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# Mental Models of Flash Floods and Landslides

**Klaus Wagner***

Perceptions of flash floods and landslides were analyzed in four communities of the Bavarian Alps using the mental model approach. Thirty-eight qualitative interviews, two telephone surveys with 600 respondents, and two onsite interviews (74/95 respondents) were conducted. Mental models concerning flash floods are much better developed than those for landslides because the key physical processes for flash floods are easier for the general public to recognize and understand. Mental models are influenced by the local conditions. People who have a better knowledge about the hazards are those who use many different sources to inform themselves, express fear about natural hazards, or have previous experience with hazards. Conclusions for how to improve information for the general public are discussed.

**KEY WORDS:** Debris flow; flash flood; landslide; mental model; risk communication

## 1. INTRODUCTION

Natural hazard management is increasingly focused on informing and involving local populations.[1] The main goal of this is to better prepare people at risk to cope with natural hazards and their consequences. In particular, for small landslides and flash floods in small mountain creeks, personal mitigation measures can modify the event itself, as well as mitigate the resulting damage to built systems. Traditionally, responsible agencies design information material according to what they believe the public needs to know. The shortcoming of this approach is that the information presented to the public can be either too complex or too basic. Atman *et al.*[5] and Bostrom *et al.*[6] provide a procedure to overcome this shortcoming. They first measure the mental models of the public concerning a particular hazard and then design information tools that fit to these models. The danger that messages will be dismissed, misinterpreted, or allowed to coexist with misconceptions is remarkably smaller with this approach.

This article explains the first part of this approach, the analysis of mental models of flash floods and landslides. While health risks are often analyzed by the mental model approach, there are fewer investigations of this type in natural hazards research.[2] In this article, mental models are defined as "the mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states."[20]

The definition places emphasis on both the development and the content of the mental models. The content is analyzed by risk communication research. Mental models of natural hazards are generally based on personal experience and information assimilated from mass media, peer groups, and responsible agencies.

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[1] This tendency can be observed worldwide. In Germany, for example, Laenderarbeitsgemeinschaft Wasser,[1] and in Europe the final reports of the EU funded projects Ribamod,[2] Riparius,[3] and Comrisk.[4]

[2] The following health risks were analyzed: radon,[5,7] smoking,[8] chemical products,[9,10] magnetic fields,[11] contaminated land,[12] drinking water,[13] health and medicine.[14,15] Only the mental models of the natural hazards wildland fire[16] and floods[17] were described. Climate change[18,19] lies on the border between natural and man-made hazards.

