https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences
Discussions

Travel and terrain advice statements in public avalanche bulletins: A quantitative analysis of who uses this information, what makes it useful, and how it can be improved for users

Kathryn C. Fisher[1], Pascal Haegeli [1], Patrick Mair[2]

[1]School of Resource and Environmental Management, Simon Fraser University, Burnaby, V5A 1S6, Canada
[2]Dept. Psychology, Harvard University, Cambridge, 02138, United States

Correspondence to: Pascal Haegeli (pascal_haegeli@sfu.ca)

Abstract. Recreationists are responsible for developing their own risk management plans for travelling in avalanche terrain. In order to provide guidance for recreationists on mitigating exposure to avalanche hazard, many avalanche warning services include explicit travel and terrain advice (TTA) statements in their daily avalanche bulletins where forecasters offer guidance about what specific terrain to avoid and what to favour under the existing hazard conditions. However, the use and effectiveness of this advice has never been tested to ensure it meets the needs of recreationists developing their risk management approach for backcountry winter travel.

We conducted an online survey in Canada and the United States to determine which user groups are paying attention to the TTA in avalanche bulletins, what makes these statements useful, and if modifications to the phrasing of the statements would improve their usefulness for users. Our analysis reveals that the core audience of the TTA is users with introductory level avalanche awareness training who integrate slope-scale terrain considerations into their avalanche safety decisions. Using a series of ordinal mixed effect models, we show that reducing the jargon used in the advice helped users with no or only introductory level avalanche awareness training understand the advice significantly better and providing additional context for the advice made the advice more useful for them. These results provide avalanche warning services with critical perspectives and recommendations for improving their TTA so that they can better support recreationists who are at earlier stages of developing their avalanche risk management approach and therefore need the support the most.

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; Techel et al., 2016). 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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, 2021).

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 (in print). Bulletin User Type B, for example, exclusively base their decision to go into the backcountry at all on the danger rating, whereas Type D 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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., (2018) 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 injures 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 make informed decisions about avalanche risk. Examples include the ground-breaking Reduction Method developed by Munter (1997), which combines 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 and 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, many 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, 2021; CAIC, 2021). In contrast, Swiss avalanche bulletins include the information alongside specific avalanche problem descriptions (SLF, 2021). 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 these statements of advice are used by recreationists. In this study, we

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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.

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 et al. (in print) and Fisher et al. (under review) respectively.

2.1 Survey Design

Our first research question was to investigate the primary audience of the TTA statements in the bulletin, so we asked all survey participants how much attention they generally pay to the TTA statements. 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 (Appendix A) 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.

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 the survey structure was designed so that individual participants were not presented with both 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 1). First, if the TTA included a key phrase (e.g., 'minimize exposure', 'hard wind slab', 'thick melt-freeze surface crust'), the phrase was highlight and participants were asked how easy it was to

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences
Discussions

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.

