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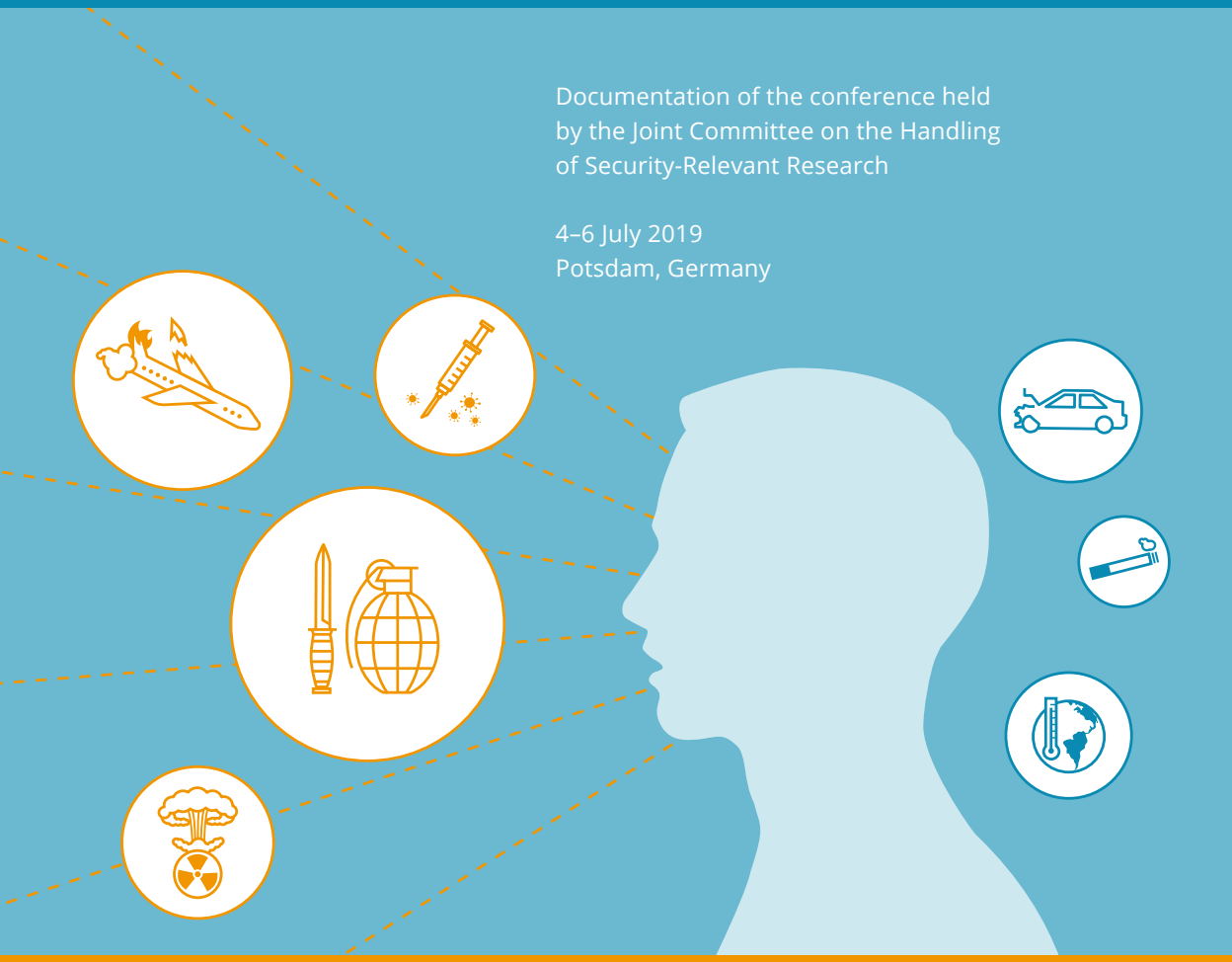
Crossing Boundaries in Science

The Mystery of Risks – How Can Science Help Reconcile Perception and Assessment?

Documentation of the conference held by the Joint Committee on the Handling of Security-Relevant Research

4–6 July 2019
Potsdam, Germany



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Crossing Boundaries in Science

The Mystery of Risks – How Can Science Help Reconcile Perception and Assessment?

Thursday, 4 July 2019
Potsdam Museum, Am Alten Markt 9, D-14467 Potsdam

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Summary

Lena Diekmann, Johannes Fritsch
Joint Committee on the Handling of Security-Relevant Research

The conference format 'Crossing Boundaries in Science' of the German National Academy of Sciences Leopoldina is meant to stimulate discussions between areas of research that are particularly dependent on new forms of interdisciplinary cooperation and method transfer. The first international conference, entitled 'Modelling Nature and Society – Can We Control the World?' took place in Weimar in June 2016. Its objective was to provide an overview and discuss current attempts to understand and control complex systems in nature and society using scientific modelling.

The second international conference took place in Potsdam in July 2019. It was organised by the Joint Committee on the Handling of Security-Relevant Research and focused on the role of science in the perception, assessment and handling of risks in our increasingly complex world. This includes the frequent overestimation of certain risks associated, for example, with terrorism, vaccination and genetic engineering as well as the prevalent underestimation of risks associated with common causes of destruction, illness and death. The scientific community attempting to assess and communicate these risks on the basis of scientific evidence is often confronted with great challenges since public risk perception systematically follows more subjective and emotional principles. This systematic misjudgement of risks often leads to irrational individual and socio-political decisions.

The conference was accompanied by the student workshop 'Risk Governance and the Role of Science and Humanities'. 15 Master and PhD students from various countries and disciplines came together to discuss and share their scientific access to risk. Participants were selected by the Joint Committee on the Handling of Security-Relevant Research and provided with travel funds. Led by Filippa Lentzos and Johannes Fritsch, the workshop introduced the students to the general aims and tasks of the Joint Committee as well as the topics of the conference. This prepared the students for active participation in the conference and offered a lively scope of discussion.

Participants of the Leopoldina students' workshop 'Risk Governance and the Role of Science and Humanities' on 4 July in Potsdam.

