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Discussions

Smartphone applications for communicating avalanche risk information – a review of existing practices

M. K. M. Charrière and T. A. Bogaard

Water Resources Section, Delft University of Technology, Delft, the Netherlands

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Correspondence to: M. K. M. Charrière (m.k.m.charriere@tudelft.nl)

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Abstract

Every year, in all mountainous regions, people are victims of avalanches. One way to decrease those losses is believed to be informing about danger levels. The paper presents a study on current practices in the development of smartphones applications that are dedicated to avalanche risk communication. The analysis based on semi-structured interviews with developers of smartphone apps highlights the context of their development, how choices of content and visualization were made as well as how their effectiveness is evaluated. It appears that although the communicators agree on the message to disseminate, its representation triggers debate. Moreover, only simple evaluation processes are conducted but there is a clear awareness that further scientific efforts are needed to analyze the effectiveness of the smartphone apps. Finally, the current or planned possibility for non-experts users to report feedback on the snow and avalanches conditions open the doors to a transition of these apps from one-way communication tools to two-ways communication platforms. This paper also indicates the remaining challenges that avalanche risk communication is facing, although it is disputably the most advanced and standardized practice compared to other natural hazards. Therefore, this research is of interest for the entire field of natural hazards related risk communication.

1 Introduction

The practice of recreational mountaineering activities, such as backcountry and off-piste skiing has increased significantly (Jamieson and Stethem, 2002; Tase, 2004; Harvey and Zweifel, 2008; Burkelijca, 2013). Unfortunately, every year people die practicing these sports by being buried in an avalanche. The appropriate way to reduce the number of fatalities lies in forecasting and education (Harvey et al., 2013). However, the best forecast is worthless if it is not communicated and fully understood by the users (Burkelijca, 2013). Consequently, the question arises if the current ways of informing recreationists about the dangers levels and the mitigation behaviors are effective. A literature overview highlighted that numerous papers presented in the proceedings of the regular International Snow Science Workshops, deal with this topic by relating to the form, the content, the use and the suitability of avalanches bulletins and tools to disseminate them (Dennis and Moore, 1996; Conger, 2004; Tremper and Conway, 2006; Statham et al., 2010; Burkelijca, 2013; Johnsen, 2013; Klassen et al., 2013; Landrø et al., 2013; Valt and Berbenni, 2013). It shows that the avalanche experts' community is highly concerned with providing effective avalanche risk communication and that discussions on what are the best practices to adopt are still taking place.

In the last years, several smartphone applications were developed to communicate avalanche risk. Generally, as the smartphone market is growing (IDC, 2015), it interesting to consider the wireless mobile technology for disaster risk reduction related communication.

The effectiveness of avalanche education, and by extension communication, is sometimes casted doubt on because change in behavior is not achieved by providing information only (McCammon, 2004a). However, the apparition of these smartphone apps shows that the development of communication is still considered useful and valuable.

Developing risk communication campaigns is very resource consuming. Therefore, risk communicators have great interest to make their communication efforts effective. Proceed to a systematic evaluation of the effectiveness is thus necessary. In the case of avalanche risk communication, and in particular using smartphone applications, no scientific research had been published on the topic. Before conducting a real evaluation research of the smartphone applications dedicated to avalanche risk communication, it is important to assess how current practices are developed, what and how choices were made, what questions and challenges avalanche risk communicators face and how the apps' effectiveness is evaluated.

Therefore, this study aims at providing a detailed investigation and analysis of their development and evaluation as a first step towards the understanding of the impact

of risk communication on the avalanche damages reduction. The interest of this work goes further than avalanche risk communication. It is interesting to focus on it as it is globally more advanced than communication related to other hazards. It is the only natural hazard for which, after long debates, an international standard for the dissemination of risk information was developed, i.e. the public avalanche danger scale. Consequently, the findings, lessons learnt limitations and recommendations that are derived from this work can be taken into account in the future development of risk communication practices linked to others natural hazards.

2 Methodology

In order to describe the way smartphone applications disseminating avalanche danger information are developed and consecutively evaluated, semi-structured interviews were conducted via Skype during the fall 2014 with developers of six of the seven available smartphone apps which focus on avalanche risk (Table 1). Those are the apps which provide avalanche forecasts and warning but that are not specifically developed for searching victims or as an aid to risk assessment.

Interviewees were identified through the webpages of the smartphone applications. Snowball effect facilitated the process of access to the interviewees. The qualitative analysis presented here is based on the interviews' reports whose content was checked by the interviewees. No discourse analysis was undertaken because it is out of the focus of our work. Observations from the authors' use of the Apps completes the interviews.