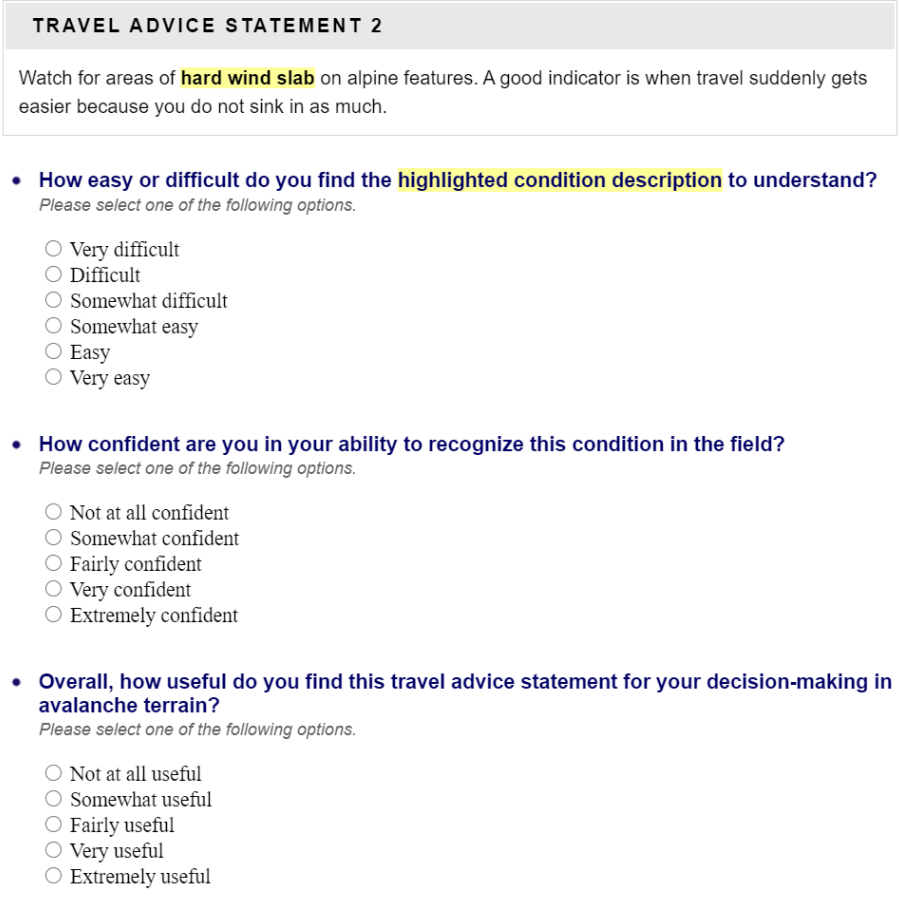


Figure 1: Screen shot of survey question for example statement

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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 recreation 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 in the survey to address the other research questions are described in Fisher et al. (in press) and Fisher et al. (under review).

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 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.

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 how 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%).

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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. In addition, we included 'statement type', 'years of experience', 'days per winter in backcountry', 'bulletin user type', and 'country of residence' in the initial models by default but removed them if their parameter estimates did not reveal a significant spread (i.e., p-values < 0.050). However, we also 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 4.4.1; R Core Team, 2021). We used the clmm function of the 'ordinal' package (Christensen, 2019) to estimate our ordinal mixed effects models and the polr function of the MASS package (Venebles and 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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.

3 Results

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. Finally, we eliminated participants who did not provide information on their years of backcountry experience and how many days they spend in the backcountry each year as they play a critical role in our analysis. The final analysis dataset consisted of 3,100 participants, which represented 84.5% of the 3668 individuals who completed the survey. These participants provided a total of 9196 TTA statement assessments. However, the dataset for the individual analyses vary as not all three assessment questions included for every TTA statement.

Of the 3,100 participants, 76.8% identified as male (2,2356 participants), 37.0% (1,144 participants) were between 25 and 34 years old, 79.8% had a university-or-higher education (2,467 participants) and 82.5% (2,556 participants) had completed at least an introductory avalanche safety training course. Backcountry skiers represented the highest proportion of recreationists in the study with 78.3% of the sample (2,427 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%, 234 participants), snowshoers (5.7%, 176 participants), and snowmobilers (5.0%, 156 participants), and less than two percent ice climbers and snowmobile-accessed backcountry skiers. The largest group of participants (30.9%, 958 participants) were relatively new to their sport, with between 2 and 5 years of experience. However, the distribution of years of experience was relatively even with 19.7%, 19.8% and 25.2% of the sample stating that they had 6-10 years, 11-20 years, and more than 20 years of backcountry experience respectively. Only 4.4% of the sample (137 participants) reported that this was their first year of backcountry recreation. Bulletin user types ‘D—Distinguish and Integrate Avalanche Problem Conditions’ and ‘E—Extends Analysis’ made up 29.3% and 46.3% of participants respectively (909 and 1434). 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

included a range of training levels at each bulletin user type (Table1). Finally, 69.4% (2,209) of responses were from residents of the United States.

Table 1: 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.

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 statements in 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 2).

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 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%[1] chance that Type D users would response 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

[1] 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.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

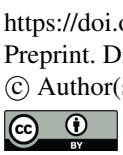
Table 2: Parameter estimates of regression model examining the attention paid to the TTA statements

Fixed Effects		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Predictor	*Level*				
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
	United States	0.3320	0.0780	< 0.0001	
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	

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%, $p < 0.0001$).

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%, $p = 0.5575$).