Over the three-day conference 18 scientists from fields including sociology, economy, philosophy, psychology, medicine, meteorology, and biology discussed the following questions:

- How are risks socially constructed?
- What are commonly underestimated and overestimated risks?
- Did our lives get riskier or do we simply know too much about potential risks to handle them objectively?
- What are positive as well as negative consequences of the misperception of risks?
- Does the precautionary principle hinder innovation and progress?
- Do we face more complex risks in times of globalisation?
- What are the origins, probabilities and time scales of certain risks and how can we reliably assess these with scientific tools?
- How can science help to reconcile the systematic misperception of risk and promote evidence-based policy in this context?
- What are short-term and long-term strategies to mitigate risks?
- How can we foster the risk literacy and resilience of individuals and society?

The answers to these questions which are presented in the edited and summarised documentation below are, naturally, as diverse as the fields of study represented. To give a short introductory overview:

Ortwin RENN (*Institute for Advanced Sustainability Studies*) illustrates the distinctions between conventional risks and systemic risks. Despite their potential severity systemic risks often do not get the attention they deserve. Although they are not well understood due to their high complexity, transboundary effects, stochastic relationships, and nonlinear cause-effect patterns with tipping points, they represent a far greater threat as they create new, unsolved challenges for policy makers in risk governance.

Martin SCHRÖDER (*Philipps-Universität Marburg*) introduces us to the paradox of risk society and discusses what twists our minds into the faulty perception of a more menacing and riskier world while measurable indicators of the quality of life are actually improving. He calls for media to transform the problem-oriented coverage into a more data-driven reporting, which puts crimes that are occurring with ever less frequency into a long-term perspective.

Ellen PETERS (*University of Oregon*) explores how risk perceptions are constructed through the psychology of individuals and their social influences. By presenting the concept of the affect heuristic, she describes how emotions act as cues by spotlighting information and thus can serve as efficient mental shortcuts for navigating the world's complexity.

Nassim Nicholas TALEB (*New York University*) discusses two flaws in conventional risk analyses when translated to the real world: 1) missing dynamics and ergodicity and 2) using thin-tailed distributions. He shows that many psychological biases seen negatively, such as mental accounting, become rational and optimal under multiplicative dynamics. He further argues that asymmetric reactions such as paranoia (and overestimation of tail probabilities) are entirely justified under the right conditions.

Didier SORNETTE (*ETH Zurich*) dissects the causes and mechanisms of catastrophic failures for the industry sector, such as the explosion of the Deepwater Horizon and the Challenger disaster, as well as for the global financial crisis. Common to these examples is that dangerous conditions that had the potential to escalate to a critical level were known from the beginning.

Practical solutions for the efficient and timely transmission of information on risks are risk analysis, accumulation of knowledge about risks, decision-making and rewarding the process of communication and not only success.

Gaby-Fleur BÖL (*The German Federal Institute for Risk Assessment*) specifies that a clear understanding of how risks are perceived and of which factors influence risk perception are both crucial for adequate risk communication. The term risk refers to the likelihood of damage resulting from a potential hazard, as well as the likelihood of exposure to such a hazard. These parameters are substantially different to those of laypersons, who turn to factors such as controllability or the potential for catastrophe. Hence why the gap between experts and laypersons should be closed.

Cornelia BETSCH (*University of Erfurt*) investigates tools and techniques used to fight misinformation spread by science deniers. Her behavioural research, mainly concerning vaccines and why they are sometimes refused despite their obvious lifesaving effect, shows a systematic pollution of the information environment. Approaches to understand and conquer science denial are an essential step for navigating through the (social) web.

Heribert DIETER (*German Institute for International and Security Affairs SWP*) examines political risks by looking at the trade war between China and the USA and the potential of this war to lead to a deep crisis of globalisation. He claims that the current clash is not only one between a rising and an established power – it is a conflict within OECD societies and a case of the threat posed by China exposing the weaknesses of the current form of globalisation.

Jochem MAROTZKE (*Max Planck Institute for Meteorology*) walks the audience through the unique global assessment process of the Intergovernmental Panel on Climate Change (IPCC) and reports on the struggle of finding the right balance between avoiding both false alarms and missed alarms. Despite their difficulties of production, the assessment reports (AR) are very powerful documents because their conclusions and recommendations are owned by both the scientific community and the governments.

Lothar H. WIELER (*Robert Koch Institute*) discusses current and future strategies for mitigating or avoiding pandemic outbreaks. Early signal detection by means of surveillance based on both official and unofficial sources is at the core of any public health response. By consistently collecting and analysing all the available data in a timely manner and on an international level, more insights into the biology of infectious diseases can be gained for the benefit of the global health emergency architecture.

Garry PETERSON (*Stockholm Resilience Centre*) stresses the connectivity of the world, which is often overlooked, by explaining how, in ecosystems, the biggest impacts of an event can be distant in time and space. As drivers for regime shifts or tipping points, he identifies a variety of factors and processes on the local and global scale where gradual change as well as shock can occur to cause fundamental change. In his comparative approach to regime shifts he is involved in developing databases in an enormous complex field and observes strategies of resilience.

Ralph HERTWIG (*Max Planck Institute for Human Development*) introduces how people's risk literacy can be boosted by specific cognitive tools and visual representations of information. He calls for a better understanding of irrational behaviours in the face of risks in terms of the description–experience distinction. Learning from description and from experience should be acknowledged as two separate learning modes that result in systematically different choices in response to threats.

Special thanks is given to the members of Scientific Board Crossing Boundaries in Science 2019 for drafting the concept and program of this conference as well as the speakers for bringing it to life. Also special thanks to Yvonne Borchert, Anita Krätzner-Ebert and Johannes Fritsch for the organisation and coordination of this event and to the Alfried Krupp von Bohlen und Halbach-Foundation for supporting it financially.

Keynote Lecture

Introduction

Thomas Lengauer
Max Planck Institute for Informatics

I welcome you cordially to this keynote lecture, which starts the international conference 'Crossing Boundaries in Science: The Mystery of Risks – How Can Science Help Reconcile Perception and Assessment?' I am a member of the Presidium of the German National Academy of Sciences Leopoldina and I also had the honour of being a member of the Programme Committee planning this conference. The Leopoldina was established in 1652 and later received the Imperial Recognition by Emperor Leopold I. It is therefore quite an old organisation and one of the oldest academies of science in the world. Today, Leopoldina comprises more than 1,600 outstanding scientists from more than 30 countries. Among these, currently, there are around 32 Nobel laureates. The members of Leopoldina represent the whole spectrum of scientific excellence, ranging from the natural sciences to the humanities. As the German National Academy of Sciences, one of Leopoldina's central and most prominent tasks is to provide science-based advice to policymakers in Germany and to the public.

