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Original Communication

Risk-Specific Search for Risk-Defusing Operators

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Active risk-defusing behavior is that performed by decision makers in risky situations when they look for additional actions that decrease the risk and allow them to favor a riskier alternative. Our study demonstrates that risk-defusing behavior depends on the type of risk (normal, medium, catastrophic, or global) as well as on the domain (health, economy, or ecology). In total, 12 scenarios (four types of risk from three risk domains each) were constructed. Using the interview techniques of active information search and thinking aloud, we conducted 120 interviews about decision-making processes with these scenarios. The results showed that active search for different risk-defusing operators depends on the type of risk, but even more on the domain of the scenario. Results suggest a need for further research about a typology of risk situations in which, besides formal classification criteria, content issues are also explored.

Keywords: risk, catastrophe, risk-defusing behavior, decision making, content effects

On August 28, 2005, there was an article on the homepage of the German magazine *Spiegel Online* that began:

> Hurricane Katrina has become a "monster" storm. Local authorities classified it as a Category 5 storm, the most intense category. This afternoon the mayor of New Orleans ordered the compulsory evacuation of the city. Katrina could become the most dangerous storm that has ever haunted the United States.

Imagine that you are a citizen of New Orleans and the storm is approaching. You have to decide whether or not to leave your home as recommended by the mayor. Would you leave all your belongings behind? Your furniture? Your new business? Would you use statistics to inform yourself about the probability of the total destruction of dams and the flooding of the city? Would you think about how you have previously decided in risky situations? Or would you start thinking about how to reduce the potential damage, maybe by installing additional security devices, like sealing the doors and windows or getting hold of emergency power supplies?

Psychological research on decision making under uncertainty looks for answers to these and related questions. Whereas previous research in this domain concentrated on probabilities of risky outcomes in lottery-type decisions (Jungermann, Pfister, & Fischer, 2004), an alternative approach studies decisions in quasi-realistic settings (e.g., Huber, 2004). When working on quasi-realistic decision problems, subjects are not interested in event probabilities, but asked about additional actions they would take that could reduce the potential risk or even eliminate it. The concept of *active risk defusing* states that such additional actions favor a decision to select the more risky option. This is in line with non-experimental decision-making research (Lipshitz & Strauss, 1997; March & Shapira, 1987; Shapira, 1995) as well as research on risk and controllability (Vlek & Stallen, 1980; Weinstein, 1984). For example, Vlek and Stallen (p. 287) showed that controllable risks are judged to be less risky, concluding: "Controllability of decision consequences seems to be one of the most important psychological factors in personal risk experience." Yates (1992) reported that decision makers try to create new options to reduce risk without sacrificing advantages. Payne, Bettman, and Johnson (1993) demonstrated such an adaptation to the particular risky situation by referring to the dependence of decision making on only minor task or context modifications. They referred to the decision makers' ability to adapt their strategy to different circumstances. The concept of *risk-defusing operators* (RDOs) describes decision makers' control or adaption strategies: In the hurricane example, the possibility of installing safeguards and taking other protective measures as risk defusers may have led some New Orleans citizens to decide to remain in the city despite the dire warnings. Such decision making can be seen as a consequence of RDOs. An RDO is defined as an "action, which a decision maker initiates in addition to the given options with the intention to reduce the risk of such an alternative" (Huber, 2004, p. 130). There are three different kinds of RDOs (e.g., Huber, 1997; Huber, Beutter, Montoya, & Huber, 2001):

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1. *New alternatives:* search for alternatives to the options presented, whereby the alternatives share the positive aspects – but not the negative consequences – of the options presented (e.g., using biological instead of chemical pest control).
2. *Possibilities for control:* check whether the risk of negative consequences can be reduced by either preventing the negative event from happening or breaking the causal link between the event and its negative consequences (e.g., wearing protective clothing at dangerous workplaces).
3. *Worst-case plans:* search for action plans that would neutralize negative consequences should they occur (e.g., backing up important files or buying insurance).

These RDOs are indicators of the cognitive process of decision making. For worst-case plans, besides the mental effort involved, additional costs arise, for example, time (backing up the data) or money (paying for insurance). The RDO new alternatives differs from the other two operators because it characterizes risk management in terms of an enlargement of the problem space. The other two RDO variants can be seen as active risk management. Huber et al. (2001, p. 411) comment: "Thus, risk defusing can be attempted in two ways: (a) by reducing the probability of the negative outcome, and (b) by transforming the negative outcome into an outcome state with a higher utility. Both ways increase the expected utility of the alternative." Subsequent articles by these authors only refer to the two general strategies of pre- and post-RDOs, which contribute to the prevention of or compensation for the damage (e.g., Huber, 2004; Huber & Huber, 2003). Our study, however, will use the differentiation explained above.

To analyze decision-making behavior in everyday risk situations, Huber, Wider, and Huber (1997) used the method of *active information search* (AIS). In this procedure, participants can pose questions to the experimenter to receive more information about two alternative actions in a written quasi-realistic risky scenario. A description of the method and empirical results from its application can be found in Huber (1997, 2004), Huber et al. (1997), Huber et al. (2001), as well as in Huber and Macho (2001). Because we used this technique in our own study, a short description can also be found below.

