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Decision-making in avalanche terrain–How does assessment of terrain, reading of avalanche forecast and environmental observations differ by skiers' skill level?

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ABSTRACT

The aims of this study was to determine how skiers' skill level concerning the assessment of avalanche risk affect how they judge avalanche terrain, how they gather information about avalanche risk, and what signs of danger they observe on a trip under considerable avalanche danger. We conducted a survey including 209 skiers, who participated in a seminar four days after several avalanches occurred in a popular ski area in Western Norway. Results showed that novices assessed the terrain for a specific site as less complex than experts, they weighted information in the avalanche forecast differently, and used different strategies to gather information about the snowpack on a trip. We also found a tendency for experts to observe more alarm signs than novices on the avalancheday. We conclude that expertise is important for making the best possible risk assessment in avalanche terrain.

Management implications: The level of expertise fundamentally affect how backcountry skiers assess the severity of terrain, make use of the information obtained from the avalanche forecast, and their choice of strategies for collecting information from the environment during a trip. We propose to promote the development terrain assessment skills among novice backcountry skiers first as it allows them to control their avalanche risk based on more easily interpretable observations and develop the more challenging avalanche hazard assessment skills gradually through experience.

1. Introduction

Increased interest in winter backcountry recreation has resulted in increased exposure to avalanche terrain and a subsequent increase in avalanche accidents. In Norway, backcountry accident rate in avalanche terrain has tripled over the last 10 years (Norwegian Geotechnical Institute, 2017). Decision-making in such hazardous outdoor settings is difficult because environmental information is complex and incomplete. This may result in exclusion of important information when assessing the situation, which makes it difficult to arrive at the right decisions (Hogarth, 2001; Kahneman & Klein, 2009; Kahneman, 2011; Shanteau, 1992).

As terrain is the more tangible component in the avalanche triangle, terrain evaluation skills provide the most secure basis for decision-making in avalanche terrain (Fredston & Fesler, 2011; Statham, McMahon, & Tomm, 2006; Tremper, 2008). Compared to the ever-changing snowpack and weather conditions, a good terrain evaluation provides the best opportunity to base risk assessment and decisions on a solid foundation of facts, rather than on uncertain assumptions, feelings, guesses, or fate. The Avalanche Terrain Exposure Scale (ATES) (Statham et al., 2006) outline several main factors for assessing the general, condition-independent exposure of terrain to avalanche hazard: slope angle, slope shape, forest density, terrain traps, avalanche frequency (events per years), start zone density, runout zone characteristics, interaction with avalanche paths, route options, exposure time, and glaciation (p. 493). Knowledge of these factors is required to assess avalanche terrain according to ATES. According to Hallandvik, Aadland, and Vikene (2016), ATES might be a valuable tool to include in the assessment of avalanche terrain, but its effective application requires in-depth knowledge of the included factors.

In contrast to terrain assessment, which is static and therefore relatively straightforward, the snowpack is more challenging to assess (Adams, 2004; Fredston & Fesler, 2011; Tremper, 2008), especially when there are deeply buried weak layers (Kronthaler, Mitterer, Zenke, & Lehning, 2013; McCammon & Schweizer, 2002; Müller, Landrø, Haslestad, Dahlstrup, & Engeset, 2015). According to McCammon and Schweizer (2002) and Kronthaler et al. (2013) there are several important observations to look for in the snowpack; 1) depth

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of the failure plan, 2) weak layer thickness, 3) hardness transition, 4) grain type, and 5) grain size. Backcountry travelers can obtain information regarding these factors indirectly from public avalanche forecasts (danger rating, aspects and elevation of avalanche problems, general snowpack and avalanche information; Varsom, 2017b) and/or directly through personal observations when backcountry touring. Regarding avalanche problems, the avalanche forecast contains information about kind of avalanche (wet or dry, slab or loose snow avalanches), where that avalanche exists in the terrain (aspects and elevation), how likely you are to trigger it (unlikely, likely or certain) and how big it will be (small, large or historic). Yet, this information might not be salient for skiers. Thus, a number of rule-based decision tools have been developed to aid the search for relevant information about snow conditions. Examples include the Obvious Clues Method (OCM) (McCammon, 2004, 2006) and the Avaluator 2.0 – avalanche accident prevention card (Haegeli, 2010), which both directs attention to important alarm signs (signs of slab avalanches in the area from today or yesterday, whumpfs, shooting cracks, loading by wind, rain or snow). However, knowledge about how to search for such information, for example by breaking your own trail and not relying on previous tracks that provide very limited information (Tremper, 2008), and possibly further probe for specific avalanche problems by digging a snow profile, requires considerable experience.

Previous studies show that novices' decision-making strategies in avalanche terrain are different from those of experts (Adams, 2004, 2005, 2006; Atkins & McCammon, 2004; Haegeli, Haider, Longland, & Beardmore, 2010). According to Haegeli et al. (2010), different user groups apply different decision-making strategies depending on their relevant training, experience and recreation preferences. They found none of the amateur user groups included in their study understood interactions between hazard factors. This corresponds to Atkins and McCammon (2004) findings of a gap between recreationists' technical avalanche knowledge and their ability to apply this knowledge in relevant situations. In addition, Adams (2004) found that recreationists seem to make decisions from isolated, passive and subjective interpretations of hazard terminologies, as exemplified by static management approaches under "considerable" (e.g., stop) or "moderate" (e.g., go) avalanche hazard rating levels.