This includes organising several public events, such as this one in the international conference format 'Crossing Boundaries in Science'. This format is meant to stimulate discussions between areas of research that are particularly dependent on new forms of interdisciplinary cooperation and method transfer. At this point, I would like to thank the Alfried Krupp von Bohlen und Halbach-Foundation for their generous sponsorship of this year's conference.

The first international conference of this kind was entitled 'Modelling Nature and Society – Can We Control the World?'[1] and took place in Weimar in June 2016. Its objective was to provide an overview and to discuss current attempts to understand and control complex systems in nature and society using scientific modelling. As a result, it was noted that many aspects of nature and society are still too complex to reliably model and predict them,

1 For conference documentation see: Fritsch, J., Borchert, Y., & Hacker, J. (Eds.). (2017). *Modelling Nature and Society – Can We Control the World?* Deutsche Akademie der Naturforscher Leopoldina – Nationale Akademie der Wissenschaften. Stuttgart: Wissenschaftliche Verlagsgesellschaft. Retrieved 20 November, 2020 from www.leopoldina.org/uploads/tx_leopublication/NAL_Nr419_Gesamt_Internet.pdf

even with modern technology. It is often a matter of knowing all relevant factors involved in understanding causal relations, for instance, regarding interactions between genetic and environmental factors in biology and medicine, or the complex interplay of many factors in economic systems.

This is the second conference in the series 'Crossing Boundaries in Science' and it is entitled 'The Mystery of Risks – How Can Science Help Reconcile Perception and Assessment?' The conference will focus on the role of the natural sciences and the humanities in perception, assessment, and handling of risks in our increasingly complex world. This includes the frequent overestimation of certain risks associated, for instance, with terrorism, genetic engineering, artificial intelligence, or vaccination, but also the prevalent underestimation of risks associated with common causes of damage, illness and death.

The scientific community attempting to assess and communicate these risks objectively is often confronted with substantial challenges since public risk perception systematically follows subjective and emotional principles. The systematic misjudgement of risks often leads to irrational individual and socio-political decisions and to the inefficient use of resources.

With that I thank all people who have contributed to the preparation and organisation of this conference and wish us all an inspiring and fruitful meeting.

The Risk Perspective – Coping with Uncertainty in a Complex World

Ortwin Renn
Institute for Advanced Sustainability Studies

Abstract: *The paper distinguishes between two types of risks: conventional and systemic risks. Conventional risks can be contained in space and time, follow linear cause-effect relationships and require effective and targeted interventions into the cause-effect chain. Systemic risks, however, are characterised by high complexity, transboundary effects, stochastic relationships, and nonlinear cause-effect patterns with tipping points and often associated with less public attention than they deserve. Systemic risks range from natural hazards, environmental threats, financial crisis to cybersecurity. Due to their special features, systemic risks are overextending established risk management and creating new, unsolved challenges for policy making in risk governance. Their negative effects are often pervasive, impacting fields beyond the obvious primary areas of harm. The paper describes the distinct features of systemic risks and explains their properties. It focuses on the issue of risk perception and the likelihood of policymakers' and the general public's insufficient attention to systemic risks. The paper argues that a graphic representation and simulation of evolving systemic risks and a participatory deliberative approach of inclusive risk governance is needed in order to prevent, mitigate or control systemic risks.*

I would like to take you back 4,000 or 5,000 years. There is a little anecdote, which, of course, is fictitious because nobody was there to observe it at the time. Imagine three cavemen sitting in front of the cave, and they are talking about life. The first caveman says, 'Look, I think we have a wonderful, safe life. If you look outside, we have clean air. There are no pollutants anywhere around, and we are in the fresh air all the time. We are working outside, and it seems to be a very safe environment.' The second caveman replies: 'Well, even more so, if you think about our water, we take it directly from the springs that we have in front of us. All clean and fresh!' The third person

enters the conversation: 'Well, and our food is all organic. We eat only food that Mother Nature has given us.' They continued to contemplate their life, then, after a while, one scratched his head and remarked: 'Well, there is only one question I have. Why on average are we getting no older than 30 years?'

1. The Increase of Life Expectancy and the Reduction of Accidents

Indeed, human lives in terms of life expectancy and health conditions have improved considerably, specifically in the last 150 years. From 1950 to today, we witness another dramatic increase. Our life expectancy in Germany has increased over the last 30 years by around 12 years, and we can enjoy a life expectancy for babies born here in Germany of around 79 for men and 83 for women. That is unheard of over the course of human history. If you think about life expectancy over the centuries, but also across different countries, this is a very spectacular accomplishment. We succeeded in making life safer, securer, and much less dangerous than it used to be. In that sense, risk is not only a mystery, it is also a paradox. Life has become safer year by year but, as revealed by many surveys, our impression says the opposite: most people believe that we face more risks to health and life today than during the previous decades. If you take the usual risk indicators in terms of premature death, in terms of health losses, in terms of accidents and other risk factors, there is a huge and very impressive record of success. We can make it even more pointed if you talk again about my home country, Germany. If you ask how many Germans will die prematurely, and I will deliberately put prematurely at the age of 70 (because I am closely reaching that age), the answer is that out of 10,000 people in Germany, 9,460 will reach their 60th birthday: that's right, 9,470 out of 10,000. That, again, is a very impressive number, and it is something that should not be taken for granted. Let me choose another country, for example Zambia, is also an interesting country because there is no civil war or something that could darken the statistics here. Out of 10,000 there, 4,300 will reach their 70th birthday. More than half of them will die prematurely. There are dramatic differences between countries. However, in nearly all OECD countries risk to life and health have been significantly reduced.

