Psychologische Beiträge, Band 39, 1997, S. 14-26

Why do real-world problems necessitate a qualitative approach to decision making?

A. C. ZIMMER [1]

Summary, Zusammenfassung

In the communication between scientists and lay people about risk one can observe that the normative models of risk implicitly applied by scientists and the subjective perception of risk by lay people do not fit together. However, this communicative gap cannot be mended by a better scientific education for lay people because it can be shown that scientists in perceiving their respective personal risks exhibit the same kind of inconsistencies normally attributed to lay people. It is suggested not to reduce the complexity of risk to simplifying quantitative values but to use this complexity as a starting point for a rational argumentation about the underlying nets of causes and effects. This perspective seems to be unavoidable especially for those situations where scientists talk about risk and by means of their argumentation influence the future chain of actions events and effects. It is argued that a scientist can only accountably communicate with the general public if he/she takes into account the qualitative aspects of risk as well as the quantitative aspects.

Key words: assessment, communication, quantitative models, risk perception

Warum ist für das Studium realer Entscheidungen ein qualitativer Zugang notwendig?

Bei der Risikokommunikation zwischen Wissenschaftlern und Laien kann man feststellen, daß die normativen Risikomodelle, wie sie von Wissenschaftlern verwendet werden, nicht mit der subjektiven Risikowahrnehmung von Laien übereinstimmen. Allerdings kann diese Kommunikationslücke nicht durch eine bessere naturwissenschaftliche Ausbildung für Laien geschlossen werden, denn man kann zeigen, daß Wissenschaftler bei der Beurteilung ihrer persönlichen Risiken genau die gleichen Inkonsistenzen zeigen, die normalerweise Laien zugeschrieben werden. Es wird vorgeschlagen, die Komplexität von Risiken nicht auf vereinfachende quantitative Variablen zu reduzieren, sondern diese Komplexität als Ausgangspunkt für eine rationale Argumentation über die zugrundeliegenden Ursachen und Wirkungen zu nutzen. Eine solche Perspektive ist besonders für solche Situationen unvermeidbar, wo Wissenschaftler über Risiken reden und damid die Ursache-Wirkungszusammenhänge in der Zukunft beeinflussen. Es wird argumentiert, daß ein Wissenschaftler nur dann verantwortlich mit der allgemeinen Öffentlichkeit über Risiken kommunizieren kann, wenn er/sie die qualitativen Aspekte des Risikos genauso berücksichtigt wie die quantitativen.

Schlüsselwörter: quantitative Modelle, Kommunikation, Risikowahrnehmung

---

[1] Prof. Dr. Alf Zimmer, Department of Psychology, University of Regensburg, Post Box 397, D-93040 Regensburg, Germany; E-mail: alf.zimmer@psychologie.uni-regensburg.de

Real-world problems confronting everyday man when he chooses a career, or decision specialists like supreme court judges when they declare a law constitutionally valid are characterized by unique combinations of cognitive processes. These processes are usually treated in separate domains of psychology, namely, reasoning and decision making. Other related problems are: the risk analysis for complex technological projects, predictions in economics, the evaluation of circumstantial evidence in the judicial process etc.. In all these cases there are some areas of knowledge where unequivocal facts are linked by unequivocal rules, there are other areas where a priori no singular facts are known but only ensembles of facts and where relations between these ensembles can only be characterized statistically and, finally, there are areas where facts and relations are principally well defined but too complex for analytical treatment. However, for lay people a decision will be regarded as satisfactory only if all relevant aspects of knowledge are taken care of, in contrast, scientists approach this problem by decomposing it.

For this reason, in economics and psychology as well as in technology one can observe 'warring camps' of scientists (Jungermann, 1983). Proponents of one side suggest a predominantly statistical approach in terms of states, actions, risks, and outcomes, this is the classical approach of decision making or statistical risk analysis. Proponents of the opposite side tend to reduce the complexity by confining the analysis to those parts of the knowledge base where facts and relations can be unequivocally determined and analyzed in simulations, which in turn result in scenarios. It should not be overlooked that in most application oriented approaches analytical procedures are adjusted for the inherent indeterminism and statistical procedures are built upon a framework of undisputed regularities. For instance, in the judicial system facts and relations are to be 'proved beyond any rational doubt' leaving seemingly no space for statistical interpretation. A closer look, however, reveals that at least in determining the outcomes, especially the amount of a fine or compensation, a decision theoretic procedure is implicitly applied, where qualitative damages are recompensed with money or the severity of a crime is equated with a prison sentence or a fine.