In classical decision-making research, the subjective value of consequences and the subjective probability of their occurrence are essential for the decision maker (Edwards, 1954, 1961). This position differs from the assumptions about the decision-making process in the quasi-realistic risky situations used by Huber (2004). In Huber's situations, a comparison of participants' decision-making behavior when they are provided with all the information they need (e.g., in the lottery experiments in classical decision-making research) with that when they are to request additional information from the experimenter (as in the AIS method) shows that most decision makers do not request information concerning probabilities. Huber and colleagues concluded that classical decision-making tasks induce the use of probability information by the way the information is presented. In quasi-realistic tasks, the information about potential negative consequences suffices. Furthermore, the majority of decision makers even search for additional actions which could reduce the probability of the incidence of risky events (Huber, 1997; Huber et al., 1997; Huber et al., 2001; Huber & Macho, 2001). Active risk-defusing behavior seems to play the more important role in decision making.

The question concerning the conditions under which which type of RDO will be used is still open (Huber, 2004). Studies have demonstrated substantial differences in the number of questions posed, that is, in the frequency of searching for different RDO types in different scenarios (e.g., Huber et al., 1997; Huber et al., 2001). There is a clear need for the development of a theory that explains decision-making behavior in different situations, that is, why decision makers show different decision-making behavior in different types of situations. A typology of risky situations would be helpful: It would provide us with a formal characterization of task types as well as a comparison of decision-making behavior in different types of situations so that we could determine whether risk-defusing behavior is a universal feature of decision making under uncertainty. To this end, the first step is the classification of risks (see pilot study below).

The literature suggests the existence of domain-specific differences in decision-making behavior. Huber and Macho (2001), for example, showed that more questions concerning probability were asked in the domain of medicine than in the domains of social issues and business. This is in accordance with results concerning naturalistic decision making about domain-specific strategies used in the decision-making process (Payne et al., 1993; Pennington & Hastie, 1993; Rettinger & Hastie, 2001; Schmitt & Klein, 1998). But research on such differences in the RDO search is still lacking. Therefore, we want to study this question more closely and look for differences in the search for RDOs depending on risk domain and type of risk. Our intention is to find out how strongly those factors affect the search for different RDO types.

Pilot Study

In order to investigate the search for RDOs in different types of risky situations, we needed a formal classification of risks. We started with the risk typology of the German Advisory Council on Global Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltrisiken [WBGU], 1999). This typology, formulated by experts, characterizes the threat of risks using several criteria: probability of occurrence, extent of damage, certainty of assessment, persistency, irreversibility, and delay effect. We were interested in how non-experts would rate different risks using these criteria and which criteria they would con-

sider relevant when rating risks. In our pilot study, we asked 20 participants (eight female; mean age 26 years) to rate 57 risk situations using the WBGU criteria. Each risk situation was to be rated along the six dimensions mentioned above on a scale from 0 to 4 (= *maximum*). Using cluster analysis, we found evidence for four different types of risk, which can be described as follows (whereby the order roughly follows an intuitive classification on the basis of event severity):

1. *Normal risks:* calculable risks involving damage that is expected to be reversible and whose extent is low (e.g., German measles, light flooding, borrowing money).
2. *Medium risks:* risks with a medium rating based on the WBGU criteria (e.g., carcinogenic substances like asbestos, waste disposal, stock investments).
3. *Catastrophic risks:* risks involving a great deal of damage for which the time lag between the triggering event and its consequences is short (e.g., avian flu pandemic, volcanic explosion, terrorist attack).
4. *Global risks:* risks involving a great deal of damage that are expected to be irreversible and have a very long removal period (e.g., genetically modified food products, extinction of endangered species, global warming).

This four-cluster solution portrays the classification of risks according to the understanding of non-experts. Besides these four types of risks, three different domains were distinguished: (a) ecology (e.g., flooding), (b) health (e.g., carcinogenic substances), and (c) economics/politics (e.g., terrorist attack). In the following, we will analyze the relationship between the three risk domains and the four types of risk.

Main Study

On the Risk Specificity of Active Risk-Defusing Behavior

The present paper discusses the question of the risk specificity of decision-making behavior in quasi-realistic scenarios. Decision making is similar to problem solving in that the construction of a mental representation of the given situation is essential. The mental representation resembles a complex system with causal relations between external events and consequences. Relations involving the decision maker's activities imply a kind of controllability and are of particular interest. They negate the causal connection between the risk situation and its negative consequences. We need to investigate under what conditions what kind of relationship (i.e., RDO) is preferred (Huber, 2004). The central questions are: (a) Does the search for an RDO depend on the type of risk situation? and (b) What type of RDO will be searched for? More precisely, do decision makers search for different RDOs in different types of risk situations?

In our attempt to answer these questions, we relied on Huber et al.'s (2001) threefold differentiation of RDOs: new alternatives, possibilities for control, and worst-case plans. By analyzing the relationship between the RDO search process and clearly defined types of risk, we will specify and extend Huber's approach: The scope and relevance of the theory, which up to now has only been tested in normal risk situations, will be evaluated for more global risk situations.

Main Research Questions and Hypotheses

Based on the typology of risks presented above, we formulated the following general hypothesis: The interest in different RDOs during decision making depends on the type of risk specified. In other words, while participants think aloud, the type and number of questions they pose and statements they make about different RDOs (new alternatives, possibilities for control, or worst-case plans) will vary depending on type of risk.