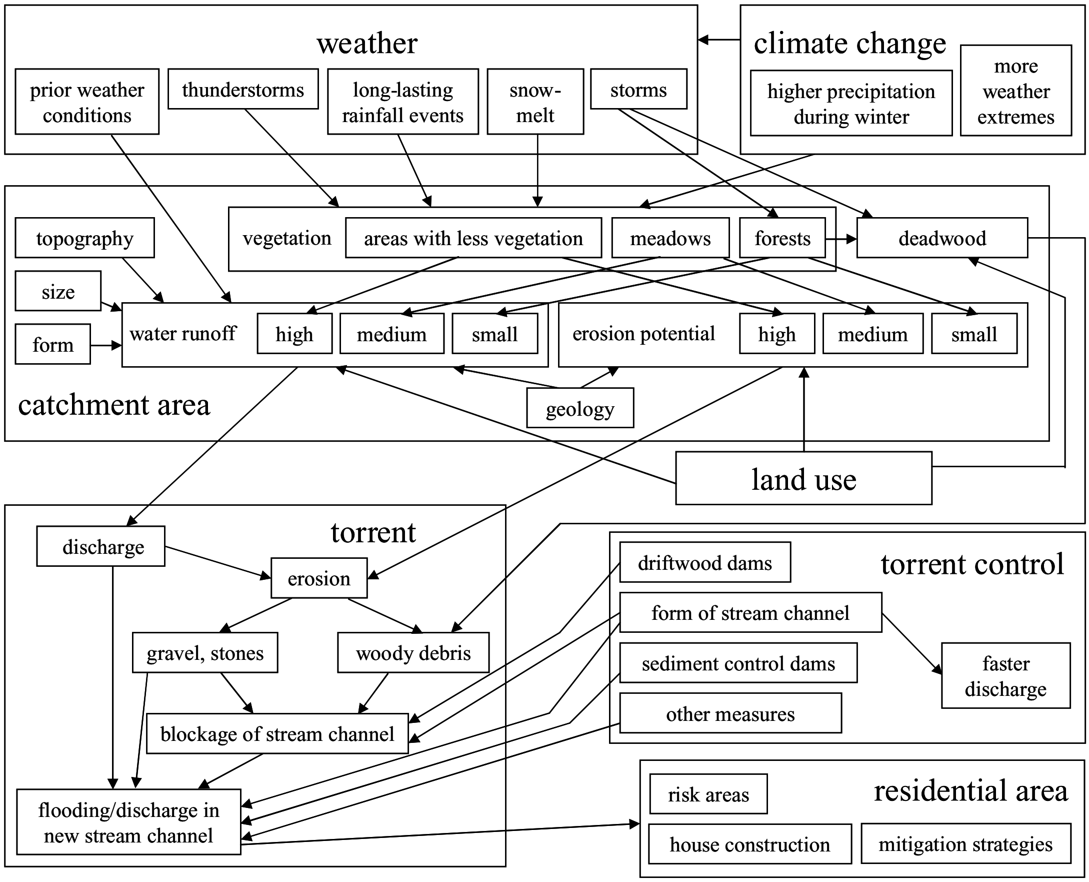


**Fig. 1.** Scientific influence diagram for flash floods.

Following the approach of Morgan *et al.*,[(7)] the lay mental models are compared with a scientific influence diagram. In contrast to Morgan *et al.*, we did not speak with experts to develop the influence diagram but reviewed scientific literature.[3] The relationship between the influencing factors (boxes) in Figs. 1 and 2 is represented by arrows.

Fig. 1 shows the main factors influencing flash floods in mountain torrents: weather conditions, catchment area characteristics, and processes within the torrent. Torrents are mountainous creeks; their defining characteristics include a very high hydraulic gradient, high bed load (stones, gravel, sand), and sometimes extreme runoff during floods. In contrast to rivers with big catchment areas, thunderstorms as well as long-lasting rainfall events can cause floods in torrents. High debris load and stream channel blockages[4] can increase the impact of flash floods. The influence of vegetation type on erosion and discharge has been simplified in this model. For example, the impact of forest on the water runoff depends on the soil conditions.[(23)] Although flash floods are called a natural hazard, human impact is obvious in terms of climate change, land use, torrent control, and residential area. For example, the decrease of management operations in the forests due to the low price of wood leads to more deadwood, leading to increased danger of blockage in the stream channel. The key issue of torrent control is to inhibit debris flow and blockage of the stream channel caused by (woody) debris. Last but not least, the distribution of residential areas in the risk zones, and any precautionary actions of the inhabitants, has a huge influence on the likely damage.

Fig. 2 shows a simplified influence diagram of landslides. To make decisions about landslide risk

[3] For the flash flood model, see Boell[(21)] and LfW,[(22,23)] and for the landslide model LfW,[(23)] Gasser and Zoebisch,[(24)] and Veder.[(25)]

[4] The German word "Verklausung" has the Latin root "claudere" = to shut, to close.

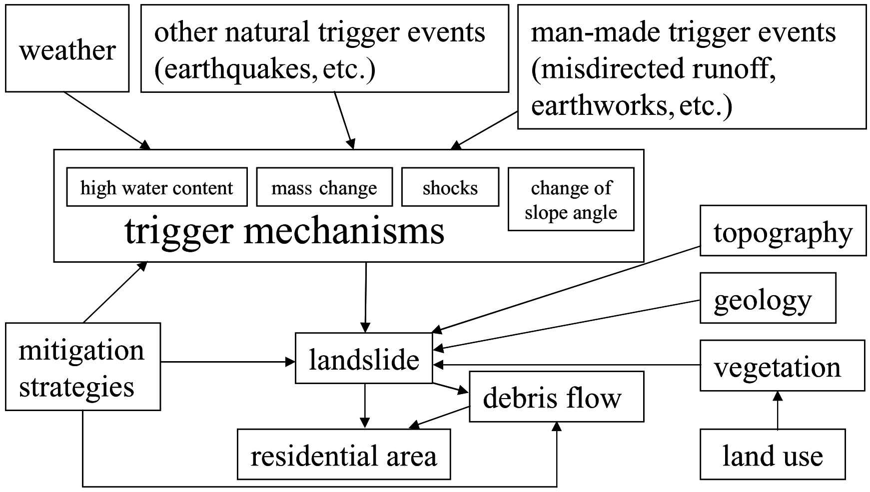


**Fig. 2.** Simplified scientific influence diagram for landslides.

mitigation, it suffices to understand the basics of landslide geology and triggering mechanisms. On the one hand, landslides can be caused by natural factors like extreme weather conditions, earthquakes, or undercutting of a steep slope by a river. On the other hand, human activities like uncontrolled infiltration of water, shocks due to traffic, or road constructions are also responsible. Geologic formations like flysch with a high proportion of clay are vulnerable to landslides. Landslides rarely endanger a residential area directly. More often a landslide causes an uncontrolled blockage of a torrent, which leads to a debris flow or a flash flood with a very high bed load. Protective measures can be used to try to stabilize landslides or to minimize the impact of debris flows. In particular, small landslides can be inhibited by an adaptive land-use strategy. For example, clear cutting a forest stand leads to higher water content in the soil and this can be a trigger for a landslide. To avoid this, sufficient small trees should remain after all big trees are removed.