In the Western tradition of philosophy, logic, and psychology until the end of the last century, it was regarded as a truism that logic is the language of thought. The scope of this Aristotelian position has been taken to its extremes by *Leibniz'* claim in his *Dissertio de arte combinatoria* of 1666 that the translation of the Holy Bible into an artificial language, integrating a descriptive language of concepts and the formal language of logic, would resolve the theological differences between denominations. Even in our century we can find vestiges of this tradition e.g. in *Carnap's* quest for the "Einheitswissenschaft" (1923) based upon the pure language of basic sentences, the rules of logic, and *Fodor's* "Language of Thought" (1975) with its neat distinction between declarative and procedural language.

This position has not been unchallenged, especially the close ties of logic and mathematics - for example - *Boole's* "*Investigations of the laws of thought*" of 1854 has been criticized for instance by *Strawson* (1967) who argues that logic should have chosen legal reasoning instead of proof methods in mathematics as its paradigmatic field of application. A closer look at the peculiarities of legal reasoning makes clear why Strawson sees it as an alternative to mathematics:

(i) A legal evaluation is accepted as binding as long as no other evaluation is put forward with a better or an at least as stringent justification. That is, there is a battle for the best justification for the time being and no final judgment is possible as in purely formal sciences. However, even in logic or mathematics a proof is not a description of the thought processes going on in the scientist when solving a problem (see *Hadamard* 1954) but an a posteriori justification of the result. The difference between an accepted solution to a problem in material sciences as compared to formal sciences is that in the former, due to the complexity of its domain and the principal impossibility of cutting it up into independent pieces, it is not possible to do an in-depth analysis independently from the rest of the domain. In contrast, formal systems are structured in such a way that microworlds can be created at where all presuppositions and interactions are known, and therefore the solution to a problem in a formal system consists in showing that this formal system can exactly generate microworlds with the desired features.

(ii) A second, perhaps even more decisive characteristic of legal reasoning is that of evaluating circumstantial evidence. In the ideal case, circumstantial evidence is complete and consistent, that is, it allows the unique derivation of a judgement. In everyday life however, circumstantial evidence might not be complete (that is, more than one competing evaluation is possible), might not be consistent (that is, pieces of evidence point into different directions, and one has to decide according to which criteria a consistent set of evidence can be selected (see *Rescher*, 1976) and, finally, the concepts as well as the operators and qualifier used in verbally expressed evidence might be vague.

In decision making one can observe a development quite similar to that of reasoning as modeled by logic. However, in this case from the very beginning it is made clear that "homo oeconomicus", the rational man, is not the average real man but an ideal. It is interesting to note that one of the two starting points for what has been coined "decision science" is the optimal behavior in betting for pure chance situations (throwing dice or playing roulette), the other being the optimal allocation of funds for insurance policies - insurance for situations which are not totally predictable but not as entirely governed by chance as for instance throwing dice. If the two approaches are combined, the St. Petersburg paradox results as observed by *D. Bernoulli* (1738). He suggested as a solution that the subjective utility is a logarithmic function of the objective value.

One of the most widely applied off-springs of this approach to decision making and problem solving is risk management where the formal apparatus is used to define an optimal portfolio. However, *Bernstein* (1996, p. 49) pinpoints the consequences of an exclusively quantitative approach: "The result is a culture that threatens to become so complex and frequently so arcane as to constitute a new religion. I see three dangers in these trends: the exposure to discontinuity, the arrogance of quantifying the unquantifiable, and the threat of increasing risk instead of managing it."