As for the use of RDOs, we have specific expectations for the different types of risks. The combination of the classification criteria (see pilot study) resulted in the following hypotheses for each type of risk:

1. We assumed that decision making would be easiest for the normal type of risk because it is calculable, involves damage that is reversible and whose extent is low. This type of risk was viewed as a kind of control group. For this type of risk, we did not expect to observe specific preferences for one of the RDOs.
2. In the event of a medium type of risk, in other words, when decision makers expected the damage to be of medium extent, largely restorable, to have a medium-term removal period, a medium-level certainty of assessment, and the time lag between the triggering event and the damage to be medium-long, we predicted that decision makers would request alternatives to the options provided. This search for alternative options is very similar to the RDO new alternatives. We therefore expected questions and statements to most frequently concern new alternatives.
3. We assumed that there would be a high amount of pressure to act in light of a catastrophic type of risk, in other words, when decision makers expected the damage to be extensive and only partially restorable, and the time lag between the triggering event and the damage to be short. In this case, decision makers may judge the potential for reducing or eliminating negative consequences to be very low. We thus predicted that they would focus more on compensating for potential negative consequences. Accordingly, we expected questions and statements to most frequently involve worst-case plans.
4. For the global type of risk, in other words, when decision makers expected the damage to have a very long removal period, to be irreversible, and the situation highly complex, we predicted that decision makers would be interested in coping with negative consequences by

means of preventive actions. Thus, we expected questions and statements to most frequently concern possibilities for control.

Exploratory Research Questions

We know from previous research (e.g., Huber & Huber, 2003) that information besides searching for RDO might be important for the decision-making process. Therefore, we wanted to explore different aspects to gain ideas for further improvements in the theory.

Background knowledge and prior experience

Because the risk situations in our study (especially our catastrophic and global types of risk) extend beyond the everyday risks that Huber studied, we wanted to check the role of prior experience and background knowledge in the decision-making process. There are clear data on the role of prior experience and expertise in decision making (e.g., Elterson, Shanteau, & Krogstad, 1987; Weiss & Shanteau, 2003). We assumed that it would be activated in connection with RDOs throughout the different types of risk. For example, prior experience with negative events such as flooding is related to the intention to buy natural catastrophe insurance (Kunreuther et al., 1978; Zaleskiewicz, Piskorz, & Borkowska, 2002). Ranyard, Hinkley, and Williamson (2001) found that risk management strategies in buying consumables using credit depended on prior experience and emotional reactions. We expected statements concerning specific background knowledge and prior experience to be important elements for the decision maker. This is in line with Huber and colleagues (Huber, 2004; Huber et al., 1997; Huber et al., 2001), who mentioned the potential role of background knowledge and experience with respect to the subjective representation of the situation and to the search for RDOs.

Attitudes and values

Based on experiences from our pilot study, it seemed useful to take into account our participants' general attitudes and values (e.g., plans, rules, and basic principles), which are independent of the particular scenario, but help participants make decisions. An example could be the opinion that "One should never interfere with nature's plans." This basic principle would support decisions concerning health problems and ecology. Decision making might be based on general attitudes and values for the global type of risk more frequently than for other types of risk.

Situation, probabilities, negative and positive consequences

Following Huber et al.'s (1997, 2001) category system, we analyzed type-specific differences in decisions about risk with respect to the frequency of questions and statements in the categories of probabilities, cost-benefit, and the general situation (see Table 2).

Choice of alternatives

We analyzed whether participants chose the risky or the less risky alternative.

Method

Participants

A total of 120 individuals (64 women, 56 men) participated in our study. Their mean age was 30.1 years. Nearly half the participants were employed (with and without university-level education); the others were schoolchildren and college students. None of them had participated in previous studies on decision making. All materials were presented in German (the participants' first language).

Design

Two independent variables were used for our main study. The first one was the type of risk (normal, medium, catastrophic, and global), the second represented the risk domains (ecology, health, and politics/economics), resulting in a 4×3 within-subjects design. Factor levels were operationalized by the content of risky scenarios. For each of the four types of risk, we chose examples from the three risk domains (ecology, health, and politics/economics).

A complete design would have required participants to evaluate all 12 scenarios. Following Ranyard, Williamson, and Cuthbert's (1999) recommendation, we decided to use an incomplete design by reducing participants' load to the evaluation of three scenarios. We selected one scenario from each domain for each participant, whereby each of the three scenarios corresponded to a different type of risk. So, data from a total of 360 evaluations were collected (120 participants with three scenarios each). The four types of risk were each covered by 90 evaluations; the three risk domains were each covered by 120 evaluations. For all participants, the sequence in which the risk domains were presented was held constant (health, economics/politics, ecology), but the sequence in which the types of risk were presented was varied. Huber and Huber (2003) as well as Huber and Macho (2001) found no sequence effects in their scenarios. Therefore, we decided to keep the sequence of risk domains constant.

The number of questions and statements related to the three types of RDOs (new alternatives, possibilities for control, and worst-case plans) served as a dependent variable. We used a category system (see below) to quantify them.