## 2. METHODS

The study was conducted in four communities in the Bavarian Alps, which are endangered by flash floods and landslides. The first community is Benediktbeuern/Ried, a village with 3,600 inhabitants, where 45 houses were damaged by a severe flash flood in 1990. Landslides are often visible in the upper course of the nearby Lainbach Torrent. The second community is Hindelang (4,800 inhabitants), which is endangered by many torrents and also by the Ostrach River, causing major damage in 1960, 1990, 1999, and 2002. In 1999, a large landslide (50,000 m$^3$) occurred near the Rothplattenbach Torrent. In response, the Bavarian Watershed Authority built two debris dams to decrease the danger of a debris flow. In the third community, the town of Tegernsee (4,000 inhabitants), over 20 small torrents exist. Many of them are often dry during the summer months. Flash floods of these torrents endanger few houses. The last big events were in 1989, 1990, and 1999. In 1999, Lake Tegernsee had the second highest level since 1899. In 1972, a red alert had to be announced due to a landslide causing a blockage of the stream channel of the biggest torrent in Tegernsee. No damage was caused because the movement of the landslide could be stopped. The fourth and final community is Tiefenbach (700 inhabitants) where only a small part is located in the danger zone of a possible debris flow. The Falkenbach Torrent undercuts an area of 2.5 hectares with a volume of 400,000 m$^3$. Since 1973, the landslide has moved faster in the direction of the torrent. The Bavarian Watershed Authority has erected two dams, one at the toe of the landslide and one in front of the village. The upper dam seems to have stopped the landslide. Since its erection, no large movements have been detected.

This mental model study was part of a larger project evaluating new and existing information tools used in natural hazard management. In 2001 and 2003, two telephone surveys, each with 601 respondents, were conducted before and after information input. Additionally, some of the information tools were immediately evaluated using observation and onsite interviews. Employing the method of Morgan *et al.*,[7] a qualitative approach was taken first to measure the mental models.[5] As a part of the presurvey, the author interviewed 24 persons living in risk areas and 14 persons responsible for local natural hazard management. The 14 local experts had no special education in natural hazard management, but because of their occupations as mayors, municipal councilors, or firefighters, were more likely to have contact with the natural hazard protection agencies—in Bavaria the watershed authority and the forest service. In total, 29 of the 38 interview partners dealt intensively with natural hazards. Respondents were asked to explain the factors influencing a flood or a landslide in their area. Using additional questions the interviewer tried to elicit explanations for each field mentioned in Figs. 1 and 2. The interviews were recorded on tape, then transcribed and analyzed by the author.[6] In contrast to standard methodology, the interviews were not fully transcribed due to time constraints. Many statements were directly paraphrased and sorted into one of the categories of the expert model because there was no further interpretation needed. Only those statements that were ambiguous or described emotions of the respondent were noted word by word. During the qualitative content analysis it became obvious that fear or anxiety plays a key role in explaining the reaction of the respondents to the different hazard types. Using Krohne‘s model of anxiety and coping modes,[(30)] the author examined whether the respondents used vigilance or cognitive avoidance techniques to cope with their hazard fear. Vigilance is defined by Krohne as an intensified search for and processing of threat-related information, for example, strategies include "anticipation of negative events" or "information search." In contrast, cognitive avoidance is a set of coping strategies that aim to avert attention from threat-relevant cues, for example, strategies include "distraction" or "denial."

Using the information gained from the qualitative interviews, two different approaches were adopted for the quantitative interviews. The quantitative approaches were developed for flash floods only because a significant lack of knowledge about landslides became obvious during the qualitative interviews. A high item nonresponse rate and the problem of ignorance errors were expected for questions about landslides. Babbie[(27)] recommends abandoning questions that people cannot reliably answer.

The first approach included the 10 statements shown in Fig. 3, with a four-point Likert response scale: fully agree, agree, disagree, or fully disagree. Because of requirements of the sponsor, the statements focus on the weather and climate conditions and represent themes often mentioned within the qualitative interviews. As mentioned above, only those parts of the expert model to which it could be expected that the respondents have firm opinions were represented by statements.

In the second approach, people were shown an aerial view of a torrent to measure what they think about the effect of different mitigation strategies. They were asked to imagine this torrent had flooded the houses in the picture during the last thunderstorm, and to explain which mitigation measures they would use to increase the security of the houses at risk if they were the mayor of the local community or a member of the watershed agency. The interviewers field-coded the answers to this open-ended question and had to elicit further information when answers were unspecific or incomprehensible. Because of this complex task, the interviewers were intensively trained so that intercoder reliability was over 90% at the end of the training.

The first approach was applied using a telephone survey, conducted in February 2001. Six-hundred and one persons were selected randomly in different risk zones in Benediktbeuern/Ried, Hindelang, and Tegernsee.[7] The "last birthday" method was used to determine the respondent within the household.[(26)] The respondent had to be older than 16 years. In March/April 2003, the survey was repeated with six statements. Four earlier statements from the previous survey were not included in the survey repetition due to financial constraints.[8] The second approach, the open-ended question with field coding, could only be used during a face-to-face interview because of the complex interview situation. Two locations were selected, the first of people leaving an exhibition about alpine hazards in Rosenheim designed by the watershed authority, and the second of people leaving a nature trail at the Lainbach in Benediktbeuern.

