one shown below

90% Complete

Travel Advice Statements

Canadian and American avalanche forecasts contain travel advice statements to help users make informed terrain choices in the backcountry. We are interested in learning more about your use of this information.

- **Overall, how much attention do you give to the travel advice statements when you read the avalanche forecast?**
Please rate your attention on a scale from 0 (No attention at all) to 100 (Great attention).

No attention at all Moderate attention Great attention

0 10 20 30 40 50 60 70 80 90 100

We are now presenting you with three travel advice statements. For each of them, we are interested in your perspective on the clarity and usefulness of the statement.

TRAVEL ADVICE STATEMENT 1

In areas where deep persistent slab problems may exist, avoid areas **like cliff bands where snow depth changes rapidly**, as well as any features that look convex.

- **Please indicate your level of understanding of the highlighted phrase in this travel advice.**
Please select one of the following options.
 - I dont understand it at all.
 - I have a vague understanding of it.
 - I think I understand it, but I am not sure.
 - I have a pretty good idea of what it means.
 - I am certain I understand it.
- **How confident are you in your ability to recognize this condition in the field?**
Please select one of the following options.
 - Not at all confident
 - Somewhat confident
 - Fairly confident
 - Very confident
- **Overall, how useful do you find this travel advice statement for your decision-making in avalanche terrain?**
Please select one of the following options.
 - Not at all useful.
 - Somewhat useful.
 - Fairly useful.
 - Very useful.

Next button cut off by screenshot

Personal information

95% Complete

Personal Information

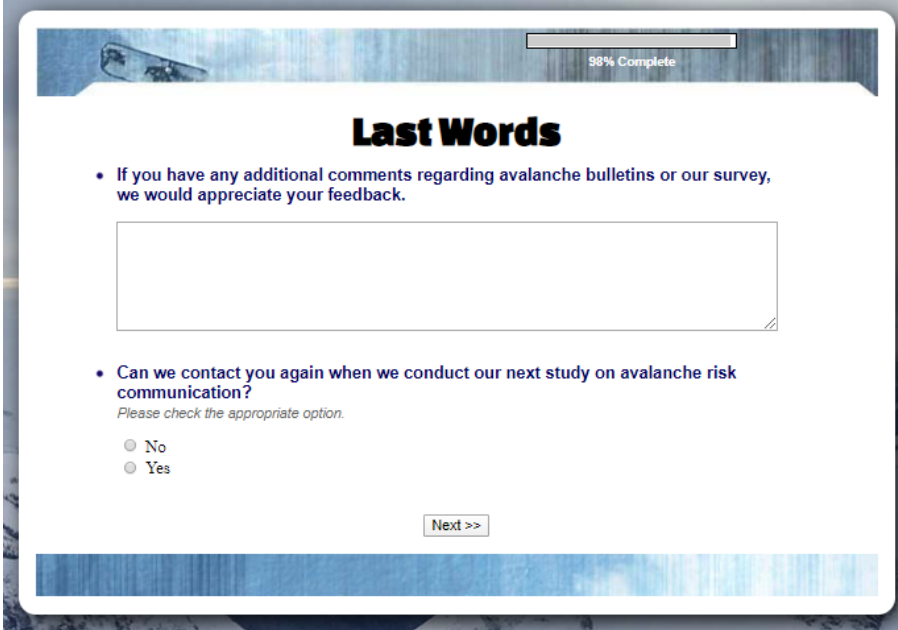
- What is your gender?**
Please check the appropriate option.
 - Male
 - Female
 - Non-binary/third gender
 - Prefer to self-describe:
 - Prefer not to say
- Which of the following age categories describes you?**
Please select one of the following options.
 - Under 20
 - 20 to 24
 - 25 to 34
 - 35 to 44
 - 45 to 54
 - 55 or over
- What is the highest level of education you have completed?**
Please select one of the following options.
 - Less than high school
 - Completed high school
 - Some post secondary education (not completed)
 - Trades or non-university certificate or diploma
 - Completed university
 - Graduate degree
- Where is your main residence?**
Please select the appropriate options.

Country:

Province/State: (only if you live in Canada or the USA)

City/Town:

Last Words



98% Complete

Last Words

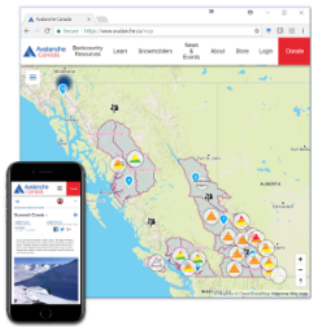
- If you have any additional comments regarding avalanche bulletins or our survey, we would appreciate your feedback.

- Can we contact you again when we conduct our next study on avalanche risk communication?
Please check the appropriate option.

No
 Yes

Next >>

Thank You



Thank You!

Thank you very much for your interest in our research and your willingness to participate in our study.

Your answers will provide important information for making avalanche bulletins work better for all backcountry users.


All the best for the rest of your season!
Katie Fisher
Pascal Haegeli


For information on the current snow and avalanche conditions in Canada, please visit the website of Avalanche Canada at www.avalanche.ca.

Click [here](#) if you want to learn more about how to better manage your risk of avalanche in the backcountry.

Click [here](#) for more information about the Avalanche Research Program at Simon Fraser University.

[Informed Consent](#) [Contact Information](#)

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