To address the way the smartphone apps were developed and evaluated, several parameters were taken into account in the analysis. There were chosen according to the pillars of risk communication (Höppner et al., 2010): (1) actors, (2) purposes, (3) modes, channels and tools that we combine into means and (4) message; as well as to risk communication evaluation research (Rohrmann, 1998). Consequently, we produced descriptions of:

– the Apps in terms of developers, content and mean,

– the development of those in terms of: purpose, target audience, choices of content, visualization approach and tools as well as the place of the Apps in a larger communication plan,

– the evaluation strategies, i.e. users' feedback, usage, understanding, effectiveness.

Additional information about the apps were retrieved from the interviews and can be found in Table S1 in Supplement.

3 The smartphone applications

3.1 Description of the communicators

Apps 1 and 2 were commissioned by warnings services of North America and Apps 4 and 5 by European ones. All the corresponding interviewees are avalanche experts. Apps 3 and 6 were created by actual apps developers who both are recreational mountaineers. They are not avalanche experts but are familiar with the topic as they both work for or in collaboration with the avalanche centers that are producing the data used in the apps they developed.

3.2 Description of the content of the apps

The smartphone apps contain several types of information (Table 2) but the main content is the avalanche bulletin with the avalanche danger level. The international standard danger scale with five levels (low, moderate, considerable, high, extreme) is used and displayed. Apps 3, 4, 5 provide an explanation of the danger scale. While App 3 provide links towards the websites of each considered forecast regions in order to get further information, the latter is included directly in the other apps. Apps 1, 2 and 5

give more detailed information using the avalanche problems "concept", i.e. the types that can occur given a set of conditions (Landrø et al., 2013). However, the use of avalanche problems are strictly present, i.e. with all defined characteristics (Table 2), in Apps 1 and 5. For those two apps, even though the danger level is still the first information to be presented, the avalanche problems are given a central position in those apps. Note that the concept of avalanche problem is not completely inexistent in App 4, as when the situation requires, it provides several danger maps according to the type of avalanches. Moreover, dangers pattern (avalanche prone location in terms of slope aspects and elevation) are described like in App 6.

Additional information such as weather condition and snowpack information are standard in all apps. In one case, it is completed with information on road conditions, the emergency contacts, the users' observations as well as the terms of use.

3.3 Ways of presenting the information

3.3.1 Use of maps

Maps are often used to present hazard and risk information in general (Dransch et al., 2010) and also related to avalanches, in particular internet mapping (Conger, 2004). However, in the case of the six Apps, the use of maps is not standardized. App 2 does not use this type of visual mean. App 1 uses maps for localization purposes and access to the regional bulletins. Apps 3, 4 and 5 display danger levels with colored polygons on a base map, while app 6 shows the icons rather than the color on the polygons. In addition to represent danger levels or to help for localization, additional use of maps is present in App 4. They are used to display snow related observation.

3.3.2 Icons

Several icons appear in the apps (Fig. 1). The symbols of the avalanche danger scale (A) are used as a legend banner (App 3), to display the highest danger rating on the

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map (App 6) or in the bulletin (App 1, while icon G is used here on the map). Single icons (B and C) are used in, respectively, Apps 2 and 5 to represent the danger ratings according to elevation and slope aspects; while two separate icons display this information (E and F for App 6; D in App 4). The four e icons are used in App 1 to display the different information that defines an avalanche problem, i.e. the elevation, the aspects, the chances and the expected size.

3.3.3 Texts

Even though the smartphone applications have a major visual component, text is used quite extensively. Typically text is used as followed: (1) one sentence, placed at the top of the main page, describes the danger situation, (2) few words are used in support of icons for the danger level (e.g. "moderate"), elevation/aspects repartition (e.g. "In all aspects above approximately 1800 m") or avalanche problem (e.g. "naturally released"), and (3) extensive and elaborated text to explain detailed information on the current danger situation, the recent activity, the avalanche problems, the snowpack stability, the weather, and/or the forecast tendency.

3.3.4 Terminology

The term "danger" is globally used. No occurrence of "hazard" were noticed. Reference to the "risk" terms was found in App 6, in the expression "risky expositions". Note that in the App 1, there is no mention of any of those words. The bulletin and forecast are expressed only with the words linked to the different levels of the danger scale, e.g. "considerable" or "moderate". The likelihood of avalanche problems are expressed as "chances" with the terms "unlikely", "possible", "likely", "very likely" or "certain" in App 1. In App 5, terms related to probability are used, for example "probable" or "low probability".