Table I shows the demographic data and the response rates of the two approaches. At the nature trail 82% of the hikers agreed to participate in the

[5] The normal technical terms that are used in the field of empirical social science are not explained. For an introduction to the quantitative paradigm, see Schnell *et al.*[(26)] or Babbie,[(27)] and for the qualitative approach, Lamnek[(28)] or Mayring.[(29)]

[6] See Lamnek.[(28)]

[7] Tiefenbach was excluded from the survey because too few inhabitants lived in the risk area. The risk zones are not based on official risk maps. In Tegernsee, for example, the researcher distinguished three zones: the flooding zone of Lake Tegernsee, the relatively secure city center, and the hill zones where landslides occur.

[8] Statements to which nearly everyone agreed were excluded. They are not helpful to differentiate between groups within the sample.

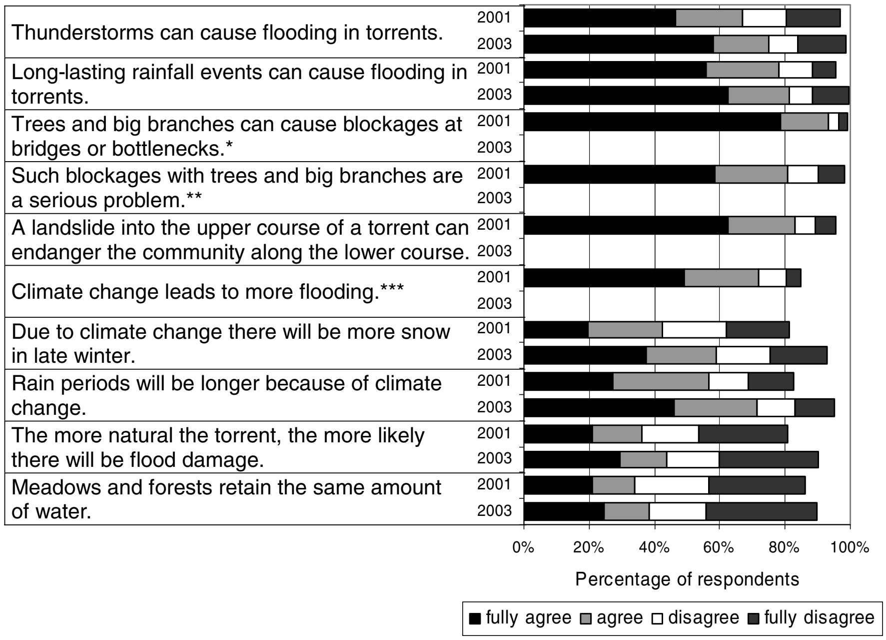


**Fig. 3.** Answers to the statements of the quantitative questionnaires (601/604 respondents in 2001/2003, respectively). The difference between the bars and 100% equals the answer "don't know." *For the interviews in Tegernsee the statement was: Branches and garden waste can cause blockages at tubes. **For the interviews in Tegernsee the statement was: Such blockages with branches and garden waste are a serious problem. ***This statement was formulated negatively: "Climate change leads to less flooding."

study. Indeed, many hikers noticed the observation and were curious about its purpose. At the exhibition, short-time visitors often did not want to spend 15–30 minutes for the interview, thus only 53% agreed to participate. The differences between the telephone surveys and the evaluations have following reasons:

- Compared to the general public people visiting exhibitions and nature trails tend to be younger and better educated.[31,32] Therefore, the median age of the evaluations is six years lower than that of the telephone surveys, which was equivalent to the census data of the communities.
- The interviewers applied the following random selection procedure for the evaluations of the exhibition and the nature trail. After finishing an interview, they selected the next person leaving the location for interview. Nevertheless, they could not inhibit self-selection within groups. Couples tended to choose the man as the interview partner.

## 3. RESULTS OF THE QUALITATIVE INTERVIEWS

For flash floods the key factors mentioned by respondents were: weather conditions, problems with driftwood and debris, and constructions of the watershed authority. Most of the respondents understood the first two factors well. Heavy thunderstorms and long-lasting rainfall events were seen as the main trigger for flash floods. Three interviewees thought that thunderstorms are not so problematic. This is a clear misconception. The role of the easily visible woody debris was better explained than the impact of less

**Table I.** Sample Characteristics

| | Telephone Survey 2001 | Telephone Survey 2003 | Evaluation Exhibition | Evaluation Nature Trail |
|---|---|---|---|---|
| Response rate | 41% | 43% | 53% | 82% |
| Sample size | 601 | 604 | 95 | 44 |
| Sex | 55% female | 53% female | 40% female | 43% female* |
| Age (median) | 16–89 years (51 years) | 16–101 years (50 years) | 11–74 years (44 years) | 20–84 years* (41 years) |
| Graduated from high school | 35% | 38% | 68% | 57% |