According to Kahneman and Klein (2009) and Adams (2005), experts use pattern recognition to make sense of a situation by comparing it with their past experiences, or by seeing subtle relationships within the complex web of factors that influence the current situation. The experts also recognized when things were abnormal. This also corresponds to findings by Stewart-Patterson (2013, 2014), who found that the decision-making process of professional ski guides defaulted into conservative options when intuition and analyses clashed. According to Adams (2005), experts' decisions were influenced by experience, knowledge, skills, human information, physical and environmental systems. This is a dynamic system thinking perspective involving both intuitive and analytic decisions. In addition, Adams (2005) study also found that situation awareness (SA) is fundamental to sound decision-making. According to Endsley (1995, 2006), SA plays an important role in situations when many quickly changing and interacting factors have to be monitored simultaneously. As such, SA involves much more than simply perceiving information in the environment. Endsley (1995, 1999) divides the properties of SA into three levels; (1) the perception of elements about the current situation, (2) the comprehension of the current situation and, (3) the projection of future states. Errors in decision-making may happen on all levels, and the decision-making process depends on development of SA on all levels. Importantly, poor comprehension of the current situation (level 2) might lead people to ignore important information, pay attention to irrelevant information or underestimate the importance of information recognized (Endsley, 2006; Feltovich, Prietula, & Ericsson, 2006). Thus, already acquired knowledge is fundamental to how people seek information, what they observe, and how this information is interpreted. The experts' rich sets of mental models are critical to control or prime their attention and therefore dictate what they expect and look for, and how to sort relevant from irrelevant information (Endsley, 2006; Kahneman, 2011; Klein, Pliske, Crandall, & Woods, 2005). Thus, the gathering of information from the surroundings is not a data driven bottom-up process, but rather a goal driven top-down process (Endsley, 2006, 2015; Klein et al., 2005). For skiers travelling in avalanche terrain, this mean that prior knowledge and experience is of critical importance to how they judge avalanche terrain, read and weight the information in public avalanche forecasts and which signs of avalanche danger they search for and observe when travelling in avalanche terrain.

Previous studies investigating differences in decision-making by expertise level have primarily relied on hypothetical decision situations presented in surveys (Atkins & McCammon, 2004; Furman, Shooter, & Schumann, 2010; Haegeli et al., 2010). While there are advantages to this approach, there are concerns about the representativeness of the results (Haegeli, Gunn, & Haider, 2012) and these differences should ideally be investigated in real-world settings. Our study aims to advance our understanding of differences in avalanche risk decision making among levels of expertise by assessing how skiers' skill level affect 1) how they judge avalanche terrain, 2) how they read the avalanche forecast and collect information about the snowpack on a trip, and 3) what signs of danger they observe on a personal backcountry trip under considerable avalanche danger rating level 3, shortly after a significant avalanche cycle in Norway.

2. Method

The present study is based on an online survey, which was conducted during an ad-hoc avalanche seminar in Sogndal on January 31, 2015, four days after a significant avalanche cycle with several naturally and human triggered avalanches occurred in the area. Sogndal is a popular area for backcountry and freeride skiing in Western Norway (Fig. 1).

At that time, the snowpack in the area contained a deep buried persistent weak layer (approx. 0.8–1.2 m deep) of surface hoar on all aspects above 1000 m elevation. The regional avalanche danger level was rated as considerable (level 3), and the snowpack structure was conducive to skier triggering. Accidentally triggered avalanches under these conditions we expected to produce medium-sized avalanches (size 3: < 10,000 m^3) (Varsom, 2015). Because of the mild climate in Sogndal, the snowpack in the area is typically more stable and avalanche conditions are less severe. As of January 31, 2015, there had never been a fatal avalanche incident in the region, and avalanche cycles like the one described have been extremely rare. Thus, this event was extremely special for skiers. (Photo 1).

Four days after the avalanche cycle, The Sogn og Fjordane University College, The Norwegian Water Resources and Energy Directorate and a local outdoor activity corporation called Bratt Moro organized an ad hoc avalanche seminar. The aim of the seminar was to present and discuss the recent avalanches, what conditions that had created the weak snowpack, and share experiences among skiers.

2.1. Online survey dataset

We collected the data for our analysis with an anonymous smartphone survey carried out using the Murvey software (Murvey, 2015). The first part of the survey included questions about sex, age, ski touring- and avalanche assessment experience (years of experience) and self-reported avalanche assessment skill level (novice, advanced beginner, competent, proficient, or expert) as defined by Dreyfus and Dreyfus (1986).

The main part of the survey is described in Table 1. Information about how the respondents judged the terrain at the north aspect of Blåfjell was assess by the question *"How do you consider the terrain north aspect of Blåfjell?"* and rated as simple, challenging or complex