4 Development of the apps

4.1 Purpose of developing the apps

The general purpose of developing those apps is to inform about avalanche risk making use of the smartphone technology. Its main advantage according to the interviewees is the ease of access of information in terms of timing and location (e.g. when people do not carry their computer or when people are on a recreational sites). This general purpose is common to all apps, but more specific purposes were mentioned as well, such as increase awareness and reduce the loss of lives (App 5), help users plan their trips (App 1) as well as retrieve users' observation (App 2). Moreover, in the case of the two apps developed by avalanches non-experts, the more specific reason for their development was that the developers wanted to fulfil their own needs. Being themselves recreational mountaineers, they wanted to quickly access avalanche risk information using their smartphone.

4.2 Targeted and actual users

From the interviews, it appeared that the Swiss app (App 4) targets the general public in its totality, while the other apps are developed for recreational mountaineers (snowmobilers, off track skiers, backcountry skiers) independently of their knowledge and skills. An additional users group is targeted by the App 5, i.e. road managers. App 6 was primarily developed for a young audience as they were the main users of smartphone at the time of development. The developer therefore chose a cartoon style of the app, i.e. colorful and with a little animal mascot. However, it is stated on the website that some part of the apps are designed for "advanced users".

The actual users of the considered smartphone applications are globally unknown. None of the developers has a way to find out. One reason that was given is the lack of resources and expertise to carry out such kind of survey. However, the assumption is sometimes made that the users must be the targeted one and there is some knowledge about some types of users. For example, the developer of App 6 knows that mountains guides are using it. A survey of the WSL avalanche bulletin, which is displayed in App 4 but also on their website, shows that people accessing the bulletin are active backcountry tourers or freeriders (Winkler and Techel, 2014). Interest to gather users' statistics was expressed by several interviewees. One action that was proposed would be to analyze where the users come from and cross this with forecasting regions in order to get insights in the differences between people living in those and the persons that do not.

4.3 Basis for choice

4.3.1 Of content

When asked how the content of the apps were chosen, it was most of the time implicitly answered that the information displayed is the useful one for the users. Common sense was stated as one basis for choice. In addition, requirement from the smartphones operating systems were mentioned to have an influence (Apps 2 and 4) as well as the opinions of the warning services (App 6).

4.3.2 Of display's approach

Except for App 3 which only provides the danger level with links to avalanche warnings services' webpages, all the other applications are constructed around a pyramidal approach. When this is explicitly stated by the interviewees, the reason behind using this approach is that the most important information, i.e. the danger level, has to be presented first. The rest of the information is presented by going more and more into details as tabs are accessed or as users scroll down. The term tiered approach was used by the interviewee of App 1. The associated reason is rather the need to address all potential users (with potentially a wide range of abilities and knowledge) than the importance of the information. This logic was also expressed by the App 5 interviewee.

A perfect bulletin should address non-experts users with headlines, dangers levels, exposed area and avalanche problems only, while trained users need more detailed information in order to take decision about the "trip" they will do.

4.3.3 Of visual tools

One given reason to display the danger level on a map is the fact that people do not want to read text and therefore using a visual is the best way to present the most important information. Moreover, it is believed that in this way a quick overview of the situation on a whole area is possible and this help for the planning of a trip. This perspective is not shared by all interviewees. In App 1, the map is only used for localization purposes and access to the regional bulletins. The given reason for not displaying the danger level by coloring the full forecast regions is that it would be a too serious simplification to make. Nonetheless, the danger levels appear on the map by the display of an elevation icon (G in Fig. 1). App 6 makes use of a map in a similar way: it is used to demarcate the forecast regions and display the overall danger with one of the icons of the avalanche danger scale, in order for users to get an overview and choose a region for their trip. Similar concerns linked to the difficulty and the danger associated to the aggregation of local information in a larger area, resulted in that fact that App 2 does not present any maps.

4.4 Place in a larger communication plan

All apps created by avalanche warning centres are not the only communication tools they used. They all have a website to communicate the bulletins, which is sometimes viewed as the most important communication tool amount all, the application only coming to support it. Other means of communication are social media, blogs, telephone and newspapers.

It is interesting to note that the Norwegian application (App 5) was built in a multi-hazard framework of risk communication. In addition to present avalanche bulletins, it shows the bulletins related to floods and landslides.