*Sometimes, the whole hiker group participated in the interview.

perceptible stones, gravel, and sand. Only the most informed persons realized the necessity of sediment retention structures. Torrent control constructions were often criticized, such as the high water speed in the Maclith-channels (Hindelang), which was seen as a possible danger for nearby houses. Two persons preferred a closed stream channel (pipes) within the residential area to achieve a perceived higher security level. This is a clear misconception. Pipes are not used because of the danger of blockage within or at the beginning of the structure and their high maintenance costs. As personal mitigation measures, people try to keep water out of their homes. They spoke about mobile levees and waterproof closures for windows and cellars. Only in Tegernsee did four interviewees see the possibility to alter the hazard processes. To inhibit blockages of the stream channels in the small creeks, they clean waste and branches from the channel, but representatives of Tegernsee complained that this is done only by a few residents. The conditions in the catchment area (topography, size, and form of the catchment area) and the impact of the land-use system were rarely noted except for the connection between forestry and blockage of the stream channel resulting from deadwood due to storm damage or bark beetle infestation. Between the four communities differences are obvious. In Tegernsee, 90% of the interviewees spoke about long-lasting rainfall events due to their experience during the Pentecost 1999 flood disaster. In Benediktbeuern, 90% of the respondents told the interviewer detailed stories about the thunderstorm, which caused a flash flood in 1990. Driftwood retention constructions are mentioned more often in Benediktbeuern too because there is a huge structure easily accessible near a local nature trail[9] (70% of the respondents mentioned this versus 30% in the other communities).

In contrast to floods, the influencing factors for landslides were poorly understood (Table II). The respondents often commented on their own lack of understanding. Nevertheless, 60% of the respondents considered high water content in the soil as a trigger mechanism. They used images such as changing underground springs or wounds in the soil surface allowing water infiltration. These explanations are not completely wrong, but the respondents were obviously unaware that the normal infiltration process during an extreme rainfall event is sufficient for a landslide release. Four inhabitants of Tegernsee mentioned the weight of big trees and the vibrations during storms as release for landslides. The role of forestry clearcuts in triggering landslides was mentioned, such as the higher soil water content following logging, and the lack of roots to reinforce soil. Interviewees described the big roots, which are often visible on steep slopes. These explanations are only partially correct as the thickness of the landslide has to be considered when evaluating the impact of vegetation. Only two of 30 respondents were aware of this.

Interviewees' mental models varied from basic awareness to complete and coherent accounts. However, it is not possible to speak about a development of mental models in terms of a linear progression from easily recognizable factors to more complex factors. Even in simple mental models, complex relationships are not ignored, for example, between discharge and catchment area, but they are poorly understood. While people with coherent mental models can explain such relationships, people with simple ones only mention them in passing or have significant misconceptions (Table II). For example, the problem of blockages at the beginning of closed stream channels—a serious problem in Tegernsee—was mentioned by all interviewees. Two of them had lived for only a short time in the area and had a basic mental model. Nevertheless, one of them explained that he regularly checks and cleans the pipe intake, which is directly in front of his house. The other said that he does not throw any garbage into the stream channel but he had no idea that woody debris could be mobilized during heavy rainfalls. Interviewees with more complete models explained that in the past, less woody debris was lying in the forests. Some of them also recommended advanced pipe intakes with woody debris retention constructions or stilling basins.

The biggest differences in the completeness of the mental models were between newcomers and inhabitants with long hazard experience. While people who have been living in this alpine area for less than 20 years mentioned an average of 8.2 influencing factors for flash floods, interviewees who were born in the research communities mentioned 12.7 factors. The other important factor influencing mental models was the readiness to deal actively with the natural hazards theme. The respondents with the most accurate mental models talked about scientific books they had read, discussions with experts they had had, and their personal experiences of being out in the open during bad weather conditions.

As mentioned in Section 2, all statements regarding the coping mode of anxiety-provoking hazards were analyzed. Interviewees speaking about flash floods used vigilant strategies more often than cognitive avoidance (63% of all statements). They tried to

[9] This nature trail was evaluated within the project.