Very often, if we talk about risks, we tend to forget about these success stories. Take occupational accidents. In 1962, we had in West Germany, not including East Germany, around 5,000 fatal accidents during work. Now including East Germany, the number is down to 672 as of last year, which

was even higher than on average over the last five years. The number of people that actually die during work has been reduced by almost a factor of 10. This statistic also includes traffic accidents during work. Great progress! And again, other countries do not fare so well. If you go to other countries, for example, Brazil, which has three times as many inhabitants as Germany, around 70,000 people are killed during work, this is massive in comparison to Germany. We can see that safety cannot be taken for granted since we have many threshold countries that are in the phase of rapid industrialization and face many more accidents than we do. Therefore, it is a very strong impetus for us to assure that these countries learn the institutional and organisational lessons as to how they can reduce the number of accidents and fatalities.

Another example is the dramatic reduction of fatal car accidents. If you take the year 1972 Germany experienced close to 22,000 fatal accidents. Nowadays we are down to 3,500. Furthermore, we now drive around 2.6 times more than 1972. If you take the ratio of accidents per kilometre driven by car, the reduction amounts to a factor of 16. These are all dramatic improvements.

These examples all refer to conventional risks, risks that we can regulate within a specific regime, that can be contained in time and space and linked to a specific sector, in particular workplace or car accidents, technological incidents or other safety failures. We have apparently been successful in developing public regulations and institutions that have been able to reduce risk so considerably that we still experience increasing life expectancy from one year to the next. It is a public preconception that life expectancy is stabilising. At some point, it will, but not yet. This is why the perception that life is getting riskier every day does not match the statistical reality.

2. Systemic Risks and the Risk Paradox

Around 78 % of the German population believes that life has become riskier over the last two decades. They believe that we face more threats, that life has become more dangerous. Taking the overall statistical numbers, that does not seem to match what we know from reliable data sets and proven statistical methods. I have called this discrepancy the risk paradox[2], but, at the same time, we also witness a phenomenon that we call risk attenuation. That goes back to a theoretical concept that Roger Kasperson, Rob Goble and others

2 Renn, O. (2014). *Das Risikoparadox. Warum wir uns vor dem Falschen fürchten.* Fischer: Frankfurt am Main.

including myself developed in the late 1980s. It claims that risks are either amplified through social processing of information, communication, perception, or they are attenuated.[3] Either the magnitude and likelihood of a risk might be augmented or amplified, or, conversely, some risks that have the potential to do great harm are more or less attenuated. Such attenuated risks are not as visible in the public sphere nor are they often discussed in public debate. We refer to these risks as systemic risks.

Systemic risks have a couple of features that make them likely to be attenuated. But before coming to the features it is necessary to define systemic risks. Systemic risks have the potential to threaten the functionality of a vital system on which society relies. The services associated with such a system, for example energy supply or internet access, are crucial. These risks can still be assessed in terms of lives lost, health impacts or impediments to wellbeing, but the focus on functionality gives us a different perspective on what is at risk here. We can talk about crucial social services in terms of energy, water, health, food security, or education. We can talk about technological services, like Internet and cyber security. They are crucial for performing all the necessary activities of and for society. We can identify risks that have the potential to endanger or threaten the functionality of those systems or even destroy these systems in such a way that recovery or fast recovery is not possible. That is the first major aspect of the concept of systemic risk.

The word itself is used frequently when referring to financial risk. In 2008 and 2009 during the financial crisis, it was called systemic risk because the chain of events acted like dominoes. If you start with one, then all others collapse, and in the end, the whole system loses functionality. We know the financial system was close to collapse. So, when referring to systemic risks, we think of the potential of a critical system being threatened by a whole set of potential activities or events that could trigger dysfunctionality or even collapse.

3 Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., Kasperson, J.X., & Ratick, S. (1988). The social amplification of risk: A conceptual framework. *Risk Analysis, 8*(2), 177–187.

3. The Characteristics of Systemic Risks

What is it that makes a risk systemic compared to the conventional risks that I mentioned before? The first thing is that these risks are very complex. I know that this seems to be the fashionable word to use, but for these risks, the attribute 'complexity' has a clear meaning. It does not mean that things are complicated but that, if you look at the relationship between triggers and consequences, between causes and effects, we experience many intervening variables in between the chain of causes and effects. So that it is either impossible or extremely difficult to reconstruct a valid chain of causal structures that help us to understand the triggers, the consequences, and the impacts of these risks. Often, we end up only with a vague representation of all the relationships and interdependencies.

Complexity means we have a whole web of intervening factors that interact with each other, that reinforce each other, and that attenuate or amplify the given causal relationships. Very often, we can retrospectively understand what happened. However, we cannot predict what will happen. This gives rise to a high uncertainty, which is a second major characteristic of systemic risks. It is not just that we need to consider the usual statistical confidence intervals. We always have probability distributions with confidence intervals when we reach into the stochastic world. But with systemic risks we enter the world of genuine uncertainty. In this world, identical causes may lead to different effects in different situations, even if you are cognizant about these situations and know perfectly well in which way they differ. This feature is familiar from health physics when you think about cancer, for example. We know the overall distribution over time but we cannot say which individual will be affected. Often, we are even uncertain about population risks; in particular if context conditions are changing. This kind of second-order uncertainty is typical for systemic risks.

The third major characteristic is that these systemic risks, due to their complexity and to their uncertainty, cross boundaries, both national and sectoral boundaries. A good example is the risk of mad cow disease, or more accurately the Creutzfeldt-Jakob disease. That is an example of the past, but what is interesting about it is the observation that the major risk event was not the health threat but the risk to the institutions dealing with the threat. In all of Europe, we witnessed about 174 additional cases of Creutzfeldt-Jakob disease, which is not a major threat if you consider that about 300 million people were exposed, but the event had a lot of repercussions as ministers had

to resign and a major economic loss for agricultural products occurred in the UK. Due to the loss of trust, many agencies were remodelled, among them the European, German and the British food protection agencies. You can see that one type of risk has caused a ripple effect from one sector to the next, from the health sector to the economic sector, from the economic sector to the political sector, from the political sector to the institutional sector. Each time it extended into the next ripple, the risk increased in intensity and impact.

For many of these systemic risks we do not know what triggers them, and there might be tiny instances that trigger major impacts. That makes it difficult, for example, for regulatory bodies to anticipate them. Conventional risks in comparison are very clear: there are high-speed cars and they can have accidents. Consequently, we make sure that the cars are improving technology-wise and the drivers are better trained. If you are in a systemic risk sector, however, you may face an impact from a very different domain that turns over to another domain and creates havoc there. Systemic risks transcend boundaries of jurisdiction, nationality or sectoral responsibility. Consequently, it is extremely difficult to regulate such risks. If you think about global risks such as climate change or water pollution worldwide or agriculture and nutrition, all these risks cannot be confined to one sector, country or legal domain.