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021



Natural Hazards and Earth System Sciences
Discussions

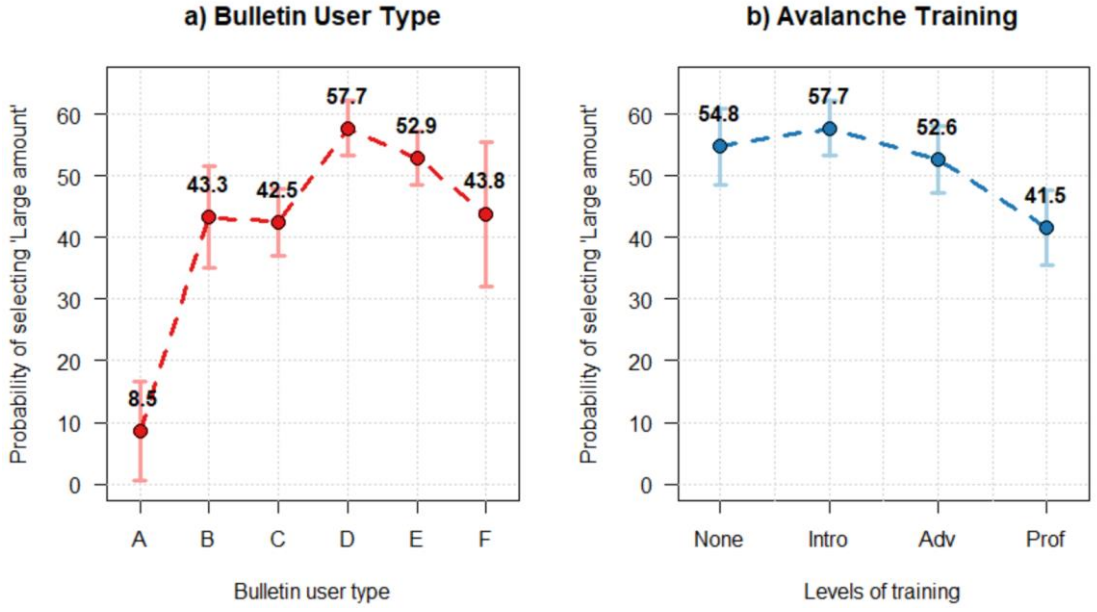


Figure 2: Estimated marginal probabilities for selecting 'A large amount' for a) different bulletin user types, and b) different avalanche training levels. Error bars represent 95% confidence intervals for probabilities calculated from the subsample for the particular parameter level.

280

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 United States were
285 more likely to indicate higher levels of attention to the TTA than Canadian residents.

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
290 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 3).

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences Discussions

Table 3: Parameter estimates of regression model examining the ease of understanding of the TTA statements

		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Predictor	*Level*				
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	
Interaction effects					
Predictor (level)	*Predictor (level)*				
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	

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences Discussions

	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 phases 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 were the least likely to find the phrases easy to understand (51.9%, 72.2%, $p = 0.4062$).

The statement treatments (i.e., 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 was modulated by the interaction effect with the level of avalanche training a participant had completed (Figure 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%[2] vs. 81.2% $p = 0.6780$, Professional: 84.1.6% v. 85.3%, $p = 0.6761$) However, among participants

[2] 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.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences
Discussions

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.

The number of years of experience a participant had in the backcountry was also a significant predictor of the chance of them finding the statements at least easy to understand (Figure 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).

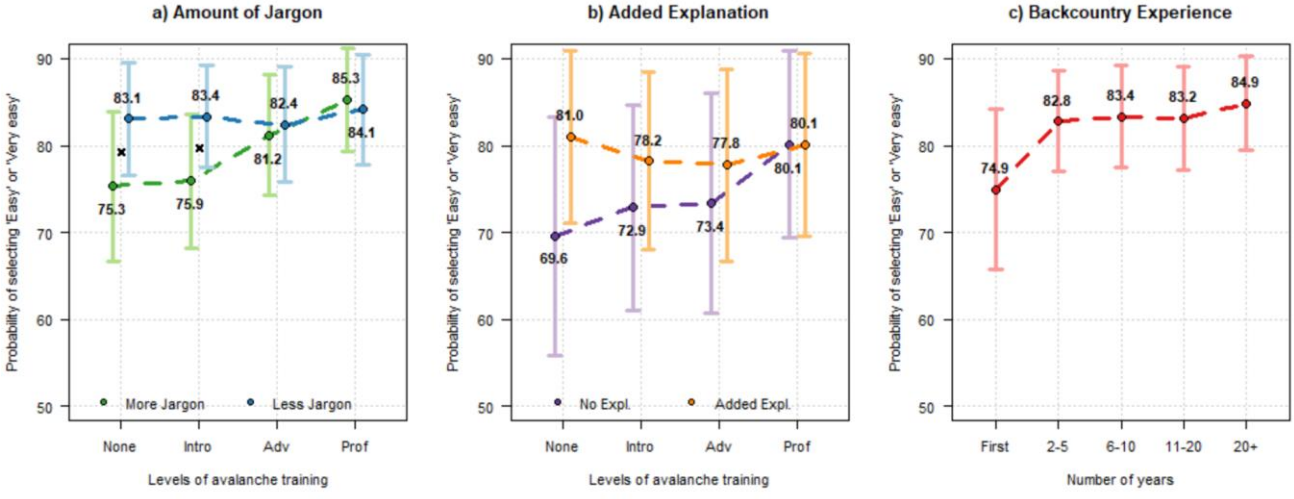


Figure 3: Estimated marginal probabilities for selecting 'Easy' or 'Very Easy' for understandability of statement as function of a) the interaction effect of avalanche training and amount of jargon, b) the interaction effect of avalanche training and added explanation, and c) the main effect of years 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 ≤ p-values < 0.05).

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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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.

As indicated by the random effects in Table 3, we observed greater unexplained variance 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 ('action', 'attitude', and 'fact'; Appendix A) did not emerge as a significant predictor of participants' understanding and was therefore removed from the model during the development of the model.