**Table II.** Differences Between Simple and Rather Complete Mental Models for Flash Floods and Landslides

| Factors | Flash Floods | | Landslides | |
|---|---|---|---|---|
| Completeness of the Mental Model | Rather Complete | Simple | Rather Complete | Simple |
| Number of factors mentioned | 17–22 | 6–11 | 9–19 | 1–4 |
| Factors described in detail | 64% | 36% | 40% | 0% |
| Factors mentioned only | 36% | 55% | 50% | 70% |
| Factors explained partially wrong | 0% | 4% | 9% | 25% |
| Factors explained completely wrong | 0% | 5% | 1% | 5% |

inform themselves about the hazard and get control over the hazard by preparing for future hazard events. "One tries to get information to calm oneself" and "I regularly monitor the creek and we still watch out" are two typical quotes. Only 2% of the responses were coded into the category "denial of the hazard." For landslides and debris flows, cognitive avoidance was the dominant strategy. Sixteen percent of the statements were coded "minimization," 16% as "denial," and 14% as "faith." For example, in Tiefenbach, a local farmer explained that his father and grandfather had never experienced any damage from debris flows, so he did not understand why the watershed authority had built such big debris retention constructions. "I do not think that anything will happen," and "[i]f it [the debris flow] would reach us, half of the mountain must have broken down" are two quotes from this man. In contrast, a newcomer thought that if his house would be seriously endangered, the local authorities would warn him. Both respondents do not consider the risk to be high and therefore do not adopt any precautionary action.

## 4. RESULTS OF THE QUANTITATIVE INTERVIEWS

### 4.1. Telephone Surveys 2001 and 2003

Approximately two-thirds of the respondents knew that thunderstorms, as well as long-lasting rainfall events, can cause flooding in torrents. Nearly 20% thought that only long-lasting rainfall events are dangerous. Similarly to the qualitative interviews, this group was biggest in Tegernsee (27% vs. 20% in Hindelang and 15% in Benediktbeuern in the survey 2001). Five percent of the respondents seemed to deny the possibility of flash floods in their area. They disagreed with both statements. Similarly to the qualitative interviews, most respondents thought that blockage of stream channels is a major influencing factor. Over 90% (strongly) agreed with the statement about the possibility of blockage of the stream channel (Fig. 3). Of the respondents who knew something about the blockage, 8% disagreed that this poses a big problem. In Tegernsee, this figure was as high as 23%. It is understandable that people think blockages by branches and garden waste are not such a big problem as blockages with trees.

The answers to the statements about climate change show more public uncertainty. Eighty-five percent of the respondents thought that climate change will lead to more flooding. The statements about the precise results of climate change (more snow in late winter, longer rain periods) show misconceptions or gaps in understanding. The uncertainty of the public is also obvious for the last two statements. The differences between the two surveys over time are very small. In 2003, the respondents chose the answer "don't know" less frequently than in 2001.[10]

For statistical analysis, the correct answers were coded as "1," the wrong answers as "0." For example, people who agreed or fully agreed with the first statement in Fig. 3 got one point. A "flash flood knowledge scale" was then built by addition of the six statements used in both surveys. The following independent variables were statistically tested on their influence on the flash flood knowledge scale:

1. *t*-test: gender (male/female), damage experience (yes/no), fear of future damage (yes/no), forest and/or agricultural land user (yes/no).
2. Univariate ANOVA: education (low/medium/high), social class (low/medium/high), engagement in natural hazard protection (no/helping neighbors/volunteer firefighter).
3. Nonparametric correlation (Kendalls tau b): age, occupancy (in 10-year steps), information scale (respondents could answer on a four-point Likert scale how often they use 10 different information channels, e.g., mass media, Internet, friends and neighbors, communities, agencies to inform themselves about natural hazards), fear scale (respondents

[10] It cannot be decided if this is an effect of the information material that people got between the two surveys, or an effect of the different sample.

**Table III.** Quantitative Telephone Survey: Nonparametric Correlation Between the Flash Flood Knowledge Scale and the Information/Fear Scale (601/604 Respondents in 2001/2003, Respectively)

| | Correlation Coefficient (Kendalls tau b) | |
|---|---|---|
| Survey | 2001 | 2003 |
| Information scale | 0.189 ($p < 0.001$) | 0.067 ($p < 0.05$) |
| Fear scale | 0.203 ($p < 0.001$) | 0.126 ($p < 0.001$) |

could answer on a four-point Likert scale to the following statements: "I fear flash floods"; "I fear landslides"; and "I am constantly aware of the flood danger").

A multivariate analysis was carried out using ANOVA for independent variables, which were statistically significant in the univariate test. Interactions between the independent variables were not assumed. In the univariate analysis, the following groups had a greater knowledge consistent for both surveys (Tables III and IV): (1) people using many different channels to inform themselves about natural hazards; (2) people expressing fear about natural hazards; (3) people with hazard experience; (4) inhabitants from Hindelang. Gender and age showed a statistically significant influence only in 2001. In the multivariate analysis, only the community of the respondent showed a statistically significant influence of little strength in either survey.

### 4.2. Evaluation of the Nature Trail and the Exhibition

The question regarding which protective actions should be implemented after a severe flash flood at a natural torrent was too difficult for one-third of the visitors of the exhibition in Rosenheim and one-fourth of the hikers at the nature trail in Benediktbeuern. In both locations, they generally recommended building torrent control constructions, or they mentioned only one of the measures listed in Fig. 4. Approximately two-thirds of the respondents noted at least one technical measure such as check dams in the upper course of the torrent or woody debris retention constructions. Twenty percent of the respondents recommended immediate rehabitation of the damaged houses. An additional 20% requested consequent spatial planning to avoid further increases in potential damage. Scarcely anyone at the nature trail mentioned personal mitigation measures, although 15% of exhibition attendees did.