5 Evaluation of the apps

5.1 Users' feedback

Possibilities for users to send a general feedback through the app are limited. Only App 6 has a form included in the app, which is said to be usually used to report on technical aspects or to ask if the app is available for other regions. App 2 provides a direct link to send an email. However, other feedback possibilities exist. On the associated webpage of App 5, it is possible for users to report if the bulletin was useful using a like/dislike button. In addition, it appears that the Avalanche Canada receives feedback by emails or phone.

Although opportunities for general feedback are not very extensive, the importance of another type of feedback, i.e. giving the users the possibilities to share their observations on snow and avalanches conditions, is put in practice or acknowledged for most of the apps. The best example is given in App 1. In addition to date, time, location and possibility to attach picture, people can report on skiing, snow, avalanches and weather conditions and they can add comments. Currently, the observations are not moderated as no inappropriate content was ever posted. In future updates, incident reports will be possible as well as more detailed observations concerning avalanches, snowpack and weather.

Although the reporting of observation from the users is stated as one of the goals to develop the app, App 2 does not propose a similar form but uses a link to send emails. However, the possibility to send more structured reports will be given in the near future. Similarly, observation forms are planned to be added to the apps in the future versions of Apps 4 and 6. There is no direct way to provide feedback using the

Varsom application. However, observation feedback can be done using its twin app, i.e. regObs.

5.2 Usage monitoring

Almost all applications proceed to a technical monitoring of the usage. The used metrics, that vary from app to app, are, for example, number of downloads, number of people using the app, number of time specific features of the app are accessed. One interviewee stated that the latter is useful for example to assess if there is a need to move or remove some features. At the time of the interview, the usage of App 5 was not yet monitored because it was launched for the first time that winter but it was mentioned to be included in the near future. Both monitoring of the usage of the apps and of the website, which also provide avalanche warning information, will be compared to see if the use of each of the tools is influence by variables such as danger level or state of the weather.

5.3 Understanding of content and visuals

Two of the six apps have been evaluated on content and presentation. App 1 was evaluated during the design phase. Basis surveys were conducted to assess what people understand/think when they see the information. It appeared that participants understood the different icons that are used and the representation of variation of danger level depending on the elevation. Moreover, risk communication experts were consulted on the ways to display the forecasts as well as on the use of icons and text.

The WSL (App 4) proceeded to a quality and usability evaluation by an internet survey in 2008 (Winkler and Techel, 2014). Note that this evaluation did not focus on the app in particular but on the bulletin that is displayed in both website and app. Nevertheless, it induced a revision of the bulletin for both tools in 2012. This evaluation resulted mainly in the modification of the display of the bulletins according to the pyramidal approach favored by the European Avalanche Warning Services (EAWS, 2009).

Danger patterns information were therefore removed from the danger level information and placed in a separate “tab”. Moreover, the interviewee reported that the bulletins’ visualization by pre-defined regions has led to non-understanding. Therefore, they were removed and currently the extent of the different levels are shown independently of any pre-definition of regions. In 2014, a second survey allowed to assess the results of these modifications. Interesting results, in the light of this work, are that the new way to inform about danger pattern is an improvement and that the large majority of the participants find the bulletin very important.

App 2 interviewee declared that a process that would allow to test the effectiveness of different ways to present the same information has started. Tests are planned to be conducted in collaboration with experts in people surveying. The use of a game environment in which people could choose, between different formats (3-D vs. 2-D, separate icons vs. combined icons), the ones they prefer or understand the best, is considered.

App 5 was not evaluated for itself but previous users’ surveys conducted for the website had an impact on the way information is displayed in the app. Apparently, users did not understand the complex drawings that were used to illustrated avalanches problems. Consequently, visuals are now only used for aspect and elevation information. Currently, only one icon is used for the two types of information (Fig. 1b). Previously, on the website, two distinct icons were used in order to ensure that the users, mainly the Norwegians, would understand. The combination in one single icon was done because it is the way that most warning centres use to present such information and that non-Norwegian are already used to this “standard” visual.

5.4 Effectiveness

Globally, the need to proceed to an evaluation of the effectiveness of the apps is acknowledged. Several goals for an evaluation, which is sometimes in the process of being developed, were proposed: satisfaction of the users, understanding of the information provided, remembering of the information, change in risk and danger per-

ception, increase of awareness as well as change of behaviors. An indirect evaluation using the users’ comments that are written on the downloading websites (Apple Store, Android Store) was also mentioned.