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. Note that this dataset is therefore 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).

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%[3] chance of being 'very' or 'extremely'

[3] 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.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences Discussions

Table 4: Parameter estimates of regression model examining participants confidence in recognizing the terrain or snowpack features described in the TTA statements.

		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Predictor	*Level*				
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	
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	0.4278	0.0468	< 0.0001	<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					
Predictor (level)	*Predictor (level)*				
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	

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

	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
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 : Statement ID	14	0.1383	0.3719	
Statement ID	7	0.5567	0.7461	

[a]Base level is 'more jargon' statement.

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.

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). 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 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%, $p = 0.0194$).

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

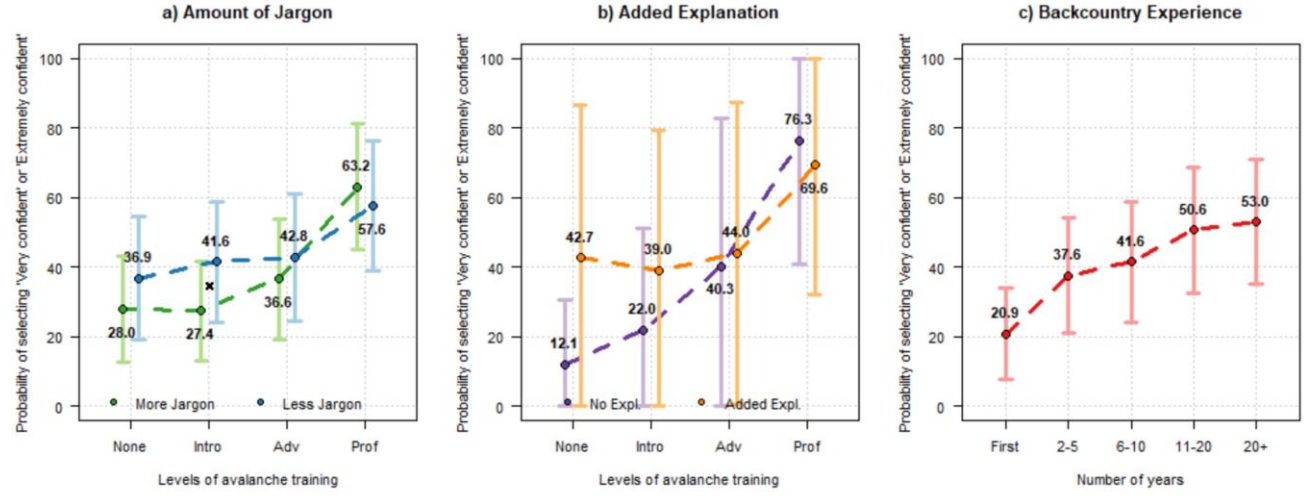


Figure 4: Estimated marginal probabilities for selecting 'Very confident' or 'Extremely confident' for recognizing condition in the field as function of a) the interaction effect of avalanche training and amount of jargon, b) the interaction effect of avalanche training and added explanation, and c) 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 ≤ p-values < 0.05).

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.

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 5.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences Discussions

Table 5: Parameter estimates of regression model examining participants usefulness ratings for the TTA statements

		Parameter Estimate	Standard Error	p-value	p-value of Type II Wald Statistic
Main effects					
Predictor	*Level*				
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	Linear trend	1.1301	0.0496	< 0.0001	<0.0001
Statement	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					
Predictor (level)	*Predictor (level)*				
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				

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

	Introductory	-0.0599	0.1869	0.7487
	Advanced	-0.0520	0.2214	0.8144
	Professional	0.4583	0.2305	0.0468
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 5)[4]. 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.

[4] 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.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

