# Avalanche Beacon Parks: Skill Development and Group Coordination in a Technological Training Ground

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## ABSTRACT
High-risk outdoor recreation has been gaining interest around the world in the past years. While those activities allow their enthusiasts to reach unprecedented levels of adrenaline and adventure, they also contain risks and require specific training (in part technological). In particular, its participants must be ready to react efficiently during an emergency or in response to an accident. *Technological training grounds* can simulate particular contexts and emergency situations as a place for recreationists to train and practice. In this paper, we use the practice of *avalanche companion rescue* as a case study to explore how technological training grounds support recreationist training. Our results offer insights into how avalanche beacon training parks support skill development and team coordination training. We also present high-level strategies to orient the design of technological training grounds beyond avalanche companion rescue.

### Author Keywords
Avalanche rescue practice; avalanche beacons; training in context; simulation; communities of practice.

### ACM Classification Keywords
H.5.3 [**Group and Organization Interfaces**]: Computer supported cooperative work; H.1.2 [**User/Machine Systems**]: Human factors.

## INTRODUCTION
In the past years, there has been an increase in high-risk outdoor recreation activities, sometimes labeled as adrenaline sports, extreme sports, 'modern outdoor activities' [20], 'skilled adventures' [4] or risky forms of recreation [3]. Those sports have been characterized as "specialised, highly technological and demanding a high degree of preparation, and are associated with individual endeavour, risk, speed, and excitement" [20:36]. Examples include climbing, skydiving, mountain biking, big wave surfing, BASE jumping, white water kayaking, kite boarding, heli-skiing, and backcountry skiing. As Bell presents, such sports are also characterized by the 'communities of interest' [3:12], comprising people who participate in those activities, use specific areas in the outdoors, and who use particular equipment. Members of these communities demonstrate a desire and interest for risk-taking [4,5] while at the same time cultivating a high knowledge for the sport they practice, including its risks and dangers [10:8].

As sports and recreation continue to develop into the more extreme and risky spheres, there is also a growing need for ongoing and simulated practice and training for recreationists and outdoor enthusiasts. That need is even more important for situations within the practice that happen rarely but that can be life threatening.

At the same time, digital technology is becoming increasingly incorporated into many of these activities, particularly through the use of portable devices running specialized apps. For example, GPS devices are critical both for routine route finding in the backcountry, and for deciding on alternative routes when problems occur (e.g. [8]). Personal satellite trackers (e.g., the SPOT GPS Messenger, www.findmespot.ca) allow people to check in periodically to inform others not only about their location and well-being, but to send out a distress and location signal when they require rescue. Various apps and devices let people monitor specialized environmental forecasts and bulletins in order to help their decision making, such as extreme changes in weather during backcountry travel, winds when skydiving, potential for flash floods when canyoneering, and local avalanche conditions when backcountry skiing (e.g., www.avalanche.ca). Some devices are solely dedicated to handling particular emergency situation, such as avalanche transceivers (beacons) that help people locate victims buried in an avalanche [7].

For these devices to be used effectively, recreationalists need to understand how to use them within the context of their real-world activity. This goes beyond reading the user

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manual. While one can read about the functions of (say) a GPS unit or an avalanche transceiver, their actual use during the high-risk activity demands far more knowledge and expertise. The consequences of mis-use or inefficient use can be extremely serious. Misreading a GPS while skiing on a glacier during a whiteout can lead the group to extremely hazardous terrain. Inefficient use of an avalanche transceiver can lead to delays, resulting in suffocation of the buried victims before they are found.

The problem is that people need to learn how to use these devices and the best practices around them within their recreational context. Yet learning while actually doing the activity is often impractical due to the inherent danger and time constraints of the activity, and the relative rarity of critical events. As a consequence, training often occurs in specially crafted physical settings - *technological training grounds* - that simulate particular contexts and emergency situations.

Our goal in this paper is to understand the use of these technological training grounds and how to better design them. We chose to study the case of backcountry skiing and the specific practice of the *avalanche companion rescue protocol* within *avalanche training beacon parks* (both will be described shortly). Avalanche companion rescue training is particularly interesting to both HCI and CSCW because its success relies on several aspects: how each rescuer masters the skills of using his or her tools during particular emergency scenarios (including technology such as an avalanche transceiver), how the rescuers as a team are able to collaborate and coordinate on scene while using that technology, and how people support the training of others through facilitation and mentorship.

After describing related work, we present our study. We start by summarizing the key aspects of avalanche companion rescue practice and the training tool at the center of our study: the avalanche beacon training park. We then report our results under the themes of skill development, team coordination training, and designing beacon parks as a technological training ground. To foreshadow, our main findings articulate the value of a progressive difficulty scale of scenarios, the importance of levels of fidelity, finding a balance between skill development *vs.* team coordination training, and the challenges in supporting communities of practice in simulations for recreationists.

## RELATED WORK

### Emergency training and simulations in CSCW

The HCI community has a long-standing interest in the relationship between emergency training and simulations, and the role technology can play in supporting those practices. As part of this, CSCW has focused on the collaborative aspect of training in these situations. Examples include observational studies of air traffic control [6], health care [2], firefighting [12,21,22], avalanche rescue [7] and real-world emergencies [16]. Researchers have also created new systems to better support training, often focusing on collaborative practices. Proposed solutions include tabletop systems [6], games [16,22], and virtual environments [17].