Material

Short descriptions of each scenario were presented to the participants. We ensured that the selected scenarios did not overlap in content. The resulting 12 scenarios and their classification according to type of risk and risk domain are shown in Table 1.

The construction of the scenarios followed the examples provided by Huber (2004; Huber et al., 1997; Huber et al., 2001). Unlike the published procedure, our scenarios were constructed in such a way that participants were to make their decisions on a societal level, that is, not for themselves, but for many others. This procedure was adopted because it is implausible to imagine individual damage for the global type of risk. Each scenario contained a statement that a negative consequence could result from a selected alternative, but no exact probabilities were given. The two alternatives were presented as follows: A riskier alternative was presented with a safer alternative, the safer one being connected with further potential negative consequences. Also, no hints at potential RDOs were given. An example of one of the scenarios (avian flu pandemic, type of risk: catastrophic; domain: health) is provided in the Appendix.

Data Collection

The AIS (Huber et al., 1997) method was used as the fundamental technique for information presentation and data collection. Quasi-realistic scenarios were presented, followed by two alternatives as described above. Participants were allowed to ask as many questions as necessary to make their decisions. Answers were provided according to a fixed pattern (see below). Participants made their decision after having collected enough information. Structuring the situation is an essential part of the decision-making process. Information is not processed automatically; rather, based on the search for information, a mental representation of the situation is created. During the AIS, participants decide for themselves what kind of information they need. We decided to use the conversation-based version (C-AIS), which was developed by Ranyard et al. (1999; see also Williamson, Ranyard, & Cuthbert, 2000) and is based on Ranyard and Craig's (1995) interview techniques. The conversation-based version can be seen as a modification of the AIS. The difference between the C-AIS and Huber et al.'s (1997) AIS lies in the role of the experimenter, who acts as an interviewer and gives verbal (instead of written) answers that are read from standardized templates. This version has the advantage of creating a more natural social interaction, but also disadvantages due to problems in verbalizing and experimenter effects. To avoid any of the known potential disadvantages, the experimenters underwent interviewer training. The interview was non-directive, that is, conducted without any evaluative comments or statements. Questions for which there were no answers in the answer templates were answered spontaneously depending on the context and immediately added to the template. In some cases, the experimenter answered, "There is no information available." To further reduce experimenter effects, we followed the recommendation given by Ranyard et al. (1999), Williamson et al. (2000), and Huber et al. (2001) to use standardized statements like "What do you mean exactly?" or "Could you please pose the question in more concrete terms?" (in order to elicit a more specific question) and "What are you thinking about right now?" (to elicit thinking aloud when a participant had been silent for over 1 min).

Williamson et al. (2000) showed that C-AIS is a well-suited process-tracing method that, unlike thinking aloud techniques, does not provoke reactivity. We thus selected it as our basic method. According to Huber et al. (1997) and Williamson et al., the C-AIS can be combined with thinking aloud, following Ericsson and Simon (1980, 1993). The thinking aloud instruction asks participants to verbalize all ideas they have while working on the task, so that their cognitive processes can be assessed afterwards. However, Russo, Johnson, and Stephens (1989) found that simultaneous verbalization affected cognitive processes and decision accuracy. Further criticism of the thinking aloud technique concerned the fact that not all cognitive processes can be verbalized (Harte, Westenberg, & van Someren, 1994; Westenberg & Koele, 1994). However, if the participant is given clear instructions to communicate thoughts without analyzing them, the independence between verbalization and primary task – that is, the validity of the data – can be assumed (Ericsson & Simon, 1993). According to Harte et al., the experimental setting should include warm-up tasks as well as ensure that enough time is allowed for partici-

Table 1
List of 12 Scenarios Grouped According to Risk Domain and Type of Risk

	Type of risk			
Risk domain	Normal	Medium	Catastrophic	Global
Health	Measles	Carcinogenic substances	Avian flu pandemic	Genetically modified food
Economics/ Politics	Borrowing money	Stock investments	Terrorist attack	Globalization
Ecology	Flooding	Waste disposal	Volcanic explosion	Extinction of endangered species

pants to familiarize themselves with the task, that participants do not have previous knowledge of the theory in question, and that at least two researchers code the data. Biggs, Rosman, and Sergenian (1993) as well as by Payne, Braunstein, and Carroll (1978) also recommend combining AIS and thinking aloud in order to construct detailed models of decision-making behavior. Combining the C-AIS and the thinking-aloud technique allowed us to collect data on the importance of the information that the participants requested (Williamson et al.). Therefore, the instruction for thinking aloud should increase the validity of the verbal data as an indicator of the thinking process.

Finally, in accordance with Williamson et al. (2000) as well as Huber and Huber (2003), a post-decision interview was conducted to assess the validity and internal consistency of the data collected during the decision process. To this end, participants were asked to give a retrospective report about their decision-making process (Ericsson & Simon, 1980). At the end of the study, they were asked to complete a questionnaire in which they described in their own words and for each of the scenarios how they had made their decision. This information was used to determine the relevance for the decision maker of the different categories of information. Demographic data (age, sex, profession) were also collected.