Resources-wise and methodological reasons were given to explain why such evaluations were not yet performed. Lack of expertise, funds and time constitute the first type of reasons. Related to the second type, the increasing difficulty of truly evaluating the effectiveness from a satisfaction survey to an analysis of the change in behavior was mentioned. Moreover, one interviewee remarked the need to conducted longitudinal surveys during several years in order to assess the changes in behavior.

6 Discussion

6.1 The communication chain

The communication chain of the considered smartphone applications takes place either between warning services and users (Apps 1, 2, 4 and 5), i.e. via direct communication flow; or between application developers, who use the information from the warning services to feed their app (Apps 3 and 6), and the users, i.a. via indirect communication flow. In the first case, the apps were created to use the intrinsic benefits of this technology as an extension of the websites that already existed. Concerns on the way avalanche information should be communicated did not start with this relatively new mean of communication but they did not disappear either with its use. The interviews did not reveal that the development of these apps is part of a clearly defined communication strategy. However, being multi-hazards (avalanches, floods and landslides), the Varsom app is taking part in a larger communication plan that aims at informing the public on all the major natural hazards that are occurring in Norway.

The indirect flow of communication is due to a combination of the need to fulfill personal needs and expertise in smartphone technology. The fact that the developers are not the creator of the information could be seen as a threat to correctness of information and an open door to the dissemination of false messages. However, this is solved by use of information directly from its source, i.e. the warning services who collaborate with the developers. Added to the fact that the information provided by the apps is relatively basic, this type of communication chain, with involvement of external parties, is thus reliable. This indirect communication flow is possible because the data is open-access (in one case under signed agreement) and because no legal constraints currently regulate the way avalanche danger information should be communicated (see Supplement). Nevertheless, most developers protect themselves from any legal action from users by adding a disclaimer at the start page of their App.

The willingness of warning center to share their data as well as the unconstraint legal context are favorable conditions for the involvement of external parties having risk communication expertise. Even though the latter were sometimes consulted, it did not come forward from the interviews that they directly took part in the development or evaluation of the apps. However, following some of the interviewees, we believe that a systematic involvement of risk communication specialists could increase the effectiveness of such communication tools.

6.2 Appropriateness of content

The central content of all described apps is the avalanche danger level. For all apps, this information is disseminated using the avalanche danger scale. This instrument, which purpose is risk communication (Statham et al., 2010) is now, after years of debates and development (Dennis and Moore, 1996), the standard to communicate avalanche forecasts. This shows that the development of the smartphone apps fall within the continuation of the framework to communicate about avalanche risk. The use of smartphone technology did not trigger a major change in the information that was already communicated using other communication tools. This means that the information at stake is easily transferrable from one platform to another and that the apps are not seen as a real different communication tool. It seems to be perceived as another type of “computer screen” on which the same danger information can be

displayed. However, there are can be differences in the effectiveness of each type of communication tools. For example, in relation to the accessibility, the use a mobile website compared to an App is more inclusive, and therefore maybe more suitable to target as many people as possible, as there is no issue related to the operating system or type of device. Therefore, evaluation and comparison studies are a must to verify if smartphone applications are as effective to communicate the same information as other communication tools and, if not so, what content adjustments should be made.

The fact that the use of smartphone app is the logical continuation of the existing communication framework can explain why the response to the question on how the choice of content was made, were hard to obtain. The interviewees seemed puzzled by this question. It seems therefore that the reasoning behind this choice is somehow implicit or following common sense as said by one of the interviewee. This and the fact that the content of the apps are relatively similar, suggest that there is no debate on what is the most important information to disseminate in effective avalanche prevention communication tools. It is interesting to note that this communicators’ community is very strong on what is the most important information for prevention while it is not always clear what is the most effective information to disseminate between hazard, risk or protective actions in order to achieve disaster risk reduction related to other natural hazards. However, avalanche communicators should not forget that the message they provide might be new to some users and that some explanation is required. Indeed, only three applications provide a description of the avalanche danger scale. But whether the absence of explanation has an impact on the understanding of the bulletin by various users is still unexplored.