However, our work differs from the above. The training and simulations typically studied in CSCW are oriented towards professionals and experts in emergency management and rescue. That audience is distinctly different from high-risk recreationists (such as the companion rescuers in the case of an avalanche [7]). Unlike professionals, they do not necessarily commit or have the time to commit to extensive formal training. Unlike professionals, recreationists often form ad hoc groups for each outing *vs.* stable teams that work together over time. Thus no single group learns how to work together as a team during emergencies. As well, a particular group may include strangers and/or people of quite different (and perhaps unknown) levels of expertise.

These distinctions are at the center of the motivation for this paper: how are technological training grounds used by these recreational groups, and how can they be designed to best train people to respond to the life or death situations inherent in their practices?

### Communities of practice and situated learning

Most high-risk recreational activities occur in a social context, where its players strongly identify with a community of like-minded people. Formal and informal clubs are common, specialized social media sites develop, open invitation social gatherings abound, and courses are offered by both professional and lay people. Similarly, training is often a social event: it would be a mistake to consider training solely from the individual perspective.

This social structure is captured by the concept of *communities of practice* as developed by anthropologists Jean Lave and Etienne Wenger [12,20]. These communities refer to groups of people who share a passion, a craft, or a profession. Central to these communities is how learning is situated in the social, where practitioners share knowledge and experience of their field of the practice, and thus learn from each other [13]. Communities of practice display a shared repertoire of experience, stories, best practices, and equipment and tools [24], all which help inform its members. The act of learning is further situated in the real world, as it often occurs as they perform their shared practice. Wenger [23] argues that it is by being part of a community of practice and by practicing alongside 'old timers' (people with considerable experience) that newcomers can learn the skills, techniques, values and norms of a community of experts. This process takes time and 'repeated and enduring exposure' is necessary for learning to happen [15].

In the case of backcountry recreationists, some aspects of the practice are passed on via this *situated learning* as they are performing the activity. Examples include the selection and review of appropriate equipment by members at the start of the activity, route finding and terrain choice discussion while travelling, and even critique and fine-tuning of skiing techniques. The practice of avalanche companion rescue does not benefit as much in situated learning. Since avalanches are rare but serious occurrences, learning must happen in different ways, such as through reading and instructional videos, and by taking formal courses. While simulations can occur in the field (e.g., by one member of a group burying a transceiver while others try to find it), they are rarely and often hastily done: people would rather ski.

We are thus particularly sensitive to the notion of communities of practice [14,23], where we see it as one way to better understand the use of technological training grounds by outdoor recreationists, both in terms of skill development and group coordination.

### Dimensions and types of simulations

The literature on simulations and training discusses the different dimensions and types of simulation. For example, Beaubien and Baker [2] offer three dimensions of fidelity in simulations: environment, equipment, and psychological. The authors articulate how each training exercise or facility can offer more or less fidelity on each dimension, which can reflect particular sub-areas of a more complex practice. However, they also state: "although the three fidelity components are inter-related, psychological fidelity is generally considered to be the most essential requirement for team training" [2:i52]. Beaubien and Baker also articulate three types of simulation: case studies/role plays, part task trainers, and full mission simulations [2]. Full mission simulations are described as allowing trainees to prepare for extremely rare, complex and critical situations that need to be understood in their holistic complexity.

Although Lave and Wenger [14] argue that learning must be situated and social to be effective, literature on simulations also proposes that some aspects of practices can be learned without the need for a complete simulation [22] and that in fact a full simulation can be unnecessary [19]. For example, Anderson et al. [1] argue that for some jobs it is necessary to learn basic tasks outside of social contexts before combining them in the more complex situation.

In companion avalanche rescue, we see the dual need of developing individual part-task skills (like using the beacon, probe and shovel), but at the same time learning group skills (such as how to coordinate and collaborate on an emergency scene).

## OUR STUDY

Our study took place in a dedicated area at Mount Baker Ski Area in Washington, U.S.A. Two of the authors were on site to install and maintain a wireless beacon park for 4 weekends, one day per weekend. Our study comprised 2 parts: an observational study with interviews of participants using the beacon park, and a reflection on our own practice of installing and modifying the beacon park in response to what we observed. As the two parts of the study happened simultaneously and influenced each other, we continuously evolved and refined our research questions. The study was run by a CSCW researcher (also a backcountry skier) and an avalanche education specialist, both on site. The education specialist served a dual role, where he acted as both as an observer and as a facilitator for those requiring or asking for help. Other volunteer facilitators were sometimes present as well.

Before we go further, we provide necessary background information for understanding backcountry skiing, companion rescue and the functioning of avalanche beacon training parks. A more detailed description of the avalanche rescue protocol written for a CSCW audience can be found in [7]. We then delve into the study method.

### Backcountry Skiing, Avalanches & Companion Rescue

Backcountry skiing (and snowboarding) is a popular activity. Skiers travel under their own power (both uphill and down) outside of ski resorts in mountains. Rewards include breath-taking views, vigorous exercise, challenging and rewarding ski lines, and pristine untouched snow. The risk is an *avalanche*, a large volume of loose snow that rapidly slides down a slope [18], which can bury and injure skiers, and that can have fatal consequences. When caught and buried in an avalanche, victims rely on teams of rescuers, often their traveling companions, to save them through a process called *avalanche companion rescue*. Companion rescue is challenging, stressful, complex, and time sensitive as the chance of survival decreases significantly after 15 minutes in a complete burial [11].