Arguing about risk - the qualitative side of decision making or: what are the risks of talking about risk in science

Since the mid-70s risk has become an increasingly hot topic of public debate, even long before anthropologist *Lagadec*, who wrote his "*Civilisation du risque*", and sociologist *Beck*, author of "*Risikogesellschaft*", chose risk taking as a theme for their research. The obvious attraction of this concept, especially for feature writers, lies in the fact that it encompasses a multiplicity of possible meanings. One can see the extent to which risk influences our everyday life in our routine encounters with medications (and today even with food products), where one often hears the phrase: "Consult your physician for possible risks and side effects". Even school-age boys talk about "the risk of getting a fat lip" and then as they grow older they try new things like bungee jumping in order to have the "flow" experience associated with the conscious act of taking a risk. There are other possibilities for those who find bungee jumping a bit too extreme. For example, they can experience risk while sitting in the comfort of their own living room and playing a board-game.

There are two aspects to every kind of risk. First, the danger in a situation, action or option and, second, the willingness to place yourself in such danger.

The Oxford English Dictionary (2nd edition, in vol. Quemadero to Roawe page 987) traces the term risk back to the Italian *"risco"* and remarks that it is of uncertain origin; two definitions are given

"1) hazard, danger; exposure to mischance, or peril [/.]
2) the chance or hazard of commercial loss."

What is striking about the term "risk" is that in the English language the term must have been used since the Renaissance because as early as 1661 Blount gives the first lexicographic definition ("peril jeopardy, danger, hazard, chance"), in Germany, in contrast, it was not until the end of the age of Enlightenment that the term "Risiko" became a part of normal language.

Unfortunately, taking the recourse to etymology does not help on the way to a more precise determination of the word "risk". For one there is the change in meaning of the Greek word "rhiza" from root to cliff, which could create a useful metaphor, perhaps of the ocean crashing dangerously onto a cliff-ridden shoreline. On the other hand there is the Spanish word "arrisco", which stems from Arabic indicating "hazardous business".

The normal scientific procedure for explaining a concept in the face of conflicting etymologies is to identify the core of the word and then to set all other meanings aside as examples to be used only in specific instances. Interestingly enough this procedure has already been used by insurance companies, that for years have defined risk as the product of the degree of loss times the probability of the loss occurring. Luce and Raiffa (1957) made this the basis of their theory. However, they did not relate their theory to directly measurable losses and their relative frequency, but rather to loss equivalents and the subjective probability of loss. Yet a number of difficulties occur in the attempt to connect this seemingly direct and immediate expansion of the insurance-oriented concept of risk to a measuring structure (an equation of the condition *"subjective risk" = g(amount of loss) times f(probability of loss)*; where g and f are monotone functions). Today, even Raiffa and Luce are giving up this definition because many losses which can be "objectively" represented as monetary values on the uniform scale, are not subjectively comparable, as shown in Allais´ paradox (1953). For example, ten separate losses of 50,000 DM correspond in no way to the single catastrophic loss of 500,000 DM. If the model of subjective loss expectations is seen as a conjoint measurement structure, then the above mentioned situation contradicts the mutual dependency of both variables. Furthermore a low subjective probability of loss appears to reduce the perceived measurement of possible loss. For example, when a driver passes another car on a two-lane side road he considers himself to be in better control of his car than the majority of other drivers. On the other hand, the occurrence of many losses in one single event leads to the overestimation of the probability of the occurrence of loss. For example, the fear of flying appears to be rational based on the number of reported catastrophes, but this does not take into consideration how seldom these losses occur relative to the total number of flights.

Are risks predictable?

The above example points to a further risk variable, namely the extent to which risks can be controlled, which is not taken into consideration in the *formula "risk = loss times subjective probability"* . Anything that the risk taker perceives as controllable, and thus enters willingly into, appears to be different from something that he or she is forced into and is unable to take action to avoid. One could argue that all of these problems could be solved by going back to the insurance-oriented concept as the only rational way of looking at the situation, discounting the deviations as irrational, but even then one encounters contradictions. They become apparent in the phenomenon of re-insurance, in other words, insurance for insurance companies against a loss which the maximum capacity of one single company surpasses. That means that insurance companies distinguish between "normal" risk and catastrophe, and react to each differently. The contradiction to the principle of maximizing expected gains and minimizing expected loss lies in the fact that the reward for reinsurance is perceived greater than the expected loss because it ensures the existence of the corporation in the face of a catastrophic event.