Procedure

Interviews were conducted individually in a quiet room, in most cases, at the Institute of Psychology at the University of Heidelberg, but some participants were interviewed at home. All interviews were recorded with a digital voice recorder and transcribed afterwards. Breaks and disturbances (e.g., by mobile phones) were reduced to a minimum. If they could not be avoided completely, the interview was briefly interrupted and continued after a short break. None of the participants cancelled the interview or refused to answer the final questionnaire. The interviews normally took approximately 45 min.

After participants were welcomed, the procedure for the study was explained and written consent to recording and subsequent anonymous analysis of their interviews sought. Participants received specific information about the procedure in written form and were asked to read the description of the first scenario, obtain further information by posing questions and receiving answers from the interviewer, and to verbalize the statements important for their decision making using the thinking aloud technique. A sample scenario called "railway club" was used as a warm-up task so that participants could become acquainted with the interview situation and practice asking questions and thinking aloud. The sample scenario was not used to collect data. Voice recording started as soon as participants stated that they had read the text and were ready to ask questions and think aloud. After participants had given their final decision concerning the central issue of the scenario (see Appendix for an example), voice recording was stopped and the next scenario presented. Finally, participants were to describe in their own words how they had arrived at their decision for each of the three scenarios. They were also to inform the experimenter about any previous knowledge they had had about the scenarios. At the end of the interviews, participants were given the chance to ask questions about the aims of our study.

Quantitative Content Analysis

The first step was the development of a category system to transform the interview data into quantitative data for analysis. Our category system was based on Huber et al. (1997) and Huber et al. (2001). Their system consists of the following categories: "situation," "probabilities," "secure/insecure consequences," "evaluation," "long-term plans," "RDO," and "information about RDO". This system was used as a basic framework and was modified in the course of our analysis (see Table 2). We added the categories "background knowledge," "experience," and "attitude/rules/principles." We did not use the categories long-term plans and evaluation because they were irrelevant for our question and could also be represented in the attitude categories. In the coding system used by Huber and his colleagues, a differentiation between insecure and secure consequences was made. We named this category "negative and positive consequences." This allowed us to measure the advantages and disadvantages connected with the risk. All participants' questions and statements during the interviews as well as all written explanations from the post-decision interview were coded according to this category system.

Reliability Check

Sixty interviews were randomly chosen to determine interrater reliability. There were two coders per interview. The results showed high interrater reliability ($\kappa = 0.94$) as calculated using the conventional method (Cohen, 1960). This demonstrated that both the categories of questions used and the thinking-aloud data had been classified with high reliability. The remaining 60 interviews were coded by two coders (30 interviews each).

Statistical Data Analysis

Data analysis of the effects of type of risk and risk domain as well as their interaction was done simultaneously by means of logit analysis. Logit models are special cases of log-linear models that are used for multivariate analysis of nominal-scale or categorical data. Natural logarithms of observed frequencies in the different fields of a multidimensional contingency table were computed and expressed as a linear combination of main and interaction effects.

Table 2
Explanation of Coding Categories Shown With Examples From the Scenario "Avian Flu Pandemic" (see Appendix)

Category	Explanation	Example
Situation	Information regarding the decision situation.	"How many people are already affected in Germany?"
Background knowledge and experiences	Background information, which does not refer directly to the decision situation / is not derived from the scenario.	"To my knowledge, the quarantine measure are much better nowadays than in times of former epidemics."
Probabilities	Likelihood of an event or prognosis for the event.	"How probable are the brain-related side effects of the vaccine?"
Negative consequences (extent of damage / costs)	Negative consequences for choosing a particular alternative.	"What brain-related side effects are we dealing with?"
Positive consequences (advantages / utility / benefit)	Positive consequences for choosing a particular alternative.	"Would a quarantine be cheaper as compared to a vaccine / treatment of the side effects?"
New alternatives	Options that point to the investigation of additional alternatives.	"Are there any alternative precautions, for example, a vaccination against the influenza virus or masks?"
Control	Control of the event or the negative consequence.	"Could the danger of side effects be reduced, for example, by administering additional medicine?"
Worst-case plans	Anything that can be done in case of negative events.	"Could they treat the side effects in the brain if necessary? Are they reversible?"
Information about RDO	Receive more information about the RDO.	"How would they treat the side effects in the brain?"
Attitudes / rules / principles	Statements concerning the content of a scenario. Personal attitudes.	"Basically, I am not in favor of mass vaccination."

Logit analyses describe a direct relation between independent and dependent variables. The aim of the estimation of multiple influence factors (type of risk and risk domain) is to make their specific effects visible (Urban, 1993). For example, the natural logarithm of the ratio between the frequencies of both categories of dependent variables (no vs. at least one question or statement concerning new alternatives, possibilities for control, or worst-case plans) are represented as a sum of effect parameters (λ coefficients) under the influence of selected categories of independent variables (e.g., of the interaction between the normal type of risk and the risk domain of politics). The explained quantities are therefore not the cell frequencies themselves, but the ratio between two probabilities of specific expressions of variables, so-called "odds ratios" (Andreß, Hagenaars, & Kühnel, 1997).

This way, the directed hypotheses regarding the influence of type of risk as well as other possible differences in the search for RDOs could be tested. Based on the computation of λ coefficients, the rank order of the influence factors type of risk, risk domain, and interaction on the influence of the three RDOs new alternatives, possibilities for control, and worst-case plans was computed. The estimation of parameters and effect sizes from the logit model is based on maximum likelihood. Using one-dimensional χ^2 tests, the frequency distributions of different variables like background knowledge, attitude, situation, probability, and positive and negative consequences were analyzed in relation to the four types of risks.