Most backcountry skiers carry tools to perform companion avalanche rescue. *Avalanche transceivers* (also called *beacons*) are portable electronic devices that transmit a locatable signal. Each skier wears one turned on as a matter of routine. Rescuers can use the same beacon on receive mode to search for the victim, where rescuers try to locate the snowpack surface directly above or nearby the victim. Because beacons have inaccuracies, *collapsible probes* (long poles several meters in length) are then used by rescuers to physically probe that snowpack area until they physically touch the victim. *Avalanche shovels* – collapsible strong shovels – are used to dig out the victim.

Companion rescue follows a well-defined protocol. It begins with *initial coordination*. Rescuers (the victim's or victims' companions who have witnessed the avalanche) quickly coordinate themselves. They discuss further risks, gather information concerning who saw what, and each assumes an initial role with particular duties (e.g., leader, searcher, prober). While taking a minute or two, initial coordination leads to better overall efficiency, better safety management, and makes sure that no time is wasted [7].

The next step is the *coarse search*. Here, searchers travel on the avalanche path in a pattern that covers the whole area that could have buried the victim. They use their beacons on search mode to find the signal emitted by the victim's beacon under the snow. Once a signal is found, the rescuer follows the indications on the beacon (a visual distance and direction cue, and an audible cue) to get closer to the victim. When close to the victim, the rescuer kneels and starts the *fine search* of the strongest signal (called *bracketing*) to further narrow down the victim's location. Depending on the depth of the burial and other factors, this location may still not be exactly over the victim. To pinpoint the location of the victim, one or more rescuers start *probing* – repeatedly pushing the probes through the snow in a regular pattern around that region – where they try to strike (and thus locate) the victim. Next is *shoveling* the snow out of the way, first to bring an airway to the victim, and then to extract the victim from the snow. The last steps are to give first aid care and transport the victim out of the backcountry as needed.

While this protocol sounds straightforward, much can go wrong. Beacon signals can be lost or confused, with searchers backtracking or even going around in circles. Rescuers may fixate on one victim's signal, at the cost of another victim. Probers may miss areas that should be covered, or think they have a 'strike' when they do not. Shoveling through avalanche debris must be done efficiently (via a well-defined method) as it is otherwise extremely difficult, tiring and time-consuming. These all matter greatly, as even the loss of a few minutes in the process may mean the difference between life and death.

Because of the above, best practices demand that recreationists learn and regularly practice with their equipment, understand the protocol for finding a victim, and know the procedure and strategies for working as a companion rescue team. They must also be ready to improvise and readjust the protocol depending on who is doing the rescue, how many people are available, and to accommodate everyone's skill levels. Recreationists are highly encouraged to take professional avalanche courses, where an instructor offers the basics of avalanche safety for backcountry recreationists. In addition to the class, backcountry recreationists also often practice their skills on their own (individually or as a group), at least once every ski season [7]. Another option is to train in an *avalanche beacon training park* (or beacon park for short).

### Avalanche Beacon Training Parks

An avalanche beacon training park is a practice field containing pre-installed avalanche beacons. They are usually located at ski hills or at road heads in backcountry areas, and their locations are advertised and signed (Fig 1c). A beacon park typically comprises 8 to 16 *practice beacons* that emit the same radio signal (457 Hz) as normal avalanche beacons. Beacons are protected in a waterproof case, and screwed to a 50 cm$^2$ plywood sheet (Fig 1a) that simulates the victim's surface area when probing. Beacons are buried under the snow at the beginning of the season, with their depth varying over time with the snowpack. Beacon parks include a *control box* (Fig 1b) controlling the operation of the practice beacons.

To use the beacon park, recreationists arrive on site with their own beacons. They turn on one or more practice beacons through the control box. They use their personal beacons to do the coarse and fine search towards one signal at a time and then use their probes to detect the plywood holding the beacon through the snow. The practice stops there: digging is generally not done within the beacon park.

### Research Questions

We focus specifically on avalanche beacon training parks as an illustrative case study of a technological training ground. We ask:

- How do recreationists use beacon parks for both skill development and team coordination?
- How can we design beacon parks to better fit the needs of the recreational community of backcountry skiers?

### Part I: Observational study and interviews

Part I of the study focused on our first research question. Observational data was gathered with the goal of constructing a detailed portrait of how recreationists used the Mount Baker beacon park.

*Participants.* We recruited participants by advertising the opportunity to practice avalanche companion rescue in a beacon park, with the option of participating in a study. We advertised on online sports-related forums, through the social media of sports equipment shops, through print ads in the local community, and on the Mount Baker ski area's website.

We had 22 participants (5 female, 17 male). 10 were part of the ski area volunteer patrol and 12 from the general public.