The fourth characteristic which is probably one of the most problematic in terms of human learning refers to nonlinear cause-effect functions with thresholds or tipping points. The tipping point problem is extremely difficult to handle because those who take risks get positive feedback for what they are doing until a specific point. As soon as you reach the point, it is too late. We have seen this pattern evolve during the financial crisis. Everybody was very confident that they would handle the risks and could go on forever. Everyone in the financial world was very much aware that you cannot inflate your virtual assets without having any real value behind it. However, if everybody thinks, 'I am out before it collapses,' then the system is bound to collapse. It was the case that even the people who felt very confident about being ahead of the financial lottery lost a lot of money. Then, in the end, the governments had to bail out the financial sector and put a lot of taxpayers' money into protecting the functionality of the banking system.

If we are confronted with nonlinear systems that have tipping points, we do not get enough feedback to learn when these thresholds have been reached. Once the thresholds have been surpassed, we may experience irreversible effects that will be very difficult to undo. That is a situation for which

our learning capacity is not very well prepared for, since we learn by trial and error. However, with these risks this is not a good strategy. If you reach the specific tipping point, it is too late to learn. You need to make changes before negative feedback arrives. That is one of the biggest challenges in dealing with systemic risks.

To sum up, systemic risks tend to be transboundary, and are stochastic in nature which means they do not follow deterministic cause-effect chains. They could occur under specific circumstances, and we do not know exactly what these circumstances are; these risks give us positive feedback along our activities but if we continue to act in the same way, we reach a point of no return. The switch moves from positive to negative almost instantly; systemic risks are very complex so we feel overtaxed in understanding these risks. As a consequence of these features we tend to go into denial. Most systemic risks tend to be attenuated, even if we are fully aware of them, like climate change, for example.

Looking back at conventional risk, we can learn that awareness is not enough. Significant risk reduction also requires effective governmental regulation alongside behavioural changes. If awareness, collective rules, institutions, and behavioural adaptations proceed in line, one is able to reduce these conventional risks to a point where they are partially marginalised.

Interestingly enough, if we ask people what they are most concerned about, many of these marginal risks are mentioned because we still have cultural memories of all the hazards and perils that endangered our grandmothers and grandfathers, mostly threats that are readily available in our memories. The new types of systemic risks appear to be more distant, but in the end, they are much more dangerous for modern people than the conventional risks that we have largely mastered during the last decades. This is another paradox, not just between perception and the results of statistical analysis, but also the paradox that some of the risks that exert a strong impact on the functionality of our systems are likely to be attenuated in spite of the fact that people know about them. It is not an issue of knowledge. It may be an issue of apprehension to understand the proportionality of these risks compared to conventional risks, but the mechanisms of systemic risk are widely known to many institutions and individuals. However, they tend to not take them seriously enough and engage in serious efforts to reduce the risks to a degree that we all would feel comfortable with. The best example of this is climate change. At this very minute, more carbon dioxide is being emitted worldwide than the minute before (this is at least true until the end of 2018). In

spite of all the conferences, summits and meetings that we have organised on climate change, we are not making progress here, at least on the global level. If you think about renewable energy, you might claim, 'Great, we have more renewable energy in the world than ever before.' While this is true, if we look at the numbers, it is not dramatic. We had around 7 % renewable energy in 1998 globally and today, we have 11 %.[4] Given all the hype on renewable energy, increasing the share of renewable energy from 7 to 11 % within 20 years is not dramatic. Compared to the other risks that I talked about, i.e. traffic accidents, occupational health and safety, technical accidents, this increase is comparatively modest to say the least. Therefore, we need to raise the question: Why are we much more hesitant to reduce these systemic risks than we are to reduce the conventional risks, where we experienced a lot of success?

4. Temporal and Spatial Connection – Issues of Risk Perceptions

Why is that that we are not so serious about systemic risks? That question leads me to the psychological domain of risk perception. Last year, there was a poll in Switzerland that asked people, 'What is the most serious risk to your life?' Number three on the list was genetically modified organisms. However, there are hardly any genetically modified organisms for sale in Switzerland because they are not on the market. If this is regarded as potentially being the third major killer in Switzerland, we can talk about a phantom risk. Why do people think they are threatened by a risk to which they are not exposed?

I would like to give you a little bit of background on the perception of risk, i.e. how people intuitively assess and evaluate risks. We should first be aware that individuals intuitively associate causation strongly with proximity in time and space. That is, from an anthropological standpoint, very prudent. Normally, if something happens to us, it makes sense to look for causes in the vicinity of where it happened. So, we ask ourselves: what happened just before the event in our vicinity. For conventional risks, the strategy of looking into temporal and local spaces close to the event makes perfect sense. If I eat something that contains a poisonous chemical, I will experience some health problems within minutes or hours after consumption. That reasoning

4 Ritchie, H. (2017). *Renewable Energy*. Retrieved 20 November, 2020 from https://ourworldindata.org/renewable-energy

does not work for complex systems. If I talk about climate change and state: 'You came by car to this place, and the exhaust gases of your car may have an impact on a flood in Bangladesh,' such a statement seems to be far-fetched. It is temporally and spatially not connected to what I or you experience. There is a very strong doubt that these complex relationships have any plausibility. It is very clear that many advocates of populist movements take advantage of the implausibility of complex relationships. They offer simple, plausible explanations. All kinds of conspiracy theories are much more plausible than the complex web of climate change triggers. Denying the threat of climate change is fortunately not a powerful movement in Germany, but we can see that specific groups in society do not believe in climate change as something that is caused by human action. And they gain momentum because the relationships are so implausible. My little car has an impact on a natural disaster in East Asia? Be serious! If you trust scientists or the science behind the claims of climate change, trust can overcome counter-intuition, but if you do not trust them, you fall back to intuition. Systemic risks are complex by nature. Their causal structure defies mechanisms of plausibility. That is the first reason for the likelihood of attenuation or even denial when it comes to complex, systemic risks.