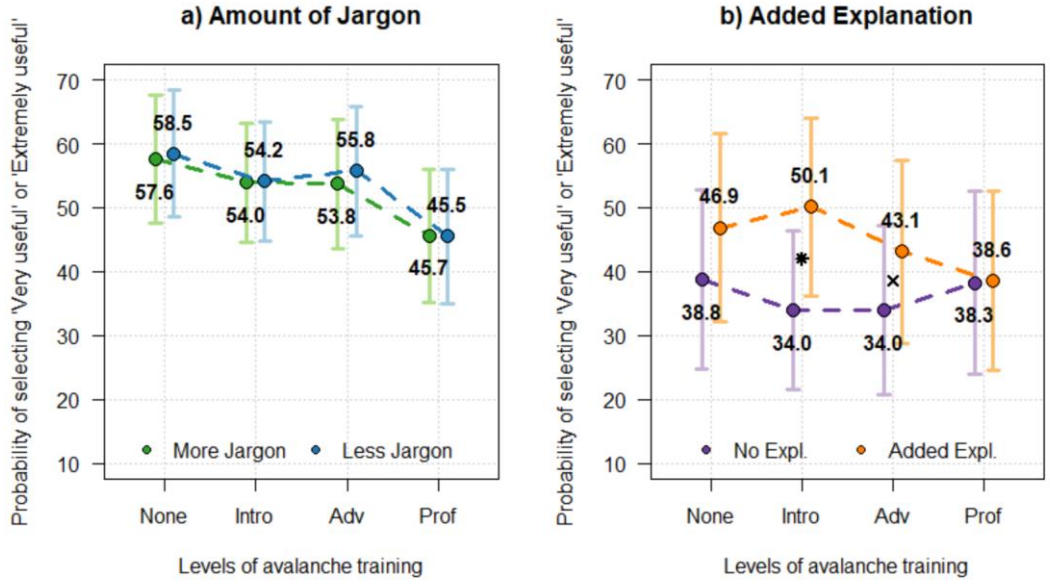


Figure 5: Estimated marginal probabilities for selecting 'Very useful' or 'Extremely useful' for usability of statement as function of a) the interaction effect of avalanche training and amount of jargon, and b) the interaction effect of avalanche training and added explanation. Error bars represent 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 ≤ 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 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.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

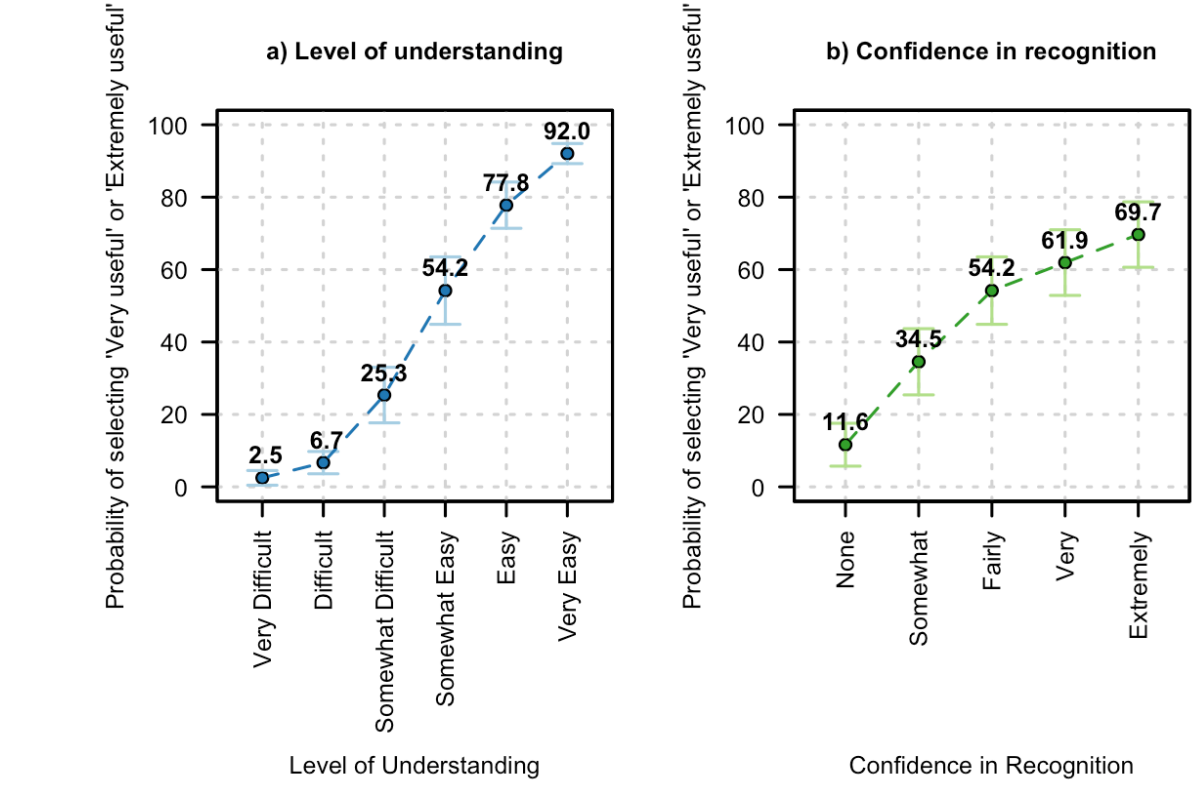


Figure 6: Estimated marginal probabilities for selecting 'Very useful' or 'Extremely useful' for usability of statement as function of a) participants' level of understanding, and b) their confidence in recognizing the condition or feature. Error bars represent 95% confidence intervals for probabilities calculated from the subsample for the particular parameter level.

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 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'.

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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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 Discussion

In this study we examined who is paying attention to the travel and terrain advice (TTA) statements 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.

4.1 Who is Paying Attention to Travel and Terrain Advice?

The TTA statements in 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.