**Figure 1. a) Practice beacon in waterproof case on plywood. b) Beacon park control box. c) Beacon park area.**

We had 10 participants that came individually, 3 groups of 2, and 2 groups of 3. 10 had never used a beacon park, while the rest had used them at other ski resorts. There was a broad range of backcountry ski experience, from no experience to 16 years of experience. All had skied at least several years at a ski hill. We note that downhill skiing expertise did not necessarily correlate with backcountry experience or companion rescue expertise. For example, many of our volunteer ski patrollers did not routinely do backcountry skiing, and may have had only a day of companion rescue training (if at all).

*Tasks.* Participants came to the tent (Fig 1c), where we introduced a particular avalanche rescue scenario. They would then do a scenario, usually returning to the tent afterwards for the next scenario. The facilitator would offer his expertise to participants (perhaps after observing participants or on participants' request), where he would offer tips, comments and even help them through particular scenarios. Otherwise, we let the participants use the beacon park in the way they wanted to keep the ecological validity of the study. We invited participants to perform as many rescues as they wanted. If participants had come alone, we let them use it by themselves. If they had come as a group, we suggested that they perform practices as a group.

*Data Collection.* We conducted a pre-activity questionnaire to gather information about each participant's motivation for using the beacon park, and their level of expertise in skiing, companion rescue, and beacon parks.

As the participants used the beacon park, we observed them with the shadowing technique. We asked them to describe what they were thinking as they were doing their practice rescues. One researcher followed them and took hand written notes. We also filmed the participants for the length of the search with a goPro camera.

We wrote a report for each participant summarizing our observations on how they performed the rescues, how they used the beacon, how they collaborated with others, and how they improved or changed their strategies of search from one scenario to another.

Finally, we conducted post-activity semi-structured interview with 9 of our participants. The interview questions focused on participants' experience of the beacon park (including positive and challenging aspects of practice, the development of skills, and the practice of coordination) and on their thoughts about how beacons and beacon parks could be designed in the future.

### Part II: Reflections on maintaining a beacon park

Part II of the study focused on our second research question where we reflected on the design strategies we used to install and maintain the beacon park, and the changes we made to our installation over the course of the study based on our observations in Part I.

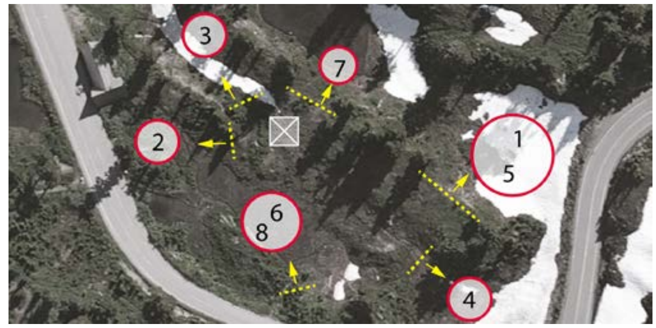


**Figure 2. Aerial view of day 3's beacon park. Red circles show the simulated avalanche debris zones; numbers indicate the buried beacons. Yellow dotted lines and arrows indicate each scenario's starting gate and direction of the simulated avalanche. (From Google Maps: during the study, snow covered the whole area)**

*Installing and Maintaining the Beacon Park.* For each day that we were on site, we created a series of scenarios. For each, we positioned and buried each practice beacon to create a variety of scenarios for participants. Each scenario used bamboo poles to indicate the start and end of the simulated avalanche path. Scenarios ranged in expected difficulty. The simplest were those simulating a single burial. More difficult scenarios simulated two victims located at various distances from one another. Multiple burials make it more difficult to locate a signal (due to multiple beacon signals), introduce coordination complexity, and add stress due to the greater amount of time that may be needed to locate victims. For each day, we used insights gathered from the previous study day to modify the beacon park setup.

*Data Collection.* The two on-site authors debriefed each other at the end of each study day. Through a written report, they recorded what they had observed in relation to the organization of the beacon park, the way the scenes were installed, the way information was communicated to participants, and impressions for what worked well and what needed adjustment. We took photos of the training scenes and our installation. We also produced an aerial map of the beacon park locating each scenario (as in Fig. 2) .

### Data analysis

We conducted a thematic analysis with the data collected from both parts. The themes that emerged were: 1) skill development (including learning how to use a beacon, learning basic steps of the coarse and fine search, understanding the technological environment of the beacon park); 2) coordination training (including communication, role distribution, team rescue strategies); and 3) the role of site maintenance, and 4) the role of mentoring and facilitation.

## RESULTS

Our results are presented under three themes reflected in our analysis: skill development, team coordination practice, and design strategies for creating beacon parks as technological training grounds. For each aspect, we describe the strategies we used as well as the challenges we encountered.

### Skill development

All participants used the beacon park to develop and master particular skills, from beginners learning how to use a beacon to advanced practitioners focusing on sharpening their skills in complex multiple burial scenarios.

#### *Familiarization with the tools and basic rescue strategies*

For some participants (P1, P13, P15b)[1], the beacon park was their first experience with a beacon and with the avalanche companion rescue protocol. Their learning largely revolved around the basics of the avalanche transceiver technology: how to turn the beacon on, how to switch between transmit and receive modes, and how to read the signals as one moved over the terrain. Even experienced people practiced with their technology. For example, the beacon park was seen as a good place to get to know new equipment, as functions and modes often differ between beacons. As P10b said, her motivation for coming to the beacon park was to "*get used to my new beacon and practice avalanche rescue*".