5. The Stochastic Nondeterministic World

The second reason for attenuation refers to the experience of stochastic relationships. Specifically, systemic risk can hardly be characterised by deterministic relationships. There are only a few 'If A then and only then is B' causal connections between drivers and consequences in the context of systemic risks. The best we can do is calculate the probability distribution over outcomes when the effect of one driver or several drivers are assessed. However, when scientists communicate these stochastic relationships, many people are confused. They think 'Oh, even the scientists do not know for sure.' They are also ignorant about this complex issue. Or even more ignorant to the point that they think 'If they are not certain, then I can just as well rely on my intuition.' Unfortunately, much of this knowledge relativism is allegedly supported by the social science concept of social constructivism, i.e. the belief that all knowledge is a product of social communication and exchange and not of observing external cues from nature or society. The confusion about what truth means and how scientific claims are substantiated have given rise to a sense of insecurity and irrationality: 'If the scientists do not know for sure,

then we are free to take whatever truth claim fits our interest.' And soon we end up in the post-factual society. People go out there and bluntly lie about factual relationships, because nobody can distinguish any more what is truth, what is a lie and what is an error. In extreme cases, people take all their prejudices as valid truth claims.

We may complain about this post-factual abuse of truth claims but there is no way back to the conventional scientific concept of determinism. Scientists have learned that there is much more complexity and stochasticity in the world than previously assumed. However, I think we have failed to make those new visions of the world become better understood by the general public. Truth claims from science are far from being arbitrary or representations of wishful thinking; they instead demonstrate the complexity of the phenomena that we want to understand better. They can be characterised and described much more accurately by using stochastic models than by using deterministic relationships.

Furthermore, stochastic modelling is also a reason for people to attenuate the seriousness of a risk. If we are not certain that all these bad consequences will happen, we take an optimistic view and assume that they will not happen. If you observe some of the debates on climate change in the United States, you will be confronted with a lot of statements saying, 'If the scientists are not 100 % sure about the anthropogenic nature of climate change, I do not believe it.' In a stochastic world, we will never be 100 % sure. It is inherently impossible. This basic message is not easy to convey to a society which has been educated to believe in deterministic natural laws. And as pointed out before, it leads to attenuation of risks.

The third element lies in trust. I first mentioned the post-intuition world, then the post-truth world, now I turn to the post-trust world. The post-trust world sheds some light on the relationship between science and the wider public. Most of the threats that we envision and that we are facing do not come from our personal experience. Most modern hazards such as ionising or non-ionising radiation, the destruction of the ozone layer by FCCs, climate change caused by greenhouse gases, health threats caused by mixes of chemicals, are not seen by our eyes or cannot be realised through our own senses or through our personal experiences. Not one of us has seen the ozone hole above us; if you eat something, you do not know if your beef has prions in it. You do not taste it. Take the debate about the pesticide glyphosate. Is that carcinogenic or not? Unless you are a toxicologist, you have no idea. In that sense, we are all relying on second-hand information. That is something

that is psychologically difficult to deal with. If you have no way of proving who is right or wrong, then you need to rely on trust. If you lose trust you go back to your intuition. And there we are again in the vicious cycle of what appears plausible. Let us stick to the topic of trust. There are three major routes we can take to resolve the issue of trust. One is that I have confidence in a reference group, say scientists, that they will tell me the truth. Under this condition, I accept whatever they tell me. They know better than me. If we look into the statistical evidence, the group of people who are loyal to a reference group is dramatically decreasing. That is true for almost all sectors of society as we can observe from recent voting behaviour in Europe and elsewhere. Established parties that had millions of devoted voters behind them lost the support of their followers almost overnight. The unattached voter is now dominating the political landscape.

The scientists still belong to a category of people that receive the best grades on trustworthiness in almost all surveys in Europe, Japan and the United States. However, if a scientist works in a factory or in a lab for genetically modified organisms rather than at a university, trust declines dramatically. Overall, loyalty towards reference groups that used to dominate the trust landscape in Germany and in most OECD countries is declining. So, what do people do when they lose trust in their previously preferred reference groups? Then they have two choices. The first possibility is to say, 'I trust nobody.' That means whatever experts or others may say, they are likely to be in error or to be lying. All statements are allegedly driven by interest. In this case I demand zero risk. Since I do not trust anybody, I would rather leave everything as it is now. No change, no innovation! We are faced with a structural conservative attitude that tends to glorify the past and be sceptical about the future. Again, we can see that populists from the right take advantage of this structural conservatism and promise to bring the 'golden days' back to the people. About 15 to 18 % of the population in Germany is in that domain.

Then we have the third strategy, which is pursued by the majority of people. We call this strategy 'vagabond trust'. Because people cannot evaluate the validity of arguments, they look for peripheral cues to assign credibility. Take as an example the usual talk shows that are aired on German TV. In most talk shows you will find four participants in addition to the host. One defends the activity that is planned or given. For example, the use of glyphosate for pesticide control. So, the industry spokesperson is going to say, 'Glyphosate is safe, there is no threat of cancer. We have tested all of this.'

Then you have the opponent, this might be a spokesperson from Greenpeace, saying, 'This is the worst thing that we have used on our land. All the bees have been killed, and of course, many citizens will get cancer'. Then the third participant comes from a regulatory agency, in this case the Federal Institute for Risk Assessment: 'It is all a question of dose, and we regulate exposure so that the critical dose is never reached.' Then we have a fourth person, normally an actor or an actress representing common sense and usually saying something like, 'I did not know it was that bad!' This is the typical composition of a host show in Germany. If you later ask the people who watched it on TV, 'Do you remember any of the arguments that the participants exchanged?', most people are unable to remember any of the arguments. But they can tell you whom they found trustworthy and whom they tend to believe. So, one might say: 'I like the lady from Greenpeace the most. First, she was very alert and attentive. Secondly, she had this elegant form of articulating herself and I appreciated the way that she really had good answers all the time. I do not remember what they were, but they sounded good. I think she is right.' People tend to judge the truthfulness of statements by peripheral cues of credibility. That does not mean that it has any real relationship with what scientifically might be true or false but that it is driven by the impression that viewers associate with each participant. Needless to say, such cues are also connected to the plausibility of what is being said. And again, we are back to the problem of intuition versus complex knowledge.