A further reason why the complexity of the risk concept is so difficult to handle scientifically is that, at least in the subjective perception of risk, there is always the possibility of positive feedback. In other words, the perception of a risk triggers actions, which combined actually increase the total risk. On the other hand, in business and the social sciences most of the models are based on negative feedback; danger recognized means danger eliminated. The catastrophe at Chernobyl shows that positive feedback does not only occur in the nightmares of the overly fearful. In this case recognized risks in the normal procedure caused the technicians to try out a new warning and regulation system. In order to do this the performance of the reactor had to be decreased. However, this lead to a critical condition and triggered measures that were intended to counteract local risks, but actually increased the total overall risk to the point of catastrophe. A cascade of dangerous situations and corresponding individual measures designed to decrease risk led to a global build-up of the total risk.

Risk and uncertainty

In the presence of the obvious difficulties of bringing the concept of risk closer to the normal range of scientific reasoning one could actually end an article in a scientific journal at this point with the sentence: "Once again reality is too complex for science." Nevertheless, there are good reasons for the existence of scientists who occupy themselves with this theme; even if the formula *"risk = subjective loss probability x subjective loss"* is not valid. As mentioned before, the definition of "risk" as either a verb or a noun in the dictionary ranges from "to risk getting a fat lip" to "the risk of nuclear war". Although, in the first instance the expected benefit of saying an inappropriate comment is considered more valuable than the consequences, the second case is more complex. Hidden behind the statement itself are numerous individual problems. At the same time it can deal with a strategy of loss-benefit-weighing. Also in this case the factors involved are not known with certainty, and this is where the risk reaches a second level, which is exactly where the deep structure of the nuclear conflict lies. There are two ways of looking at this problem. The first view states that it is better for both sides to use weapons simultaneously, than for only one side to make a destructive strike; this is a so-called prisoners-dilemma situation and leads to the justification of both sides using their weapons. The other view is that if both sides destroy each other simultaneously then everyone looses, thus making it only rational for both sides to opt out; this is the chicken-game situation. In order to determine the actual deep structure of a risk situation, further more remote risks must first be analyzed. In this case these risks would be, for example, the long-term effects of radioactivity on human health and the growth of plants and animals, as well as the possibility of mutation.

All these facets of the risk concept have in common the fact that, whether it is a personal or societal decision, the possibility of incurring loss is always present. This is what leads to the above mentioned classic definition of risk, namely the probability of loss. This definition, which at first glance appears to be so clear and enlightening, actually clouds the risk problem, because it is practically never applicable. Therefore, if one wants to behave responsibly in a world marked by complications and corresponding uncertainties, it is necessary to analyze rationally the concept of risk.

If one wishes to cope with the complexity of the conditions for specific risks in order to scientifically evaluate the real-world dangers then one has to take into account that even experts have only limited knowledge leading to simplifications or partializations. The combination of this expert knowledge leads to influence diagrams, which make apparent that not only nature-given variables constitute the resulting risk but also human interventions, or rather human decisions.

Similarly as with the concept of risk, the concept of uncertainty is also multilayered in its meaning. In many contexts, uncertainty is based on the idea that information is incomplete. For example, the number of pensioners in the year 2010 is uncertain. Nontheless, this uncertainty does not relieve politicians of their duty to plan for the future. Uncertainty can also stem from disagreement between different sources of information. Thus, the estimation of the income of a prominent public figure may be completely different depending on whether it is based on his life style or his tax returns.

Another source of uncertainty stems from vague verbal expressions. For example, what is meant by "an excessive speed"? Furthermore, varying conditions produce uncertainty, as in the statement "The average water level of the Danube in Regensburg-Schwabelweis is 3.82 meters". Uncertainty is further related to a quantitative aspect, for example, how does the effect of a medication increase in relationship to the dosage? Other cases concern the qualitative aspect, as in the question of which effect model is appropriate for the facts of the case: Is there a threshold or does the effect increase continually? Even in a case where there is essentially complete information, uncertainty can result from the simplification of implicit or explicit model assumptions that are necessary to process the information. In the same way a traffic situation controlled by government regulations can trigger uncertainty by using too many signs and rules all of which must be simultaneously observed, thereby exceeding the perceptual and cognitive capacity of drivers.