The beacon park also served as a catalyst for participants to become aware of technical or logistical issues with their equipment. For example, P4 arrived at the beacon park with his own beacon, but he realized that his beacon had dead batteries. This small incident took on an important meaning when the participant reflected on what this would have meant if he had been in the backcountry and he had to rely on his non-functioning device.

While beginners tended to focus on the technology (at least initially), they – along with more experienced people – were also interested in acquiring skills about using that technology within the context of an actual search. As P3c said: "*It's not just about turning the beacon on, but about the way to do the rescue too*". For example, P16a (who had companion rescue experience) used the beacon park as a place to show his girlfriend (P16b) the basic search movements during the coarse and fine search, including how one should respond to the signal seen in the beacon.

#### *Mastering particular skills*

Some participants used the beacon park to focus on particular skills in order to master them. For instance, participants P3b, P5 and P10c all mentioned that they wanted to use the beacon park specifically as a way to become more proficient with multiple burial scenarios. In their case, they used the simpler scenarios (single burials) as a warm up exercise before engaging with the scenarios they wanted to gain more experience with. The beacon park had two multiple burial scenarios. This allowed participants to acquire new skills and strategies in the first one, and then practice those in the second one. This is something that is rarely done when recreationists practice on their own, since multiple burial scenarios require more time, organization and equipment than preparing single burial scenarios.

In another example, P11a and P11b, a couple, pushed each other to get the fastest times on the single burial scenarios. While one was performing the rescue, the other observed and timed the rescue. This outstanding example showed how certain exercises could be created ad hoc in the technological setting of the beacon park without the need of external facilitation or suggestion.

Reaching a mastery level for avalanche companion rescue requires more than knowledge about the beacon. It also includes a clear understanding of all the steps of the rescue, including getting equipment outside backpacks, and knowing how to shovel most efficiently. The beacon park cannot mandate that all aspects of the companion rescue should be practiced. However we saw some participants making the most of the current set up. For example, P11a and P11b made sure every rescue started with all their equipment in their backpack and their beacons under their coats. This allowed them to practice not only how to use the beacon, but also how to perform seamlessly the steps required beforehand, such as getting the probe outside of the backpack and assembling it, and getting the beacon outside their coat and turning it to search mode.

#### *Teaching Skills*

Skill learning was not always individual. The beacon park proved a natural setting for teaching. More experienced participants in a group would teach the less experienced participant basic skills (e.g., as in the P16a,b couple above). The beacon park also served as a place for professional teaching. As previously mentioned, the on-site facilitator(s) would respond to questions from participants, and observe their actions and offer assistance as needed. This included walking them through scenarios that they found problematic. Importantly, the beacon park served as a place to support the sharing of knowledge between the practitioners of the same community of practice.

#### *Breaking the false sense of confidence*

In previous research, it was pointed out that practice that is too simple or too easy can lead to a false sense of confidence for backcountry recreationists [7]. In this study, we found that the way the scenarios were organized on the beacon park site and the variety of their expected difficulty could help break that false sense of confidence for participants. This allowed them to realize the complexity and challenges that are part of some avalanche accidents and served as a confirmation that practicing is important for avalanche preparedness.

We often observed the following pattern. Participants who began with a sequence of single burial scenarios got faster and more efficient at finding the single victim. This boosts their sense of confidence about their ability to perform

[1] Participants who came to the beacon park by themselves are referred to as P#. Participants who came as a group are referred to as P#a, P#b and P#c, with same #.

successful rescues. When participants moved to more challenging scenarios, such as a coarse search on a multiple burial scene, difficulty increased significantly, e.g. because they encountered challenging or confusing indications on beacon signals, and because more group coordination was required. In these cases, we saw some participants able to find a first victim but not the second one. In other cases, participants could find both victims but took a much longer time relative to the single burial scenarios. In most cases though, the participants' confidence and trust in their beacon was shaken.

One issue appears to be that participants – particularly those with less experience – had an incorrect view of the accuracy, precision and robustness of the technology they were using. Beacons have significant problems with the multiple signals received in a multiple burial scenario. They do not always display competing signals in an understandable manner. For example, some beacons alternate distance numbers between the two victims, which some found confusing (e.g. P1), while others fix onto one signal while hiding the other. Beacons sometimes lose the signal due to the rapid movements of a searcher. In these cases, they may display messages that tell the searcher to slow down or to stop (e.g. P1, P9), or the screen can even go black. Some beacons try to simplify searching by allowing the search to hide a particular signal (called 'marking'), yet this is considered an advanced feature and introduces further problems. A beacon may even have to be turned off and on again to reacquire a lost signal (e.g. P5). These events are, of course, stressful (as reported by various participants over particular incidences) as this is often the first time they have seen their beacon act like this. Their confidence is shaken, and their mental model of the technology is broken. It is only through practice, repetition and mentoring that participants were able to make sense of the nuances of their beacon and of those signals, where they could eventually perform rescues more successfully.

A sequence of progressively more difficult scenarios helps mitigate this loss of confidence. Although harder scenarios were more challenging, participants appreciated the opportunity to sharpen their skills. For example, P15a said: "*Keep the progression of difficulty going. Maybe also add a 3 person burial scenario, something even more complex*". Our decision to seed the beacon park with multiple scenarios representing different levels of difficulty thus proved important. Scenarios of similar difficulty allow people to return and practice their skills; advancing to the next level gives them opportunity to tackle more complex situations, which forced them to acquire a higher skill level (which they appreciated) and increased confidence.