In both locations, one-third of the respondents answered the question in accordance with a lowland perspective. On big rivers, it is common to build dams or to reestablish water retention areas. The interviewees transferred these measures to torrent control. They also spontaneously developed proposals like redirection of the course of the torrent or erection of water retention basins. These measures were neither shown at the exhibition nor at the nature trail. They are also rarely used in practice for torrent control.

In Rosenheim, the proportion of respondents who could not answer this question or preferred "lowland solutions" was markedly bigger. There are two possibilities to explain this result. First, at the Lainbach, people could see the torrent control constructions in addition to the explanations on the nature trail panels. The respondents therefore only had to transfer the measures they had seen at the Lainbach to the question. Second, 30% of the respondents in Benediktbeuern belonged to the local community. Locals noted more protection measures typically used for torrents (1.3 measures vs. 0.7).

## 5. DISCUSSION

### 5.1. Mental Models—Founded on Personal Experience, Consisting of Observations

The trigger events for flash floods are better understood than those for landslides. Two explanations

**Table IV.** Quantitative Telephone Survey: Flash Flood Knowledge Scale with Statistically Significant Influencing Factors (601/604 Respondents in 2001/2003, Respectively)

| | Average of the Flash Flood Knowledge Scale | | | |
|---|---|---|---|---|
| Survey | 2001 | | 2003 | |
| Independent variable | | | | |
| People who have experienced damage by natural hazards | 3.67 | $t$-test: $p < 0.001$ | 4.01 | $t$-test: $p < 0.05$ |
| People who have not experienced damage by natural hazards | 3.22 | | 3.72 | |
| Benediktbeuern | 3.30 | ANOVA: | 3.95 | ANOVA: |
| Hindelang | 3.55 | $p < 0.01$ | 3.93 | $p < 0.01$ |
| Tegernsee | 3.13 | $\eta^2 = 0.017$ | 3.55 | $\eta^2 = 0.017$ |

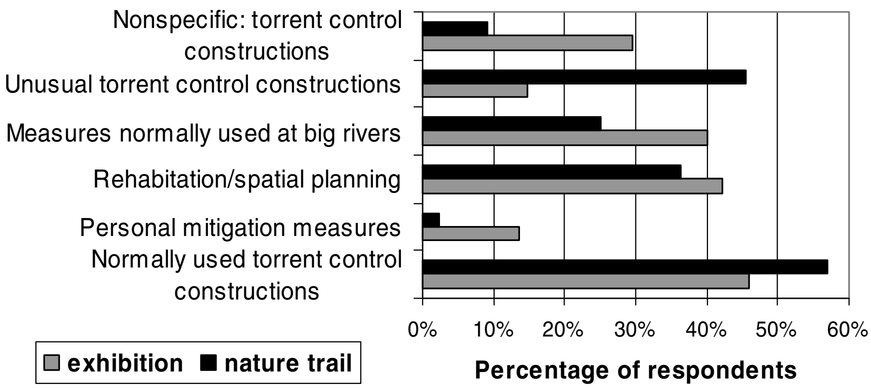


**Fig. 4.** Proposed mitigation measures against flash floods at a close to nature torrent (exhibition: 95 respondents; nature trail: 74 respondents).

could be given for this result. First, in the communities studied, flash floods occur more often than landslides. Personal experience is very important to comprehend the dangers. The interviewees frequently explained the influencing factors according to their own experience or that of friends and neighbors. The importance of local conditions is also obvious in the results of the different communities. Both in the qualitative interviews and in the telephone survey, the inhabitants of Tegernsee mentioned long-lasting rainfall events more frequently. This corresponds with the most recent significant damaging events being caused by such heavy rainfall.

Second, the more visible an influencing factor, the better it is understood. The processes that are responsible for generating a landslide are not visible with the exception of weather phenomena. Without scientific explanations, lay people are unlikely to understand what causes a landslide. Mental pictures with underground springs or wounds in the soil surface allowing better water infiltration are attempts to illustrate the invisible. Visibility has also great explanatory power for mental models about flash floods. Woody debris is more visible than gravel. Gravel and stones are noted more often than erosion or geologic factors. In addition, factors that are constant for years seem to be invisible. However, for scientific modeling of discharge patterns, the size and form of the catchment area and distribution of different land-use systems are highly important. Few respondents stated these factors and only one interviewee correctly mentioned the form of the catchment area as an explanation for how fast the water level rises following heavy rainfalls. Bernet *et al.*(33) have shown differences in the ascribed causes of flash floods and landslides among diverse social groups in the community of Sachseln. The mass media reported very little about the triggers of the flash flood but when they did it was attributed to climate change. The authors could not find a detailed risk analysis in the records of the local authorities. The authorities tended to think that erosion was the main problem, as they built many check dams to inhibit side and vertical erosion on steep slopes. On the other hand, the main question for the scientists was the connection between the occurrence of landslides and land use.(34) The people at risk had similar mental models to those explained here. They tended to search for responsible persons, so they intensively discussed the torrent control constructions.[11]

Bader and Kunz(37) reported that people in Switzerland had a relatively good knowledge of avalanches and storms. Landslides and flash floods were less understood. If the visibility of important processes is used as the key explaining variable, common alpine hazards can be sorted into the following order: storms – avalanches – flash floods – landslides.