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 statements included in 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 information on the location and nature of specific avalanche problems as part of their risk management approach for determining their trip objectives (St. Clair, 2019; St. Clair et al., in press). 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 existing conditions. In contrast, Type C users make their travel decisions by 'opening and closing' avalanche terrain at a larger scale (St. Clair, 2019), and so the drop in attention we observe in this group may be because they tend not to incorporate the specific terrain features described in the TTA into their risk management approach. The alignment of our results with predictions based of the bulletin user typology show that the TTA statements are 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 included in 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

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 United States 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, we hypothesize that it may be related to differences in avalanche bulletin format or outreach efforts. Many US-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 US 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 United States.

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. In addition, the observed differences between Canadian and US participants should prompt additional communication between US and Canadian avalanche warning services to identify successful strategies for reaching more users in Canada.

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

With a better understanding of who is using the TTA statements, 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.

4.2.1 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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 identified by Finn (2020). Most importantly, it highlights a need for continued opportunities for improvements in the application of the information provided in the bulletin, both during trip planning at home 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.

4.2.2 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 statements was a significant predictor of how 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 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 statements 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

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 practices.

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 statements 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 and usefulness, attention and understanding, and understanding and usefulness are strong and work together to drive user engagement with the TTA.

4.2.3 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, the direct effect of training on the usefulness ratings turns out 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 included in 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

4.3 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.

4.3.1 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

565 training. 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;
570 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
575 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.

580 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
585 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.

4.3.2 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
590 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., "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.
595 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

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 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 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 and 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 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 believe that they are appropriate for the objectives of 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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

trends in how the TTA is phrased, or if alternate coding of 'statement type' could lead to further insight into the 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.

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, many 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 with introductory level avalanche awareness training who integrate slope-scale terrain considerations into their risk management decisions (i.e., Type D bulletin 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 participants' level 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 statements are 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.

Code and data availability. The data, code, and output for our analysis and the data and code for the figures and tables included in this paper are available at https://doi.org/10.17605/OSF.IO/ACZX5 (Haegeli et al., 2021).

Author Contribution. KF and PH designed and executed the study and prepared the original draft. PM assisted with data analysis and reviewed the draft. All authors reviewed the draft prior to submission.

Competing Interests. PH is a member of the editorial board of *Natural Hazards and Earth System Science*. The authors have no other competing interests to declare.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences Discussions

Acknowledgements. The authors thank Avalanche Canada, the Colorado Avalanche Information Center, and the Northwest Avalanche Center for their input during the design of the survey and their promotion of the study among their communities. We also thank all of our survey participants without whose contribution this research would not be possible. We are grateful to the Coast Salish peoples including the Tsleil-Waututh (səl̓ilw̓ətaʔɬ), Kwikwetlem (kʷikʷəƛ̓əm), Squamish (Sḵwx̱wú7mesh Úxwumixw) and Musqueam (xʷməθkʷəy̓əm) Nations, on whose traditional and unceded territories Simon Fraser University and our research program resides. This research was conducted across Canada and the United States, which include the traditional territories of many other Indigenous Peoples.

Financial support: Kathryn C. Fisher received funding for this project from the Government of Canada Social Sciences and Humanities Research Council via a Joseph Armand Bombardier Canada Graduate Scholarship Masters (CGS M). Public avalanche safety research at Simon Fraser University Avalanche Research Program is further supported by Avalanche Canada and the Avalanche Canada Foundation.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Natural Hazards and Earth System Sciences Discussions

675 **Appendix A**

This appendix includes all the pairs of travel and terrain advice statements used in the survey.

Table A1: Travel and terrain advice statements used in survey

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: theses overhanging drifts of snow along ridge lines are large, fragile and can trigger slabs on slopes below.	Explanation	Attitude	Understanding, usefulness

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

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

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

References

Avalanche Canada: Avalanche Canada 2019 Annual Report, https://issuu.com/avalancheca/docs/ac_2019_annual_reportissuu, 2019

Birkeland, K.W., Greene, E.M., and Logan, S.: In Response to Avalanche Fatalities in the United States by Jekich et al, Wild Environm Med, 28, 380-382, https://doi.org/10.1016/j.wem.2017.06.009, 2017.

Bullock, O.M., Amill, D.C., Shulman, H.C., and Dixon, G.N.: Jargon as a barrier to effective science communication: Evidence from metacognition. Pub Underst Sci., 28(7), 845-853. https://doi.org/10.1177/0963662519865687 ,2019.

[CAIC] Colorado Avalanche Information Center: https://avalanche.state.co.us/forecasts/backcountry-avalanche/steamboat-flat-tops/, last access 27 February 2021.

[CAIC] Colorado Avalanche Information Center: National Avalanche Accident Dataset. https://avalanche.state.co.us/accidents/statistics-and-reporting/, 2020.