Results

Mean frequencies can be misleading if one participant asks a lot of questions in one category and other participants ask no questions at all (see Huber et al., 2001). Therefore, we counted the number of participants with at least one statement or question in a given category.

Data Analysis Based on Logits

First, we specified a model which identified the main effects of type of risk and risk domain as well as the interactions between them. The resulting Pearson χ^2 ($p = 0.64$) and the likelihood ratio ($p = 0.34$) showed that the observed and expected values were congruent. Thus, the specified model can be used to explain our data.

Testing for risk specificity of active risk defusing revealed a significant negative λ coefficient for possibilities for control and worst-case plans for normal risks: $\lambda = -0.85$, $p < 0.05$. For normal risks, fewer participants formulated questions or statements for possibilities for control and worst-case plans than for new alternatives. For medium

risks, a significant positive λ coefficient was found for new alternatives: λ = 1.39, $p < 0.05$. In accordance with our expectation, more participants formulated questions and statements corresponding to new alternatives than for the other two RDOs.

For catastrophes, a significant positive λ coefficient of 1.19 ($p < 0.05$) was found for new alternatives. Contrary to our expectation, the number of persons with questions or statements corresponding to this RDO was higher than for worst-case plans (λ = 1.01, *ns*).

For global risks, a significant λ coefficient of 1.61 ($p < 0.05$) was found for possibilities for control. In line with expectations, most participants produced at least one question or statement concerning this RDO.

λ coefficients of the different RDOs are shown in Figure 1, separated according to the four types of risks. Even if the results are not consistent with the hypotheses in every respect, there are still significant differences in the interest in various kinds of RDOs used for different risks. Therefore, we accept the general hypothesis of risk specificity of RDOs.

In addition, we investigated for which type of risk a given type of RDO received the most questions: New alternatives was the most frequent for medium risk (λ = 1.39; $p < 0.05$), possibilities for control most frequent for global risk (λ = 1.61; $p < 0.05$), and worst-case plans for catastrophic risk (λ = 1.01; $p < 0.05$). Moreover, the interactions between risk and contents in relation to RDOs are interesting (as the following three parameters were redundant in the log linear model, no probabilities will be given). New alternatives (λ = 6.24) and possibilities for control (λ = 7.18) were most often produced under the combination of global risk in the ecology domain. Worst-case plans were most often mentioned in the ecology domain (λ = 3.69).

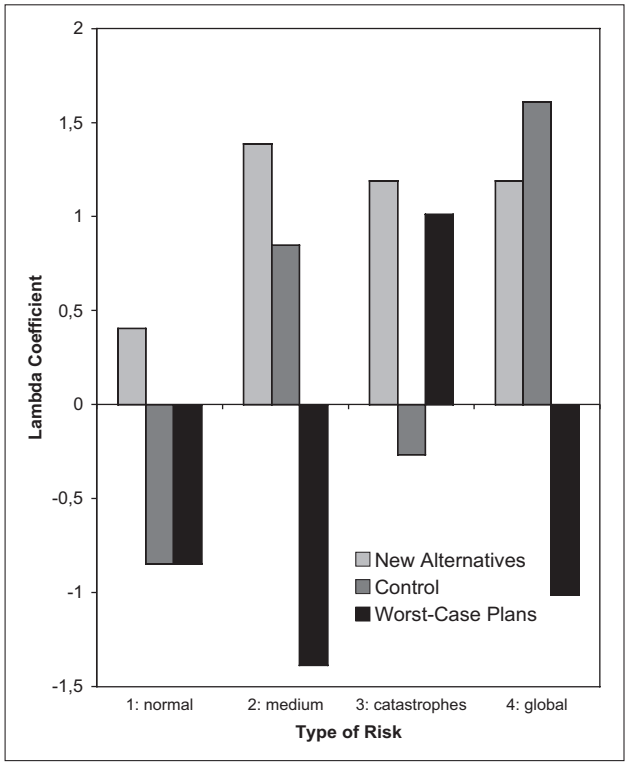

Figure 1. λ coefficients for the three types of risk-defusing operators new alternatives, possibilities for control, and worst-case plans; separated for the four types of risk (normal, medium, catastrophic, and global).

In total, there is clear evidence for risk specificity of active risk-defusing behavior. The combination of type of risk with risk domain has the greatest influence on search for RDOs.

Explorative Data Analysis

We analyzed the difference between the number of participants with at least one question or statement in the category background knowledge/specific previous knowledge via χ^2 tests. Frequency differences between types of risks were not significant for this category, χ^2 (3, $N = 79$) = 1.86. In the category attitudes/rules/principles, a χ^2 (3, $N = 55$) = 15.04, $p \leq 0.05$, was significant. The standardized residuals for normal types of risk (–2.37) and global types of risk (3.04) showed that this category was significantly infrequent and frequent, respectively, which makes sense: The more risky and therefore dangerous the decision, the more attitudes affect decision making. There were no differences for the category situation, χ^2 (3, $N = 321$) = 1.21. But the questions on probabilities significantly deviated from chance, with the χ^2 (3, $N = 166$) = 15.64, $p \leq 0.05$, and a standardized residual of –3.34 for the global type of risk. Negative consequences were homogenously distributed over all four types of risk (χ^2 (3, $N = 323$) = 0.43, *ns*). Positive consequences showed significant deviations with a χ^2 (3, $N = 201$) = 8.61, $p \leq 0.05$, and standardized residuals of –2.2 with Type 3 catastrophic risk and 2.01 with Type 1 normal risk. For Type 3, there were fewer statements on positive consequences, in Type 1 more statements. Table 3 summarizes the result of these exploratory research questions.