For completely determined cases there is the option of automation; in simple cases through system technology and in more complex cases through the so-called knowledge based systems. However, even the use of computer technology does not reduce uncertainty to zero, because calculations are only possible up to a fixed level of precision; fatal mistakes can be made due to truncated parameters. One example is the case involving the Korean jetliner (KAL OO7) that was shot down over Sachalin. Incorrect coordinates in Anchorage, Alaska were not recognized because all the board computers used the same program to check the plausibility of the parameters. The error of truncating parameters led to a mistake of great consequence. Cases like these have led to the principle of "diversified redundancy". In other words diverse control and observation systems have been chosen so that they will not all make the same mistake or function error.

Uncertainty does not only affect the outside world, but also our personal preferences, for example, how our subjective profits fit together with objective values. The conditions of the outside world will also affect what decisions one is finally pleased with. In the end we cannot know, and thus are uncertain about, the degree to which we are certain or uncertain. In other words, we cannot know how much or how little we actually know.

Similar to the way that expected loss imposes itself on the definition of risk, uncertainty is tied to the concept of probability. In the same way that this definition of risk fails, the varying aspects of uncertainty cannot be expressed in the framework of probability theory either. Nonetheless, as before, these difficulties do not relieve us of our obligation to contribute toward an exact analysis of the concept of uncertainty, which will lead to rationally acceptable decisions in situations of uncertainty.

The combined effects of the different aspects of the risk concept, as well as the concept of uncertainty, are perhaps best visualized through an example concerning the dangers of the poisons Aflatoxin and Dioxin (see Table 1).

Based on this table it is not possible to determine the numerical value of the risk or the probability of the occurrence of a loss. However, the information does make it possible to structure a plan of action in a rational manner. In general public opinion there is little consideration for the clear and considerable danger of Aflatoxin poisoning due to eating peanuts. This is largely the case because incidents of poisonings have not been publicized in the news and also because Aflatoxin is a "natural" poison. The first step toward rectifying this situation would be for peanuts and all similar products possibly containing Aflatoxin to carry warning labels, or for the dangers to be explained clearly to the public. Even if information about Aflatoxin were as plentiful as that about Dioxin the subjective danger of Dioxin would still outweigh that of Aflatoxin, because one is more or less helpless when it comes to Dioxin poisoning and one can voluntarily decide for or against the enjoyment of peanuts.

Table 1: Comparison of two toxic chemicals, Aflatoxin B_1 and Dioxin
(Source: Center of Disease control)

	Aflatoxin	Dioxin
toxicity		≈
cancerogenity for humans (kg x days/mg)		≈ (500)
mutagenic potential	high	low
mode of effect	causal	moderating
possibility of threshold-dose reaction	low	high
origin	natural	artificial

Why clever predictors say so little with so many words — and why we, as a result, cannot do without the prediction of risks

Upon reading the second part of the title of this introductory essay, the question of how it can possibly be risky to discuss risk comes up. The fact that this is the case is perhaps best made clear by looking at predictions themselves.

The Delphic Oracle in its answer to Croesus is an example of a prediction without risk. It said that an entire kingdom would be destroyed if Croesus stepped over the Halys. As far as the seer, Pythia, was concerned this prediction contained no risk, because it carried a double meaning and one of the two implied statements was certain to come true. For Croesus the risk lay in the assumption that when information is announced it only ever carries one meaning. Thus, from his point of view the information was not ambiguous. The correct decision for Croesus would have been to forget the prediction altogether and to analyze the strengths and weaknesses of his west Anatolian kingdom in comparison to the Persian kingdom of Dareios.

In contrast, predictions with valuable information are, by necessity, always risky both for the predictor and for those addressed. This is because the predictor commits himself to a certain model and interpretation, thus assisting those addressed in making a decision by giving different weights to the various options, and in extreme cases excluding some options entirely. The risk for those addressed lies in the fact that they are not in a position to evaluate the advice they have been given, because they do not have full knowledge of the model on which the prediction was based. If the predictor had used a different model, the options would have received different weights.

Aside from the risks taken by the person making the prediction and those receiving the prediction, which one can see as a form of responsibility for both sides, there is the general risk of communication. This can range from misunderstandings due to multiple meanings, overlooking a limiting constraint, the misinterpretation of metaphors or analogies, to failure to detect irony, and there are many more. The communication aspect of risk, which has been above all studied in the area of language pragmatics and the formation of human inferences, is important but for this line of argumentation it only constitutes part of the background. The important aspects to be investigated here are the responsibility of the person who makes statements about risks and the possible responses of the person whose actions will be influenced by a risk analysis of the actions involved.