Mental models for the public are influenced not only by personal experience but also by the mass media. Persons with a special interest in the topic also use scientific literature. Mass media introduce a lowland river mental model because they more frequently report widespread disasters on the Rhine or Danube. Straightening of the river course is depicted as being bad, renaturation good, and river beds, which are close to nature, are seen as an indicator for flood security. Respondents applied these common messages on torrents even where such conclusions are false.(38)

### 5.2. Development of Mental Models

In the literature, it has been discussed whether specific or general mental models predominate.(20) For example, Jungermann *et al.*(15) assume that people

[11] Particularly for floods, people think they are caused by mankind; therefore, someone must be responsible, e.g., governmental agencies.(17,35,36)

have a general mental model for drug effects, which is expanded or confined according to the patient package inserts of a particular drug. Explanations of parents, physicians, pharmacists, and the information on patient package inserts form the general model. Many of the respondents do not seem to have such a general model of landslides or flash floods. For example, the interviewees had difficulties answering the question about influencing factors for flash flood damage without the image of a specific torrent. Rouse and Morris[20] think that specific, context-dependent models are prevalent.

Coherent mental models consist not only of a higher number of factors mentioned in comparison to simpler mental models, but they also explain the factors in a more detailed and factual manner. Kempton[39] describes that in some mental models false scientific explanations lead to correct conclusions. This could be observed in terms of the impact of clearcuts on the release of landslides. People think that clearcuts should be avoided if there is no regeneration. This conclusion is correct, independently from whether the explanations—increase of soil water content due to less transpiration of old trees, or lower ability of the roots to reinforce the soil—are scientifically sound or not.

## 6. CONCLUSIONS

As shown before, personal experience and the visibility of processes are the two main influencing factors explaining the content of mental models. Accordingly, if agencies want to inform the public correctly and meaningfully about natural hazards, they have to bear those two factors in mind. Information tools should explain the important factors that lead to local conditions whilst realizing that the conditions in the home community play a major role in the perception of alpine hazards. In this regard, pictures showing former disasters in the home community are helpful because they are viewed and remembered longer than more impressive pictures from other areas.[40] For this reason, the author recommends against, for example, a general leaflet on alpine hazards distributed by the Bavarian Watershed Authority. While it is likely that developing a well-styled leaflet for every individual community would be prohibitively expensive, a general leaflet with an insert containing information about local hazards could be a good compromise solution.

Information strategies should be concentrated on the invisible triggers because mental models already account for visible processes. But how can this be done? First, good examples that explain the influencing factors should be used. The connection between the wetness of sand and the ability to build sand castles is commonly known. With this simple example, it is easy to explain the importance of the soil water content as a trigger for landslides. Second, exhibition objects could be used to visualize the processes. For example, the influence of the angle of repose for different materials could be shown with a rocking table. Third, using computer models, people could learn how changes in certain factors would increase the discharge or generate a landslide.

Fear and the tendency toward using the coping strategies of cognitive avoidance may be a result of the poor mental models and the influence of mass media. Journalists only report on those landslides that are (extremely) large and that the local people have no control over. One example is the landslide in Gondo in 2002 in the Swiss Alps, which destroyed one-third of the village and killed 13 people. Television, radio, and newspapers gave this disaster wide attention. Because of ignorance, people do not distinguish between these uncontrollable huge landslides and those smaller landslides that can be prevented by adequate land use. They also do not imagine scenarios of differing intensity. Respondents in Hindelang imagined only a huge disaster would result if the landslide at the torrent "Rothplattenbach" caused a debris flow. They did not think about scenarios where only 10% of the landslide reaches the torrent at one runoff event and so causes damage that could be prevented. Therefore, the responsible agencies should explain the landslide danger using multiple scenarios. They also should describe the precautionary actions that can be applied to each scenario.

There are also implications for scientific research. For landslides and flash floods, risk perception is highly influenced by local conditions. To increase the proportion of explainable variance in quantitative approaches like the psychometric paradigm, local conditions have to be measured. This statement seems to be true for all natural hazards. Plapp,[35] for example, found significant differences in the perception of storms, floods, and earthquakes in six German towns. The respondents in the different towns estimated the danger for floods most diversely. Plapp explained this result by the different experience of the people at risk. While in Passau and Cologne people are used to coping with floods, the inhabitants of Neustadt at the Danube were shocked by a dike break. Therefore, it is not enough to measure personal experience only by the number of damaging events experienced but rather also by the local perceptions of those events.

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