Participants' tendency to choose the more risky option decreased as type of risk increased. For normal risks, 71% chose the more risky option as compared with 58% for medium risks, 56% for catastrophic risks, and only 37% for global risks (χ^2 (3, $N = 222$) = 10.61, $p \leq 0.05$).

Discussion

Risk Specificity of Active Risk-Defusing Behavior

The main question of our study was related to the existence of RDO and their connection to different types of risk. We will start the discussion with our hypotheses concerning these relationships. For the normal type of risk, good understanding and management of these risks did not lead to

Table 3
Number of People Asking at Least One Question for Each Category and Risk Type

	Type of risk				
Category	Norm	med	cat	glob	$\chi^2(3)$ value
Background knowledge / experience	18	24	16	21	1.86
Attitude / rules / principles	5	12	13	25	15.04*
Situation	82	85	82	72	1.21
Probability	53	45	48	20	15.64*
Negative consequences	82	81	76	84	0.43
Positive consequences	62	42	38	59	8.61*

Note. *$p < 0.05$. Type of risk: norm = normal, med = medium, cat = catastrophic, glob = global.

an equally distributed exploration of the different RDO options, but decision makers, as for the medium type of risk, looked more intensively for new alternatives, in other words, they went beyond the given frame of reference. It might be that the normal type of risk with its combination of classification criteria does not differ enough from the medium type of risk. For the medium type of risk, most questions and statements were about new alternatives. We are not sure if this result can be interpreted as a phenomenon specific for the medium type of risk because according to the logit analysis, the catastrophic and global types of risk also had a similar influence on new alternatives. According to Huber et al. (2001), new alternatives is the most prominent risk-handling behavior. Therefore, our reported result may be less due to the influence of the medium type of risk but more a consequence of this RDO working as a "general-purpose strategy."

For the catastrophic type of risk, logit analysis shows a significant positive influence on worst-case plans, but at the same time the influence on new alternatives is stronger. In comparison to other types of risk, worst-case plans are the most frequently mentioned here. With a high extent of damage and short delay of effects, decision makers seem to want to reduce the consequences of damage beforehand. Instead of possibilities for control, which is used least frequently, new alternatives (the general-purpose strategy) is searched for. It might be that worst-case plans are searched for in cases in which no adequately evaluated new alternatives are available. Participants may have tried to generate at least a plan for the catastrophe. This explanation supports our assumption that worst-case plans might be one way of risk-defusing in catastrophic risks.

For the global type of risk, the results of the logit analysis follow our expectations that possibilities for control is the most frequently used RDO. No other type of risk had such a strong influence on it. Why is the global type of risk so strongly related to it? First, one can assume that the control of global risks is the only "correct" risk-specific preference (a normative solution). Second, it could be caused by the construction of the scenarios. In our pilot study, we found that global risks were evaluated most coherently according to the evaluation criteria. It could be that global risk is the most homogenous type of risk in the present study. Altogether, there are obvious aspects of risk type specificity, but other factors (risk domain, interaction) were also influential.

Consequences for Active Risk-Defusing Behavior

The results for the influence of risk domains and the interaction between risk domains and types of risk demonstrate strong effects on the number of questions and statements concerning different RDOs. We interpret these results as support for domain-specific effects. Those effects are in line with the results reported by Huber et al. (2001), Huber and Macho (2003), and Payne et al. (1993) on risk domain-specific decision behavior.

The main difference between the present study and others can be seen in a comparison of the effects of different factors on RDOs. The interaction between type of risk and risk domain is especially important for the frequent use of new alternatives and possibilities for control because it depends on the specific scenario. Most worst-case plans are found in the risk domain of ecology, however. The connection between RDO search processes and clearly defined types of risk allows a specification and extension of the approach to RDOs: The scope of this approach could be extended from everyday risk up to more global risks used in our scenarios.

Exploratory Research Questions

The exploratory questions were analyzed with respect to risk-specific frequency distributions. The results allow the following conclusions: Attitudes, values, and principles are mentioned significantly more often for global risks. This is a plausible procedure: The evaluation of global risks, which cannot be assessed for long-term effects, relies more strongly on general individual attitudes, principles, and rules than any other type of risk. For questions from the situation category, there are no significant differences between the types of risk. This implies that, for all four types of risk, situation influences will be checked in a similar way. Nearly all par-

ticipants requested information about positive and negative consequences. This seems to be a result of the construction of the scenarios and from the general understanding of risks. Cost-benefit notions can be seen as an elementary part of decision making, and this seems to be quite independent of the type of risk with the exception of normal and global risks, for which negative consequences were more important.