As a matter of fact, previous knowledge, ability to understand and needs of potential users are elements that must be considered to ensure effective risk communication. This is especially the case when the information is ample. In addition to the avalanche danger scale, half of the apps present “avalanche problems” (see Sect. 3.2). Those are considered to assist in decision-making (Atkins, 2004 from Klassen et al., 2013; Landrø et al., 2013) as they can help recreationists to make choices of area to go to

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and techniques to avoid danger (Klassen et al., 2013). Avalanche problems can help understanding local conditions while danger levels give information on the extent of the issue (Landrø et al., 2013). In other words, danger levels help for awareness raising while avalanche problems are risk mitigation information (Klassen et al., 2013). Even though risk mitigation was not specifically stated as one of the purposes of Apps 1 and 5 which do include avalanche problems, it is implicit that they were designed in this line of thought. Note that risk mitigation can be addressed using other means than avalanche problems. App 4 proposes a wide range of tools (e.g. situation analyzer, risk reduction method) to help decision-making. Consequently, there is a need to pursue the effort started by Landrø et al. (2013) of evaluating the use of avalanche problems as a risk mitigation tool for different types of audiences (e.g. experts and lay persons).

6.3 Non-uniformity in the use of visualization tools

While the use of the avalanche danger scale is not under discussion, not all its components are uniformly used. Its icons (Fig. 1a) are only used in 3 of the 6 Apps (ID 1, 3 and 6). App 4 uses a different color scheme for level 5 (black-red checked pattern instead of black). In addition, travel advices, which are one of the components of the avalanche danger scale, can be found sometimes in the textual explanation of the danger situation in all apps (except App 3). They are only systematically presented in avalanche problem sections in Apps 1 and 5. Finally, non-uniformity in the use of maps or aspect/elevation icons, is an illustration that the current debate among avalanche experts focusses on the representation of the forecast and related information rather than on the content to disseminate or the terminology to use.

Uniformity in terminology is taking place. The term "danger" is used in all apps, while "risk" and "hazard" terms are not used. Similarly, the level terms of the Avalanche Scale (e.g. considerable) are the same in all Apps. As explained by Dennis and Moore (1996), the debate on which terminology to use took place in the 1990's and the observed uniformity of terminology used in the smartphone applications shows that avalanche experts have reached an agreement on that point.

6.4 Reasons to develop an app

The primary purpose of creating these danger apps is to take advantages of the smartphone technology, e.g. popularity and mobile network spatial coverage. These are good reasons as using a support that is popular can favor access to information. Moreover, the portability of smartphones tackles the issue of overlooking some details or forgetting the bulletin that was checked in the morning while being out in the field, a problem that even seems to happen to the most educated professional (Tremper, 2006). However, this purpose is not one on which a communication effort can be assessed to be effective or not in terms of disaster risk reduction. The effectiveness of a given risk communication effort, similarly as for an educational program, depends on the goal for which it has been developed (Covello et al., 1991; McCammon, 2004a). Such types of goal, like raising awareness or helping users to plan trips, were sometimes mentioned by the interviewees, although generally after the reference to the technical goal of using the smartphone technology. Note that only once the decrease of loss of lives was stated as the goal for creating such apps. It is startling as that this goal can be expected to be the ultimate one for avalanche risk communication. One reason that could explain why this purpose is not mentioned by all communicators might lie in that it is now known that the reasons for being caught in an avalanche are most of the times not due to lack of awareness, knowledge or expertise but rather heuristics (McCammon, 2004b).

6.5 Target audience and tiered approach

This analysis shows that the smartphone applications are targeting a more or less defined audience, from general public to a more precise group, i.e. backcountry mountaineers. There is clearly a need to target the latter as most accidents involve them or off-piste skiers (Harvey et al., 2013). However, the targeted audience is perceived to be heterogeneous in terms of several variables, e.g. level of skills and knowledge or demographical characteristics such as age. Differences between experienced/trained and not experienced/trained users are acknowledged and taken into account by the way the information is presented, i.e. pyramidal or tiered approach. Demographical characteristics are taken into account in one of the app by using an intuitively appropriate design, i.e. cartoon type in order to target a young audience. All these considerations about the audience seem sound. However, there is no verification as the risk communication agencies, except the WSL, do not have data on who are actually the users of the smartphone apps.

The pyramidal approach as well as the use of some icons was recommended by the European Avalanche Warning Services (EAWS, 2009). None of the interviewee specified that they created their apps according so. Therefore, it is not known if the fact that the tiered approach is globally used resulted from this advice, except for the WSL which stated it in a publication (Winkler and Techel, 2014) or from another source. Nonetheless, this shows that the community reached the agreement to use this approach.

6.6 Evaluation types

Evaluations of the apps that were performed fall in the three goal-related types of evaluation of the effectiveness of risk communication described by Rohrmann (1998): content, process and outcome.