[CAA] Canadian Avalanche Association: Technical Aspects of Snow Avalanche Risk Management─Resources and Guidelines for Avalanche Practitioners in Canada (C. Campbell, S. Conger, B. Gould, P. Haegeli, B. Jamieson, and G. Statham Eds.). Revelstoke, BC, Canada: Canadian Avalanche Association, 2016.

Christensen, R.H.B.: "ordinal—Regression Models for Ordinal Data." R package version 2019.12-10. https://CRAN.R-project.org/package=ordinal , 2019.

[EAWS] European Avalanche Warning Service: Information Pyramid. https://www.avalanches.org/standards/information-pyramid/, last access 11 February 2021.

Finn, H.: Examining risk literacy in a complex decision-making environment: A study of public avalanche bulletins.M.R.M. research project no. 745, 2020-04. School of Resource and Environmental Management. Simon Fraser University, Burnaby, B.C., 2020.

Fisher, K.: How can avalanche bulletins be more useful for recreationists? Exploring three opportunities for improving communication of avalanche hazard information. M.R.M. thesis. School of Resource and Environmental Management. Simon Fraser University, Burnaby, B.C., 2021.

Fisher, K. C., Haegeli, P., and Mair, P.: Impact of information presentation on interpretability of spatial hazard information: Lessons from a study in avalanche safety, Nat. Hazards Earth Syst. Sci. Discuss., 2021, 1-35, https://doi.org/10.5194/nhess-2021-147, in print.

Fisher, K. C., Haegeli, P., and Mair, P.: Exploring the avalanche bulletin as an avenue for continuing education by including learning interventions. Manuscript submitted for publication for Journal of Outdoor Recreation and Tourism on Sept. 19, 2021, under review.

Gavaldà, J., Moner, I., and Bacardit, M.: Integrating the ATES into the avalanche information in Aran Valley (Central Pyrenees). Proceedings of 2013 International Snow Science Workshop, Grenoble, France, 381-384. https://arc.lib.montana.edu/snow-science/item/1984, 2013.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021

Haegeli, P.: Avaluator V2.0 - Avalanche accident prevention card, Canadian Avalanche Centre, Revelstoke, BC., 2010.

Haegeli, P., Fisher, K., and Mair, P.: Travel and terrain advice statements in public avalanche bulletins: A quantitative analysis of who uses this information, what makes it useful, and how can we make it better?—Data and Code, OSF, https://doi.org/10.17605/OSF.IO/ACZX5, 2021.

Haegeli, P., Gunn, M., and Haider, W.: Identifying a High-Risk Cohort in a Complex and Dynamic Risk Environment: Out-of-bounds Skiing–An Example from Avalanche Safety. Prev Sci, 13, 562-573. https://doi.org/10.1007/s11121-012-0282-5, 2012.

Haegeli, P., and Strong-Cvetich, L.: Using discrete choice experiments to examine the stepwise nature of avalanche risk management decisions–An example from mountain snowmobiling, Journal of Outdoor Recreation and Tourism, 32, 100165. https://doi.org/10.1016/j.jort.2018.01.007, 2020.

Harrison, X.A., Donaldson, L., Correa-Cano, M.E., Evans, J., Fisher, D.N., Goodwin, C.E.D., Robinson, B.S., Hodgson, D.J., and Inger, R.: A brief introduction to mixed effects modelling and multi-model inference in ecology. PeerJ, 6, e4794. https://doi.org/10.7717/peerj.4794 , 2018.

Harvey, S., Schmudlach, G., Bühler, Y., Dürr, L., Stoffel, A., and Christen, M.: Avalanche terrain maps for backcountry skiing in Switzerland. Proceedings of 2018 International Snow Science Workshop, Innsbruck, Austria, 1625-1631, http://arc.lib.montana.edu/snow-science/item/2833 , 2018.

Larsen, H.T., Hendrikx, J., Slatten, M.S., and Engeset, R.V.: Developing nationwide avalanche terrain maps for Norway. Nat Hazards, 103, 2829-2847. https://doi.org/10.1007/s11069-020-04104-7 , 2020.

Lenth, R.: Estimated Marginal Means, aka Least-Squares Means. R package version 1.4.3.01., https://CRAN.R-project.org/package=emmeans, 2019.

Morss, R.E., Cuite, C.L., Demuth, J.L., Hallman, W.K., and Schwom, R.L.: Is storm surge scary? The influence of hazard, impact, and fear-based messages and individual differences on responses to hurricane risks in the USA. International Journal of Disaster Risk Reduction, 30, 44-58. https://doi.org/10.1016/j.ijdrr.2018.01.023, 2018.

Morss, R. E., Demuth, J.L., Lazo, J.K., Dickinson, K., Lazrus, H., and Morrow, B.H.: Understanding public hurricane evacuation decisions and responses to forecast and warning messages. Weather Forecast, 31, 395-41. https://doi.org/10.1175/WAF-D-15-0066.1, 2016.