#### *The beacon park as an individual training tool?*

It was interesting to note that almost half of our participants came alone to the beacon park. For them, the beacon park was understood to be more an individual training tool to practice and develop skills related to the beacon technology and to probing. Yet this is only a small portion of the companion rescue protocol. It is disconcerting that the beacon park is used primarily as a place for individual skill development. An important component of a successful companion rescue relies on the coordination between practitioners, something that also needs practice, as we will see shortly. In addition, when participants came alone to the beacon park, they missed opportunities to learn from each other and to further deepen their relationships with other members of their community of practice. We should note that the presence of our on-site facilitator is the exception rather than the rule with beacon parks.

### Team coordination training

Our second study theme was how the beacon park supported group coordination training. As we described previously, coordination is one of the hardest aspects of avalanche companion rescue, and therefore one of the areas with the most opportunities for improvement. In our discussions with participants, they were enthusiastic at the idea of practicing as part of a group:

"*I think that a group setting is more effective, and more fun that training alone. It is rare, or at least unwise, to travel in the backcountry alone, so training with other people seems to make sense. Also, from personal experience, communication is absolutely crucial in emergency situations, and it's something that is often overlooked, so working it with other forms of practice, or training is a good idea*." (P13).

Yet although most participants agreed that coordination and communication were highly important for the success of companion rescue, only 6 out of 22 reported to have practiced group organization during the last year. In addition, as we will show below, practicing coordination did not come intuitively to various participants.

#### *Lack of communication*

When participants arrived on scene as part of a group, it was only seldom that we saw groups who overtly discussed roles or strategies for the rescue they were about to perform. Instead, we saw couples and groups going in a scenario and starting to focus each on their beacons to look for signals. That is, participants focused on mastering the technology rather than team coordination, and on the details of their search rather than the big picture of what was going on. This lack of communication often carried through to the rest of the search.

For example, P3a, P3b and P3c arrived on a multiple burial scene and started their search. All three found the first signal and focused around it. As the three participants started to do a fine search on the first signal, they were too close together. P3a and P3b were in the way of P3c who was trying to narrow the probing area. Not only was this sub-optimal, but it also meant that no one was searching for the second victim. This could have easily been prevented by simple and short communication between the participants, e.g. 'I'll finish this search, P3b get your probe out, and P3c start the coarse search for the second victim'. Similarly, had a leader been selected, their role would have included identifying and remedying issues such as these.

After observing the above situation, the facilitator debriefed these points with the participants. The participants then moved to the second multiple burial scenario and were encouraged to work more closely as a team and specifically to communicate better. Even so, that communication was lacking, and participants still showed signs of working individually instead of as a group. This is a disconcerting finding. It reveals that coordination and communication may not come easily, and that considerable practice is required to achieve a level of group coordination proficiency.

In summary, participants in groups that lacked communication unduly focused their attention on the beacon. They did not maintain a broader perspective of the situation, which resulted in a loss of situational awareness. This is similar to the finding described in [7] and critiqued as a flaw in beacon designs.

#### *Fluid distribution of roles*

As a contrasting example to the previous case, the group of P10a, P10b, and P10c (who had never performed a rescue together) had much better communication and were able to coordinate on the scene. At the entrance of the scenario, P10c proposed to his teammates to split the avalanche path into search paths for each of them. As they walked down the hill, P10c reached the first victim. P10a and P10b got closer to him as well, as their beacons also indicated that direction. While P10b got ready to help P10c by probing, P10a recognized that he was not needed there and walked past them to search and find the second victim. In this case, the group was able to monitor each other's actions and fluidly take the roles that were the best for the group's success (rapidly deciding to be a prober, or to leave the first victim and start the search of the second).

#### *Specialized roles*

Our results also show a third (but sub-optimal) strategy for groups practicing together: mastering specialized roles as part of a team. In some cases, participants, often groups of 2, would each lean towards a role that they would keep from scenario to scenario. For example, P11a acted as the prober while P11b did the fine search and the bracketing.

"*The most challenging parts were probably working out how to best work efficiently as a team. After several tries, we realized that it was best if as soon as one of us got a signal, the other one immediately started getting out their probe. Since it is relatively quick to follow a signal and relatively time-consuming to get out a probe, it almost always still worked out that the person following the signal was bracketing the site by the time the person with the probe was ready to start trying to get strikes*". (P11a)

Their strategy led to very efficient practice rescues. However, the challenge with this strategy is in the lack of flexibility between the roles. In a real accident, one never knows who might be a victim and thus not able to perform their role as rescuer. Hence, it is as important to practice other roles to be more versatile. P11a and P11b eventually recognized this as a problem, where they exchanged roles during their last scenario in order to get a feel for each other's role.

### Designing beacon parks as technological training grounds

An important component of how a beacon park is experienced relies on its set up on the terrain and how it is presented to recreationists. In this work, we evolved the beacon park over our study period. Based on our observations and self-reflections about our practices, we now share the varied decisions we made about this technological training ground, and how it influenced participants' ability to practice and develop their skills and team coordination practices.