The degree of information distribution, is (will be) partially performed by all developers. Monitoring the usage of their apps falls into the outcome type of evaluation. Conducting this is an obvious precondition as the apps can in fact only be effective if they are used. However, although the usage is monitored, the characteristics of the users are basically unknown. Therefore, no validation of the choice of target audience and display approach is available to the communicators. The need to obtain information on the users, essential for effective risk communication, is shared by the interviewees. In addition, they are very conscious that deeper outcome evaluations are needed to assess the effectiveness of smartphone apps in terms of understanding, change in risk perception and behavior. The fact that it is not done appears to be due to a lack of resources and expertise and not to a lack of interest or willingness.

However, other types of evaluation are performed. The evaluation of the comprehensibility of the icons (Apps 1) and message (App 4), which is essential for effective risk communication, relates to a content evaluation. These evaluations were useful as they confirmed the adequate use of icons in the first case and resulted in an effective modification of how the message is displayed in the second case. This type of evaluation was the most cited by the interviewees when asked what evaluation are needed or will be implemented. This shows that the communicators acknowledge that efforts are needed to make the representation of the information understandable as it is suggested by Burkelijca (2013). Second, requests for feedback are implemented. Those relate to a process evaluation. Although not conducted directly in the concerned App but in the linked website, satisfaction with the bulletin is asked using a like/dislike button. It might be useful to allow this feedback directly in the apps in order to increase the amount of data collected for this evaluation criterion.

Another kind of process evaluation is the (future) possibility for users to send observations of the current situation to the providers via the apps. Therefore, there is an exchange of information between the risk communication agencies and the information receiver. The potential of this feedback is important. It goes towards citizen science, volunteered geographic information or community-based monitoring (e.g. Buytaert et al., 2014; Haklay, 2013; Stone et al., 2014); approaches that are increasingly used for disaster risk reduction (Maskey, 2011). In the context of important local heterogeneity of the processes, or in case of data-scarcity (Storm, 2012), the collection of observation by the users can help to improve the forecast. Moreover, observations and incidents' feedback brings a social media component to the smartphone apps where users can exchange information not only with warning services but also between themselves. If this feedback features develop further, moderation will be needed by the warning services in order to avoid the dissemination of erroneous information. Moreover, it will require to decide whether feedback becomes a real dialogue-oriented two-way risk communication practice which has been proven to be effective in terms of awareness raising and willingness to learn risk mitigation (Kuhlicke et al., 2011).

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7 Concluding remarks

This paper analyzed the context and the ways smartphone applications dedicated to avalanche prevention were developed and evaluated. We were able to highlight how choices were made and what are the remaining challenges that avalanche risk communication faces. The two main results that were highlighted by the interviews conducted with the developers of the available apps are that the debate is currently focusing on the way information is presented rather than on what is the most important content and that the effectiveness of the apps, including the choices of display, is unclear and urgently need to be evaluated.

The avalanche experts' community is a tied one. This was shown by several observations. The way a snowball effect facilitated the access to the interviewees is a first example of this fact. Moreover, it was mentioned, most of the time implicitly, but explicitly as well in some cases, that each app creator knows about the other apps, get inspiration and adopted perceived good practices from each other. This is not only true for the development of the apps but in general. There were long debates among the avalanche forecasters on the ways to disseminate danger information. A result of these discussions was the development of the standard avalanche scale. The fact that this tool is used in all apps shows that avalanche risk communication has reached an uniformity and a consistency that is beneficial to users that are traveling worldwide to enjoy mountaineering. This uniformity is also seen in the fact that the content is presented using a tiered approach, and that information helping for decision-making and thus risk mitigation are existent in the apps. However, the specific ways this type of information is presented is not standard yet. Therefore, the risk communicators are facing an exploration phase in terms of how to display, visualize and explain the message that they want to bring to their users.

The need to evaluate the quality and the effectiveness of the apps is widespread acknowledged. Efforts in this sense have been made and further evaluation processes are envisaged. However, several issues are hindering them. Practically, lack of re-

sources and expertise prevent evaluation to be conducted. Moreover, there is a need to define more precise the purposes of the apps. Effectiveness of a communication tool should mainly be assessed by an output evaluation that can only be performed if the goal is precise. Many valid purposes are attributed to the apps: from raising awareness to help for decision-making and planning. Ultimately, it is legitimate to ask whether these smartphone applications contribute to the change in behavior and therefore to a reduction of losses, which is the ultimate goal of any prevention campaign. A sound, scientific, assessment is demanding as it requires longitudinal studies that are complex to operationalize, but are urgently needed. Note that information is not the sole contributing to decision-making (McCammon, 2004b) and as such could be considered of limited use. However, not enough knowledge is currently available to confirm or infirm this position. Therefore, risk communicators should pursue their intention to assess if the message they disseminate using the apps is appropriate, understandable as well as useful. This need for further evaluations can be and should be supported by the contribution of experts in risk communication as well as researchers.