In connection with this there is another completely different case of the prediction of risk, which due to its structure defies empirical evaluation: The prediction of a risk which prevents the occurrence of this very risk. It cannot be empirically evaluated. Not because the predicted event must occur, as in the case of the transgression of the Halys, but rather because as a result of the prediction a fearful event will be avoided - the opposite of a self-fulfilling prophecy. There are many examples from every day life that demonstrate this. One could say that the successful management of everyday life is to a large extent the result of our ability to foresee fatal consequences and hence to avoid the actions that would lead to them. (Later we will see that awareness of the fatal consequence of an action does not always prove successful in avoiding the consequence.) In this case danger is easily avoided and it appears irrational to disregard the option which could avert the danger.

The situation becomes more difficult if not only the specific dangers of each action are predicted but also those resulting from the lack of action. At this point the ethical implications of a decision based on the prediction of risk are not trivial. An example will clarify.

In the 1970s in Sweden meteorological experiments with rockets were carried out; follow-up experiments of these are still done in the area of Kiruna, Lapland. The goal of these meteorological experiments was to carry out a more detailed investigation of the upper atmosphere and the stratosphere in order to make meteorological predictions more precise. This is a task of great practical importance because early warnings of thunderstorms or hail could avoid, among other things, the destruction of millions of dollars worth of crops. Although, on the positive side of this issue, there was the value of the research for the Swedish economy, there was, on the negative side, the danger of humans being injured by falling rocket pieces. In order to minimize this risk, the location chosen for the experiment was the lightly populated area of Lapland. Still, there remained the danger that the shepherds, who look after the reindeer herds in that area, would be injured or killed. In the end, the decision was to evacuate the people in that area by helicopter; this is where the dilemma emerges: The risk of someone being killed in a helicopter accident is significantly higher than the risk of being hit by a falling rocket piece. The question is whether the decision to evacuate was a responsible one or not. If one considers it from the viewpoint of liability, then the decision seems to be, without a doubt, correct. This is because shooting off of rockets, with the accompanying danger to the people, would be considered negligence resulting in possible death or bodily damage. However, a helicopter crash during the evacuation would be regarded as an event beyond human control, therefore the decision maker cannot be made liable for the adverse consequences. However, if one considers the situation from an ethical point of view, then one must ask if, given the over-all importance of this experiment, the ethically correct course of action for the decision maker would have been to choose the alternative statistically resulting in less harm (non-evacuation), despite the fact that then he would be personally persecuted in the case of an accident.

Responsibility in this example can be seen on three levels. On the lowest level there is the technological decision regarding only the general economical usefulness of this meteorological experiment and the small possibility of danger to the residents of Lapland. On the next level is the responsibility of the decision makers from the point of view of criminal or civil law. On the third level is a decision, which, as far as content is concerned, cannot be distinguished from the decision on the first level, except that here its ethical consequences are weighted. The decision for the maximum benefit for many people and the minimal potential danger to few people is made in spite of the knowledge, that in the case of a negative consequence the decision maker will be legally responsible for his actions and must be prepared to accept whatever judgment is made on him.

The dilemmas involved in risky decisions often disappear behind the aspect of inaccuracy, which is so often discussed concerning risks. The reason for this is that in the case of most risks, perhaps the most important ones, there is no quantitative, detailed information and therefore one must simply rely on estimation.

About the difficulties in estimating risks

The degree to which the perception, and therefore the subjective evaluation, of the risk is regarded as alarming depends on how one asks about this perception. This can best be seen if one uses differently formulated, but equivalent, questions in order to elicit the subjective risk sensitivity for different hazards. For example, one can ask in a variety of ways about the dangerousness of different illnesses.

1. Estimate how many of the people who come down with illness X will die from it.
2. If 10,000 people come down with illness X, how many of them will die?
3. In the case of illness X what is the proportion of those who die from it to those who survive?
4. If 100 people with X illness die, how many other people with the same illness will survive?

One can quickly see that the answers to these questions should correspond perfectly. However, if one does this experiment, each mode of question will produce a reliable but unique ranking of risk, each having only a moderate correlation with the objective risk.