#### *Physical constraints in the beacon park*

The beacon park is a technology-augmented context for training, where it should be designed to mimic real-life threat situations. This implies a combination of two things: real life elements as reflected in the terrain; and the technology itself.

Ideally, we wanted terrain that was on a steep slope resembling an avalanche slope. However, this desire had to be balanced against how accessible the beacon park would be for participants, and the constraints imposed by the terrain the ski resort management provided for us to use. The somewhat flat terrain we used (which is true of most beacon parks) did not match a typical avalanche slope. As well, the snow quality (usually packed snow from people walking on it) differed from the very hard-packed and jumbled snow that results from an avalanche. In addition, the trampled ground of a beacon park does not visually resemble a real avalanche, which rescuers would normally scan for visual cues indicating the avalanche path and the debris zone. For example, P3c critiqued:

"*The beacon park is generally in a flat area, on snow that is easy to access and walk on. In a real avalanche, the terrain would be much steeper and walking in avalanche debris is more like walking on boulders. So this is not exactly realistic*." (P3c)

The technological factors are the number of practice beacons and how they were located and buried across the area at various depths. This greatly influences scenario difficulty. Deeper burials are more difficult to pinpoint, and particular combinations and distances of activated beacons alters how searchers see signals.

Thus our terrain choice and where to position each beacon had an important impact on the degree of a scenario's simulated avalanche accident fidelity.

*Scenarios require explicit communication of their details*

Because there is no real avalanche, details of scenarios have to be explicitly communicated to the participants. This includes where the scenarios are located and the number of victims. In our study, the facilitator verbally explained each scenario to the participants, and bamboo poles marking the top and bottom of the imagined avalanche zone served as visual cues. Although participants were generally able to imagine the avalanche path and the debris zone, others found that more challenging. For example, P10a mentioned:

"*The run out zone (or where the debris would be) requires a lot of imagination on my part, maybe this could be improved.*" (P10a)

*The role of the facilitator*

A good facilitator is someone recognized as an 'old timer' in the practice of backcountry skiing and avalanche companion rescue, and one who is able to pass on their skills to others. However during avalanche courses, most beacon parks do not operate with a facilitator. Thus if a group uses the beacon park, its members often rely on a more experienced group member to mentor them (although that person may not necessarily have appropriate training).

In our study, many of our participants were novices and needed some orientation for how to use the beacon park. Because we supplied facilitators, their first role was to introduce the park and how to best use it, including what scenarios to do, in what order, and where scenarios are physically located. As participants pursued scenarios, the facilitator answered many questions, ranging from specific questions about advanced functions on beacons to deeper understanding of rescue strategies.

Finally, we found that participants appreciated debrief sessions or feedback from the facilitator. Once a scenario was completed, the facilitator summarized his observations and asked participants to describe what they saw, how they felt and how they think things could have been better. Through this discussion, the facilitator encouraged the participants to realize what they could do differently. Those conversations often led to improvement in the next scenario performed. For example, with the couple P11a and P11b, the facilitator explained a specific strategy for probing that is particularly efficient with two rescuers; a strategy they tried and found successful in the next scenario.

In our view, the presence of the facilitator (which as we mentioned is not the norm) was crucial for an effective use of the park. Without the facilitator, people could easily develop poor practices that could jeopardize how they performed companion rescue during a real avalanche. Participants recognized the value of the facilitator: "*Having [the beacon park] staffed also really helped, because when you have someone teach you, this makes a large difference*." (P10c)

## DISCUSSION

Our results provide insights to particular changes that can make beacon parks more efficient, more inviting and more tailored to the training of backcountry recreationists. In this discussion, however, we focus on high-level strategies that we believe can be applied to technological training grounds beyond avalanche companion rescue. These include training and simulation systems for non-experts in many fields, including but not limited to extreme sports.

### The value of progressive scales of difficulty

We saw significant value in using progressive scales of difficulty in beacon park scenarios. As previously described, the facilitator encouraged participants to follow a progression, where he asked them to do simple single burial scenarios first until they mastered their basic skills, and only then to make their way to the complex multiple burials. While solidifying basic skills increased self-assurance, the complexity progression of the scenarios did not lead to a false sense of confidence. Instead we saw how more complex scenarios provided a space to ask questions, reflect on more difficult situations, understand device and personal limitations, and overall provide a sense for how hard companion rescue could be. Learning is influenced by the progression of scenarios, by practicing in that scenario's context, and (sometimes) by group mentoring. This follows the theory of situated learning [14] where the physical and social situation constructed a context for participants to make sense of some functions or errors of their beacons as they pursed their practice.

The idea of progressive learning and learning by mastering is, of course, not new. Indeed, many formal learning environments are structured so that students must achieve proficiency at a given difficulty level before they are allowed to continue to the next level. In spite of this, technological training grounds (such as a beacon park) are not structured in this manner. They are offered as environments where people attempt to learn on their own in an ad-hoc manner. We believe these training grounds can be improved dramatically by offering scenarios of increasing difficulty (as we did), by explicitly describing skills that should be mastered at that level, and by offering a way for learners to 'grade' themselves in terms of mastering a scenario level. For example, some beacon park control boxes are configured to trigger particular beacon patterns (as beginner, intermediate or expert scenarios) rather than ad-hoc beacon activation. Posters and booklets on-site can indicate scenario difficulty and the skills that should be worked on. Printed or digital material (accessible via a mobile device) can accompany each scenario that describes best practices (e.g., by printed storyboards or through digital videos). Criteria can be included (e.g., expected time to find a victim in a given scenario). These techniques are readily applicable to other training grounds.