Munter, W.: 3x3 Lawinen: Entscheiden in kritischen Situationen, Agentur Pohl & Schellhammer, Garmisch Partenkirchen, Germany, 220 pp., 1997.

[NWAC] Northwest Avalanche Center. https://nwac.us/avalanche-forecast/#/west-slopes-north, last accessed 27 February 2021.

Pielmeier, C., Silbernagel, D., Dürr, L., and Stucki, T.: Applying the Avalanche Terrain Exposure Scale in the Swiss Jura Mountains. Proceedings of 2014 International Snow Science Workshop, Banff, AB, 883-889, https://arc.lib.montana.edu/snow-science/item/2170, 2014.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences Discussions

R Core Team: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/, 2021.

Rau, N.M., Basir, M.A., and Flynn, K.E.: Parental understanding of crucial medical jargon used in prenatal prematurity counseling. BMC Med Inform Decis, 20, 169. https://doi.org/10.1186/s12911-020-01188-w, 2020.

Schmudlach, G., and Köhler, J.: Method for an Automatized Avalanche Terrain Classification. Proceedings of 2016 International Snow Science Workshop, Breckenridge, CO, 729-736, http://arc.lib.montana.edu/snow-science/item/2356, 2016

[SLF] WSL Institute for Snow and Avalanche Research SLF. Avalanche Bulletin, https://www.slf.ch/en/services-and-products/forecasting-and-warning/avalanche-bulletin.html last accessed 11 February 2021.

St. Clair, A.: Exploring the Effectiveness of Avalanche Risk Communication: A Qualitative Study of Avalanche Bulletin Use Among Backcountry Recreationists. M.R.M. research project no. 738, 2019-10. School of Resource and Environmental Management. Simon Fraser University, Burnaby, B.C., 2019.

St. Clair, A., Finn, H., and Haegeli, P.: Where the rubber of the RISP model meets the road: Contextualizing risk information seeking and processing with an avalanche bulletin user typology, International Journal of Disaster Risk Reduction, 102626, https://doi.org/10.1016/j.ijdrr.2021.102626, 2021.

Statham, G.: Avalanche hazard, danger and risk - a practical explanation. Proceedings of 2008 International Snow Science Workshop, Whistler, BC, 224-227. http://arc.lib.montana.edu/snow-science/item/34 , 2008.

Statham, G., Haegeli, P., Birkeland, K. W., Greene, E., Israelson, C., Tremper, B., Stethem, C. J., McMahon, B., White, B., and Kelly, J.: The North American public avalanche danger scale. Proceedings of 2010 International Snow Science Workshop, Lake Tahoe, CA, 117-123. http://arc.lib.montana.edu/snow-science/item/353 , 2010

Statham, G., Haegeli, P., Greene, E. Birkeland, K., Israelson, C., Tremper, B., Stethem, C., McMahon, B., White, B., and Kelly, J.: A conceptual model of avalanche hazard. Nat Hazards, 90, 663–691. https://doi.org/10.1007/s11069-017-3070-5, 2018.

Statham, G., McMahon, B., and Tomm, I.: The avalanche terrain exposure scale. Proceedings of the 2006 International Snow Science Workshop, Telluride, 491–497. https://arc.lib.montana.edu/snow-science/objects/issw-2006-491-497.pdf, 2006.

Techel, F., Jarry, F., Kronthaler, G., Mitterer, S., Nairz, P., Pavšek, M., Valt, M., and Darms, G.: Avalanche fatalities in the European Alps: long-term trends and statistics, Geographica Helvetica, 71, 147-159, https://doi.org/10.5194/gh-71-147-2016, 2016.

Thomas, M., Hariharan, M., Rana, S., Swain, S., and Andrew, A.: Medical jargons as hindrance in doctor-patient communications. Psychol Stud, 59(4) 394-400. https://doi.org/10.1007/s12646-014-0262-x , 2014.

Venables, W.N., and Ripley, B.D.: Modern Applied Statistics with S, Fourth edition. Springer, New York. ISBN 0-387-954570 https://www.stats.ox.ac.uk/pub/MASS4/, 2002.

https://doi.org/10.5194/nhess-2021-324
Preprint. Discussion started: 15 November 2021


Natural Hazards and Earth System Sciences
Discussions

Zimmerman, M., and Jucks, R.: How experts' use of medical technical jargon in different types of online health forums affects perceived information credibility: Randomized experiment with laypersons. J Med Internet Res, 20(1)e30. https://doi.org/10.2196/jmir.8346, 2018.

Zuur, A.F., Ieno, E.N., Walker, N., Saveliev, A.A., and Smith, G.M. (Eds.).: Mixed effects models and extensions in ecology with R. Springer New York, New York, NY, 2019.