Upon further consideration it becomes obvious that there is not one "best" question. In each case there are both over- and underestimations and nowhere there is a perfect correlation between the actual and the estimated risk. On the other hand, this contradiction is not due to whether one has confused the subjects by asking misleading questions, because their answers are largely based on preconceptions about the illness. In other words, in a reliable way the risk of a certain illness will be overestimated in some questions and underestimated in others. Above all, the results indicate that the risk of an illness will be differently stressed depending, not primarily on general ignorance about the subject matter, but on the different questions accentuating different aspects of riskiness.

This issue is of eminent importance for applied decision making under risk, for example in the assessment of technology. On the one hand, risky decisions are only possible with the acceptance of those directly affected, in other words if consideration is shown for their subjective risk. On the other hand, this subjective risk is obviously not one-dimensional. This, in turn, means that in the case of a socially responsible risky decision, first the most important decision dimensions concerning the subjective risk of those directly affected must be identified and then be taken into consideration when communicating about the risk.

How the perception of risk differs from the objective risk

The results in the previous table make it apparent that, depending on the form of the question, different mental representations of the risk will be activated, which will determine how the risk will be perceived finally: For instance, the risk will be overestimated if the event happens close by, happens to children, or implies many fatalities at one location and one point in time, that is, if the motivational factors are given for focussing the attention on the event. From the point of view of an evolutionary approach to cognition (see *Cosmides,* 1989) such an allocation of attention appears plausible.

As a consequence of the various components of the subjective concept of risk, the "objective" risk is often not any good for bringing about the desired changes in behavior. For example, in the case of car driving or cigarette smoking almost all of the components work toward the reduction of the subjective risk (limited potential for catastrophe, high familiarity, personal control, etc.). On the other hand, in the case of nuclear power plants all characteristics accentuate the subjective risk, in spite of the fact that objective risk is low, even if one uses the more pessimistic estimates of the Union of Concerned Scientists.

What does risky behavior tell about the risk taker´s value system?

If it is not possible to compare perceived risks with different characteristics, then one could, as in the experiments on decision making, attempt to avoid these difficulties by analyzing the observable decision behavior as it appears when clearly ascertainable, objective facts are given. This is indeed a possibility for the analysis of risks. One must simply take a different perspective and then it should be possible to establish a scale of values underlying observable behavior in the face of risk. One could, for instance, compute the benefits of different safety measures and the willingness of organizations to promote or the legislature to regulate the use of the measures. If one compares the cost/benefit relation of seat belts vs. airbags, the decision of the German legislature to make seltbelt usage compulsory but not the installation of airbags in cars, reveals that they implicitly value the average human life at less than 1 million DM.

However, this conclusion is not as unequivocal as it appears at first. In the case of risks which are not so well known and socially acceptable as those in traffic, politicians and organizations will drastically change their value for a human life. For instance, in the case of asbestos the monetary equivalent of a human life is 3 million DM and in the case of formaldehyde it is over 1.5 billion DM.

This concluding example also shows how multi-faceted, and thus difficult for scientific investigation, the concept of risk is. Nevertheless, the reasons why certain risks are taken and others are avoided should not only be considered in retrospect. They can also help finding socially acceptable, or at least justifiable, solutions for the risky situations, which society must face in order to continue to exist.

The difficulties with the concept of risk - more than just a post-modern hangover

J. Rousseau has been the first to point out that our very civilization produces many of the risks which threaten it with catastrophe. In a letter to Voltaire written on the 18th of August 1756 concerning the earthquake in Lisbon, Rousseau puts the blame on the "free, perfected, and consequently spoiled people", because it is not nature that is responsible for the destruction of "20,000 six to seven story buildings", but rather the people who built them. If the buildings had been predominantly single story and placed further apart then the inhabitants of the area "would have met the next day 20 miles away as if nothing had happened". This shows that the difficulties in determining the causation of a risk are not new: Apparently, it is not easy to determine whether a risk is natural, and thus unavoidable, or whether the fault lies in humans.