However, the vagabond trust assignment has another problematic consequence. The first week, the spokesperson from Greenpeace may be the person who gets the most trust credits, but a week later this might shift towards another participant, maybe the representative from industry or the regulatory agency. Then people reconsider what they thought was right or wrong and might change their judgment. Changing judgements is not pleasant, psychologists call this the pain of cognitive dissonance. Most people can get very angry if that happens to them and out of frustration and insecurity about what is right and what is wrong they tend to develop a feeling of anxiety and sometimes aggression.

6. Uncertainty and Insecurity

So, people change, they trust first this person and then the other person next week and so on. They get more and more nervous about that. They feel increasingly insecure about an issue. Insecurity leads to heightened

risk perception. The more people feel insecure about the severity of a risk they will rate it higher than risks that are more familiar to them. Thinking and re-thinking about threats and being torn between competing cues affects risk ratings. You first get annoyed about it, but secondly, in order to get over this cognitive dissonance, you start to see the risk as more pronounced than if you had delegated it, regardless to whom, or if you had factual insight into the argumentation. That has major impacts, for example, on crime. Individuals who have the least experience with crime tend to have the highest anxiety of it, because they rely on contesting testimonials of crime commentators on TV, other media or social media. The same is true for refugees. In areas where we have the least refugees, we can observe the highest anxiety with respect to refugees committing crimes. That is a mechanism of a vagabond trust situation in which trust is becoming a currency that is changed and exchanged from time to time, heightens the anxiety and the preoccupation with that specific risk. In the end, it may lead to high attention to some of the rather well-managed conventional risks (that still may raise controversies) and leaves no room for dealing with the complex systemic risks that are less attractive for TV host shows.

7. Cognitive Dissonance in a Post-Communication Environment

The last reason for the attenuation of systemic risks is related to the topic of post-communication. It does not mean people have ceased to communicate. They communicate more than ever, but in a different form. Now we are in the domain of media communication, specifically of social media. I would like to draw your attention to virtual spaces in which people exchange their views and ideas. These virtual spaces are optimal opportunities to avoid cognitive dissonance. That is less prevalent in Germany than, for example, in the United States but the appearance of so-called echo chambers is a serious problem. In these people want affirmation of and confirmation for what they already believe. When we engage in physical communication or use conventional media such as newspapers we are always confronted with judgments and opinions that differ from our own positions. Under these conditions we are more or less forced to reconsider our own position. Cognitive dissonance is a driver for learning. If you avoid cognitive dissonance, you do not learn anymore and you believe that anybody sharing your opinion is your friend and anybody who disagrees is your enemy. There is no in-between. This is very prevalent in social media, where users can get really upset if you say some-

thing opposite to what they believe. The structure of social media facilitates this kind of avoidance of cognitive dissonance. It creates polarization.
A couple of years ago, we conducted two focus groups at the same time and at the same location. One focus group assembled individuals who strongly believed that an expansion of mobile communication would be dangerous for their health. The second group was convinced that we would need more, powerful infrastructure for mobile telephony. The two groups met separately in two different rooms. I moved between the two rooms. Then I heard a person from the first group saying, 'Well, if you go to Google, you get immediate proof that magnetic fields are very dangerous for your health.' When I entered the other room, I heard somebody saying, 'When we go to Google, they say there is no problem.' So, we asked both groups to convene in one room and I took one laptop from each group and asked the owners to type in 'What are the health risks of electromagnetic fields?' The first group started the Google search and got as their first hit a headline entitled 'Even cows get cancer from electromagnetic fields.' This was a Bavarian study conducted several years ago and reported on cows near transmission lines.[5] The second group entered the same question into the Google search engine. Here, number one was the paper entitled 'WTO foresees no problem with cancer when expanding networks on electromagnetic fields.'

What happened? Clearly, both groups had included the learning mode when conducting searches. The first time they consulted Google they looked for something that confirmed their view, and they did this many times. Over half a year, Google learned what they liked to hear and made sure that the negative entries were placed among the top five of the search list in the first group and, vice versa, the most positive entries in the second group. Most people do not look further than the first three entries. And those confirm what they already believed. Since the Google search produced more and more confirming statements over time, the user was left with the impression that the world has slowly but surely learned that he or she was right in the first place. However, this was true for both groups. Having no experience of cognitive dissonance, the only conclusion for both groups was that non-believers are either dumb, bribed or cynics. If someone is bribed, dumb or cynical, you do not have to talk to that person anymore. Then communication is a waste of time. Polarisation will take place and we can see this right now in the United

5 Wenzel, C., Wöhr, A. C., & Unshelm, J. (2002). Das Verhalten von Milchrindern unter dem Einfluss elektromagnetischer Felder. *Der praktische Tierarzt, 83*(3): 260 - 267.

States between the adherents of the two major parties. There is no need for further conversation, for deliberation or negotiation. There is only right or wrong. That is a real danger for democracy, by the way another systemic risk that we may be underestimating.

What does post-communication tell us about systemic risks? These risks do not lend themselves to a polarisation in right or wrong. The stochastic nature of the issue, the non-linear features of the causal effects and the complex structure require shades of grey between the two extremes of right and wrong. In those countries where polarisation has strongly evolved during the last decades, the governance of systemic risks has led to a paralysis of the political regulatory system since there is no way to compromise in a polarised world. Climate change advocates and climate change deniers are irreconcilable and make climate change an issue of almost religious belief. The new Fridays for Future movement also tends to use science as an ultimate stronghold against the inactivity of politics and economics. Those who believe in climate change blame others for not doing anything; those who do not believe have no reasons for change. Non-action is the consequence. Again, the risk tends to be attenuated rather than amplified even if the verbal fight for climate change protection has increased in intensity.

8. What We Have Learned About Systemic Risks: A Summary

Now, given these effects, let me conclude in a few words what I have tried to point out. First, it is helpful for the discussion on risk governance and risk management to distinguish between conventional and systemic risks. Conventional risks can be contained in time and space, they are fairly easy to assess using scientific methods and can be managed by introducing effective interventions at the right places in the known cause-effect chain. So far, we have been extremely successful in dealing with conventional risks in most of the OECD countries (the picture is quite different in many threshold and developing countries). Conventional risks need to be distinguished from systemic risks. These are characterised by complex relationships within the cause-effect chain as well as by their interaction with external systems. They follow stochastic patterns of relationships, they include sudden tipping points and tend to transcend traditional geographic, political or sectoral boundaries. In this field of risk all our management and governance approaches are less successful. It is also less obvious as to what science can do to assist risk managers and policy makers in reducing systemic risks. One major obstacle for

bridging the gap between the acknowledgment of systemic risk as a serious challenge and the lack of actions that are required to deal with these risks effectively is the likelihood of risk attenuation in the public discourse. This is due to specific heuristics of how most people perceive these risks. In this talk, I identified four major reasons that may trigger the likelihood of attenuation.