No matter how, the potential of those smartphone applications is important. In particular in relation to the tendency of these tools to be medium for a two-ways risk communication process. The planned upgrade to develop further the possibility for users to report observations and incidents opens the door to adapt these applications for community-based monitoring that can help forecasters or/and sharing information platforms between users.

This study presented the way risk communication tools for avalanche prevention was developed, evaluated and modified. The wealth of expertise and experience available in snow avalanche risk communication should be analyzed and used by communication experts of other types of natural hazards in order to build their own risk communication tools.

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Table 1. Smartphone applications analyzed.

ID Number	Smartphone application	Developer
1	Avalanche Canada	Avalanche Canada
2	Utah Avalanche Center	Utah Avalanche Center
3	Avalanche Forecasts	Independent developer
4	White Risk	Swiss Federal Institute for Forest, Snow and Landscape Research
5	Varsom	Norwegian Avalanche Center
6	SnowSafe	Independent developer

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Table 2. Content presented in each smartphone applications.

CONTENT		Avalanche Canada	Utah Avalanche Center	Avalanche Forecasts	White Risk	Varsom	SnowSafe
Danger level	By defined forecast regions			√		√	
	By forecast regions and by elevation zone	√					√
	By forecast regions, by elevation zone, by aspect		√				
	By homogenous zones				√		
Danger description		√	√		√	√	√
Validity period of the bulletin		√			√	√	
Current day bulletin		√	√	√	√	√	√
2 days forecast		√		√		√	
Confidence level of the forecast		√					
Avalanche prone locations (aspects/elevations)					√		√
Avalanche problems	Type	√	√			√	
	Trigger					√	
	Amount and types of slopes					√	
	Elevation	√				√	
	Aspects	√				√	
	Likelihood	√				√	
	Expected size	√				√	
	Travel and terrain advice	√	√			√	

Table 2. Continued.

CONTENT	Avalanche Canada	Utah Avalanche Center	Avalanche Forecasts	White Risk	Varsom	SnowSafe
Terrain and travel advice		√	(√)	(√)		
Avalanche summary	√				√	
Snowpack summary	√			√	√	√
New Snow (1 day/3 days)				√		
Snow depth (total, at 2000 m, at 2500 m)				√		
Snowpack stability				√		
Measured data at stations for the last 3 days (wind, temperature, snow)				√		
Current weather conditions	√	√		√	√	√
Weather Forecast	√	√		√		
Road conditions/ traffic cams		√				
Inclinometer				√		√
Analyzer tool				√		
Risk reduction tool				√		
Tour planning tool				√		
Explanation danger level/scale			√	√	√	
Explanation (patterns, core zone publication time/validity, avalanche size, interpretation guide slab avalanche, safer six, slope angle, group composition, weather, warning signs, new snow, behavior)				√		
Gear information	√			√		
Emergency contacts		√				
Users' observations	√	√				
"Tutorial" use of the app			√			
Terms and conditions/disclaimer	√	√	√	√		√

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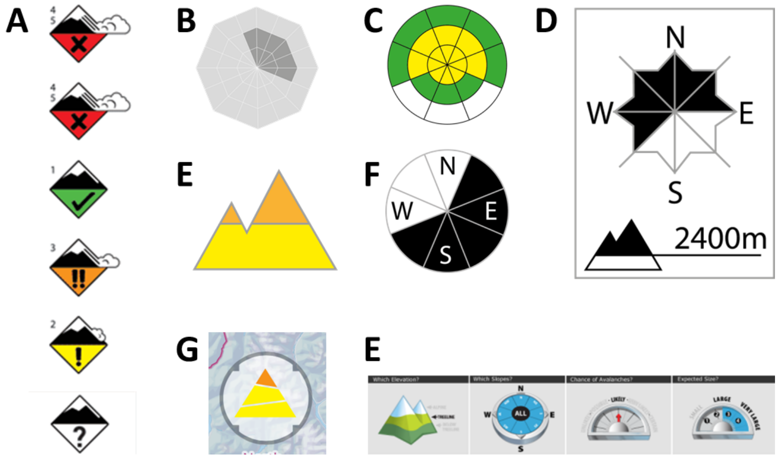

Figure 1. Icons used in the smartphone applications.