However, a more detailed analysis of the subjective processes of risk perception can be traced back to classical literature. In "De natura deorum" *Cicero* indicates "that everything true is tied to certain false ideas; they both resemble each other so much that safe criteria for judgment and agreement cannot be found". Faced with these difficulties he continues: "[/.] this leads to the principle that a sage will choose his course of action by taking into account that which is plausible but he will still lack precise understanding because his choice will reflect his subjective perception of reality still lacks precise understanding, because it reflects perceptions of reality." (translation by the author)

Still, less than 100 years after Cicero, the citizens of Pompeii were warned of a coming earthquake and nevertheless took no action to relocate their city. Thus, by not behaving as Rousseau would have suggested, they suffered the consequences of this plausible threat.

In my opinion, an ill-advised consequence of these difficulties would be to implore the end of rationality in the face of risk. The essence of rationality lies in knowing as much as possible and working according to this knowledge to the greatest extent possible, in order that decisive prognoses may be made. However, the idea that in complex situations there has to be only one right solution must be discarded. Further, it should be remembered that this is not just a problem of today but that it has existed already in the time of Cicero: "[/.] Because there is no problem where there does not exist a multitude of views about it, not only of lay persons but also of experts, and the views are so different or contradictory that there actually exists the possibility that none of them are right." Cicero has to be distinguished from today´s risk experts by his optimism in believing that there is a unique possibility which is correct. Such a situation tends to provoke skepticism about experts and many examples can be found to support this.

And what does all this mean for the scientist interested in feasable applications?

With few exceptions the success of a scientist does not exist in its effect on concrete cases, but rather in the changing of a statistical parameter: the reduction of a danger by x%, the lengthening of the average life span or the reduction of the uncertainty of a prediction. In most situations the effect results from multiple causes and the optimism of the scientist is based on the presupposition that a local improvement will improve the entire system. Even though the statistical improvement will never carry the same weight as the physician´s emotional experience when healing a person, the statistical characteristics of a risk make it possible to evaluate the advantages and disadvantages from a detached point of view, usually termed the ´stance of rationality´ and assumed to characterize the scientific community.

However, it is exactly on this point that one can find the causes for the occasional gap in communication between scientists and the public. While the scientific report speaks of probable changes in the balance of risks and benefits, the public reacts on the basis of concrete incidents, which are imaginable and therefore more comprehensible in their implications. As a result the top speed on a certain road will not be decreased from 140 km/h to 100 km/h because the kinetic energy and the potential of danger would be cut in half, but rather because one concrete and tragic accident has occured. The scientific reports regard risks resulting from new technology as reasonable because they are in the same order of magnitude as already existing and accepted risks. On the other hand, in the eyes of the public, who are politically aware about technology, the assessment of this technology may give rise to a scenario of imaginable, potentially catastrophic events: Both accounts are open to argument. The multiplication of single probabilities, as in a fault tree, might result in an estimate according to which the average danger does not increase as a result of this kind of technology (the **probabilistic** line of thought). On the other hand, possible catastrophes can be imagined, which would be impossible without this kind of technology (the **possibilistic** line of thought).

Since both, the probabilistic and the possibilistic, lines of argumentation are rational in themselves but nevertheless incommensurable, a decision science aimed at practicable ways of advising the process of policy making must provide a framework in which this traditional incommensurability is overcome. The concept of **Qualitative Decision Making** is intended to provide such an integrative perspective.

References

1. Allais, M: Le comportement de l´homme rationnel devant le risque: critique des postulats et axioms, de l´école Américaine. Econometrica 21, 19853, 503-546.
2. Bernoulli, D.: Specimen theoriae novae de mensura sortis. Comentarii academiae scientiarum imperiales petropolitanae, 1738, 5, 175-192 (Transl. by L. Sommer in Econometrica 22, 1954, 23-36.)
3. Bernstein, P. L.: Thinking about the new religion of risk management. Harvard Business Review 3/4, 1996, 47-49.
4. Cosmides, L.: The logic of social exchange: Has natural selection shaped how humans reason? Studies with the Wason selection task. Cognition 3, 1989, 187-276.
5. Jungermann, H.: The two camps on rationality. In: R.W. Scholz (Ed.) Decision making under uncertainty. Amsterdam: North-Holland, 1983
6. Luce, R. D., Raiffa, H.: Games and Decisions. New York: J. Wiley & Sons, 1957.
7. Rescher, N.: Plausible reasoning. Amsterdam: Van Gorcum, 1976.