### A variety of levels of fidelity

The beacon park is a technological training ground that includes a variety of levels of fidelity along the three aspects of environment, equipment and psychological [2] (as described in our related works section). Throughout our results we have articulated how certain aspects could reach a higher level of fidelity while others could not. For beacon parks, the level of environmental fidelity is difficult to manage, for it is heavily constrained by the terrain available. If varied terrain is available, areas should be chosen to match the scenario conditions (e.g. steepness of the slope, the presence of terrain traps, etc.). However, the level of fidelity for equipment is under our control. As we saw, signals from buried beacons are indistinguishable from real beacons, and we expect learners to bring in their own personal equipment including their personal beacons.

The low level of environmental fidelity can be partially remedied by manipulating the psychological level of fidelity, i.e., the ways participants construct believable stories for themselves about the rescue situation. This is especially important for practicing team collaboration [2]. In our study, this was done by constructing scenarios that included a story of how the avalanche happened, using buried beacons to represent victims, and by visually marking areas in the environment to simulate environmental conditions (e.g., bamboo poles indicating avalanche boundaries). We saw that participants were largely able to construct the story in their minds and reach a higher level of psychological fidelity. The novelty of each scenario added to their believability since scenarios were created by others. In addition, we could manipulate people's stress (e.g., by observing, timing and critiquing people's rescue performance), which proved effective in increasing the level of psychological fidelity.

More generally, technological training grounds should follow similar practices. When environmental high fidelity is not possible, they should offer a story behind each scenario (again, through on-site posters and visual markers, and/or through print and digital media). At its best, the technological training ground should offer a 'full mission' context for practice (in the words of Beaubien and Baker [2]) while still operating within the constraints of multiple ranges of fidelity.

### Balancing skill development and coordination training

We saw a large number of participants focus on learning individual skills at the cost of communication and coordination training. This likely occurs because, at the surface level, the beacon park emphasizes the technology itself (beacon search), whereas the need for communication and coordination learning is tacit and thus easily overlooked. This very likely happens with other technological training grounds.

The solution is, in part, to make communication and coordination learning an explicit activity. The scenarios and learning descriptions mentioned earlier should include these not only as goals to incrementally master, but should describe the steps on how to achieve them. If individuals (rather than groups) appear on site, the usage descriptions of the area should highly encourage them to find other like-minded people to do the exercises together. Perhaps meeting times can be advertised as a way for ad hoc groups to gather opportunistically.

Moreover, in our study we saw how the facilitator played an important role in orienting discussions and debrief sessions around group communication and coordination. In cases where a facilitator cannot be present, questions or themes for discussion can be available on site on cards, posters or through mobile devices for participants to use as discussion starting points.

### Supporting the community of practice

As we have presented earlier, we see backcountry recreationists as a community of practice. However, we also observed that learning from others within beacon parks is not as common as it could be. As with communication and coordination, this is also likely due to the emphasis on the technology, which seemingly favors individual skill development over group learning. This also likely occurs with other technological training grounds

A partial solution is to recast the technological training ground in a way that encourages mentorship and facilitation within the community of practice. Since the scenarios are structured and ready to use, members of the community can go straight to the heart of the topic without spending a whole day preparing the site. For example, it could be presented and advertised as an area inviting people with more skills to teach novices particular skills. For instance, when a person has mastered a particular scenario difficulty and skill, they could be encouraged to mentor others going through simpler scenarios. The payback is that people often gain even more mastery by teaching.

Communities of practice often have structured clubs and organizations, where its members gladly teach others or act as facilitators. Importantly, technological training grounds such as beacon parks provide a common space where members of the community can group and build relationships between each other, which creates opportunities for more knowledge exchanges. To encourage this, technological training grounds should be bookable by such organizations, where they can offer lessons, facilitators, and/or scheduled times for a group of like-minded people to meet. As part of this, the meeting times should be advertised, perhaps by on-site schedule posting or through a social media network associated with the site.

## CONCLUSION

In this paper, we have looked at the specific case of avalanche beacon training parks as a way to illustrate how technological training grounds can support skill development and team coordination training for recreationists. With regards to the design of technological training grounds, our findings point to the importance of progressive scales of difficulty; the management of different levels of fidelity; the balance between skill development and team coordination training; and strategies for supporting a community of practice.

We reiterate that one of the distinctive aspects of this work is our focus on recreationists rather than professionals. We also believe our findings can apply to other non-expert groups in non-extreme situations. For example, Dunlap et. al. [9] explored the role of technological training grounds for learning by citizen scientists who may have little background in the area. While the authors initially focused on skill acquisition (which also involved a mobile device), feedback from citizen science experts suggested that they should also consider citizen science as a community of practice, i.e., where citizen scientists should be expected to learn and perform the activity together, including self-coordination. While their context and methodology differs significantly from ours, the fact that their results are similar to our own suggests that these results are likely generalizable to technological training grounds supporting different communities of practice in a variety of domains.

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