Significantly more participants asked questions about positive consequences for normal risks than for any other type of risk. This over-representation of the normal type of risk seems to be consistent with the possible outcomes of these risks. In the normal area, decision makers want to know about the positive chances that are inherent in the risks. This "looking for a chance" might be easier if the risk is not as high as other types of risks because of the potential reversibility of actions. That matches the significantly smaller frequency of this type of statement for catastrophic risks. For such risks, positive aspects are less apparent at first glance. With respect to the alternative selected in the end, a preference for the more secure alternative in cases of increasing extent of damage and decreasing degree of reversibility was shown, corresponding with the classification criteria.

Final Reflections

The combination of C-AIS, the thinking-aloud method, and a post-decision interview was chosen to collect a broad spectrum of verbal data. The comparison of the mean number of questions posed and statements made shows that nearly half of the verbal information collected came from thinking aloud. Therefore, this method can be seen as an important source of information and as a useful addition to the AIS. Especially the new category "attitudes/rules/plans" seems to play an important role in the context of global risks. Further research using this multi-method approach seems worth the high investment of time, which is needed for transcription.

The results of the present study do not reveal whether a specific type of risk would allow the prediction of RDO variance. Because risk domain and the specific combination of domain and type are influential as well, it seems more promising to construct an even more detailed typology including formal and content criteria that could explain variations in decision-making behavior. This is not an argument against a formalization of risks, but it points to the importance of a detailed analysis of risk situations. This is in accordance with the naturalistic approach to decision making in which concrete situations, partly single case studies, are the focus of the research.

Some researchers (e.g., Brase, Cosmides, & Tooby, 1998; Cosmides & Tooby, 1987; Gigerenzer & Goldstein, 1996) assume that humans' cognitive machinery has had to adapt to many different situations during evolution; therefore, no one general, but many problem-specific, adaptive processing mechanisms have developed. It follows that only a detailed model, which integrates many problem- and situation-specific aspects, can map real decision problems.

It remains open whether further factors beyond the ones analyzed here (type of risk, risk domain, and the interaction of the two) affect the preferences for certain RDOs. So the scope of the RDO concept must be more clearly defined. The intention of our study was to appraise non-experts' assessment of risks and to investigate how critical aspects of risks can be reduced. For all types of risk, the decision makers tried to precisely explore the situation and the potential negative consequences. These components seem to be an important condition for evaluating and planning. Sufficient information could mean a safety for the further handling of risks. If an RDO is supposed to reduce negative consequences, then these consequences have to be investigated closely. For practical purposes, this means that the opportunity of the risk can be used by adequate strategies as far as a priori calculations are possible. There is evidence that the frequency with which the more risky alternative is selected decreases from normal to medium to catastrophic to global type of risks, whereas the amount of detailed information about consequences decreases, too, due to increasing complexity.

Well-founded education about risk-taking should be supported and put in place specifically for global risks with long-term effects. There seems to be a high need for information because non-experts fall back on existing and less well-founded attitudes (e.g., "I have preferred organic products for years, so I would never support genetically altered food"). Under the condition of sufficient information, active risk-defusing could be supported accurately. The generally preferred strategy (within all four types of risk) of new alternatives shows that it could make more sense to look for new ways – even for risks that are extremely threatening – than to restrict the damage afterwards or before (participants often suggested the search for "something else," e.g., another kind of rubbish dump, another kind of stock).

In addition, detailed and comprehensive worst-case plans should be available for catastrophes (e.g., participants intensively explored information about the side effects of medicine). Participants showed a good feeling for situations in which preventive strategies could not guarantee risk reduction but where, instead, compensation strategies were helpful. As for global risks (characterized by long-term effects), participants proposed that time be used effectively to create controlling strategies until the triggering event occurs (e.g., they suggested that genetically modified food should be labeled). In this case, simulation studies referring to possibilities for control would be very useful for dealing with complexity and the long-term effects of such risks (participants requested simulation studies very often in the interviews). As an aim for upcoming research, such considerations could be investigated in detail to support efficient risk management.

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Appendix

Sample Scenario "Avian Flu Pandemic"

[The original text was written in German.]

You are a member of the Robert Koch Institute. This is the central institution of the German government in the area of disease control and prevention. The Institute has to decide how to deal with a potential avian flu pandemic in Germany. Avian flu is a viral illness that affects birds, especially chickens and turkeys. The contamination from animal to human through close contact with infected animals can lead to a mixture of human and animal influenza virus material when humans and animals are infected simultaneously. That is how the virus can be transmitted from human to human.

Avian flu, which started in Asia, is now also present in Europe. The first cases have been registered in Germany. The situation is problematic insofar as no adequate vaccine is available. Pharmaceutical companies are working on a vaccine for humans, but it is unknown if it will be ready immediately in the event of a pandemic. The vaccination has strong side effects on the brains of people vaccinated with it. Your task is to decide whether such a vaccination should be continued in Germany.

Alternative A: You decide to stop the current vaccination and try to prevent the upcoming pandemic by means of a quarantine. If this is not successful, the pandemic will start immediately.

Alternative B: You decide that the current vaccination should be continued in order to prevent a potential pandemic as quickly as possible. But, at the same time, you accept the strong side effects of this procedure and risk the lives of many healthy individuals.

What information do you need to make your final decision?