The first reason is that most complex systemic risks run counter to our intuition that serious dangers are caused by factors close in space and time. Anything that appears 'far-fetched' is also seen as less plausible and obvious than risks where we can immediately recognise the driver in our own neighbourhood.

Secondly, science cannot provide deterministic and non-ambiguous models for systemic risks. Although they are far from being arbitrary, people tend to withdraw trust and credibility from information that is associated with uncertainty and ambiguity. Public perception often oscillates between the belief in determinism on the one hand, which is scientifically problematic, and arbitrariness on the other hand, which is far away from what science can actually offer.

The third reason refers to the need to trust in scientific assessments even if they are not plausible, visible or reconfirmed by personal experience. To rely on information that only others can provide and that we cannot prove right or wrong creates a lot of tension. Distrust in science is still not widespread but is clearly increasing. Furthermore, as soon as scientific dissent is openly recognised most people refer to so-called peripheral cues to assign trustworthiness or credibility. Since these cues change over time and are often contradictory, people feel irritated and frustrated and usually prefer inaction rather than taking the risk of doing the wrong or the inappropriate thing.

Fourth, confusion is reinforced by new communication tools in the IT world, in which everything that we believe, every prejudice we have, finds support in social media and gathers enough followers to confirm whatever we believe is true. As a consequence, knowledge camps become polarised and differentiated and approaches that are crucial for dealing with systemic risks become marginalised.

9. What Can We Do?

Last not least, I want to address the question: What can scientists and science institutions do to deal with systemic risks and the obvious attenuation due to public perception? As I pointed out, our usual learning mode of trial and

error is totally inadequate for dealing with non-linear cause-effect chains with sudden tipping points. However, trial and error as a heuristic is deeply engrained in our learning process. So, we need to create a virtual environment in which we can simulate trial and error. If the virtual error occurs people can experience what it means to trespass these tipping points. Fortunately, these negative experiences are only simulations and not real events. But they can sensitise people not to wait for negative feedback before changing their behaviour and lifestyles. This method of virtual preparation for relying on anticipation rather than trial and error is effective only when the simulations are framed in a form of a plausible, easy-to-grasp and credible narrative. It has to be so convincing that people conclude, 'Oh, if that is really happening, I better change now before this kind of disaster approaches.' The simulations need to be not only scientifically well designed. They also need to be so well visualised that people feel as if they were real. This task is not trivial and requires a joint effort between excellent modellers, natural scientists, social scientists, communication specialists and psychologists. I may even be wise to include professional writers and science fiction authors.

Beyond encouraging anticipation, it is crucial to include people more in collective decision making. Once you get people engaged in making decisions collectively for their community, they are much more willing and determined to learn about the complexities in which they operate. If they sit around a regular table in a pub, they will not care much about facts and complexities; they know what is right for the world and nobody can make them change their opinion. However, if you are invited to join a round table with other citizens, the situation transforms dramatically. You are aware that your opinion and your judgment will have an impact on the wellbeing of the community in which you live. You feel more accountable for all the preferences that you articulate. We have accumulated good evidence that people in the situation of collective decision making are, firstly, more willing to look into more complex relationships and deal prudently with uncertainties and ambiguities. Secondly, they are willing to resolve conflicts by looking into the trade-offs between different options and consider not only the consequences for themselves but also for others who ideally are all represented at the round table. For this to happen we need excellent opportunities and open spaces that provide such a catalytic service to the communities. Social scientists are capable of investigating and designing the appropriate institutional structures and processes in which people are encouraged to develop the civic virtue of evidence-informed and value-based collective decision making.

The last point I would like to raise may be more contested than the two I just elaborated on. The recent development in the sociology of science and knowledge towards a postmodern understanding of science as one narrative among others is, in my eyes, a disservice to society. My main argument is that all our efforts to explicitly mention and characterise uncertainty, to stress the stochastic nature of what we know and to point out the various ambiguities in the interpretation of complex relationships, helps society obtain a more accurate and more truthful representation of what we frame as reality than their gut feelings or intuition. We should make it very clear that through sciences we are able to set boundaries of legitimate knowledge. To step outside of these boundaries means that we accept knowledge claims that are either absurd, lacking evidence or that are mere wishful thinking. That is where scientists are really needed because normal intuition is not a good guide if you try to make inferences about complex systems. Scientists should be encouraged to make these boundaries more visible and pronounced in public discourse. 'Everything goes' is not an adequate response to complex challenges and even less so when dealing with complex risks. True is also: To resolve complex problems we cannot rely only on systematic scientific knowledge, we also need experiential or tacit knowledge but without scientific knowledge and its rigorous methodological approach we are likely to fall prey to 'comfortable' illusions or manifestations of special interests and value camps. We need science as a watchdog for what we really know about a phenomenon and the relationships between phenomena. Only on that premise can science fulfil its role as an honest broker in societal discourse. If we talk about complex systems and their impacts, nothing is better than a very good, rigorous scientific analysis. We should be proud of what science has offered and still can offer to society. While science is not the only actor, it is an indispensable one when it comes to the identification, analysis, and governance of systemic risks.

Further Reading

Lucas, K., Renn, O., & Jaeger, C. (2018). Systemic risks: Theory and mathematical modeling. *Advanced Theory and Simulations, 1*(11), 1800051.

Lucas, K., Renn, O., Jaeger, C., & Yang, S. (2018). Systemic risks: a homomorphic approach on the basis of complexity science. *International Journal of Disaster Risk Science, 9*(3), 292–305.

Renn, O. (2019). *Gefühlte Wahrheiten: Orientierung in Zeiten postfaktischer Verunsicherung*. Opladen; Berlin; Toronto: Verlag Barbara Budrich.

Renn, O. (2014). *Das Risikoparadox. Warum wir uns vor dem Falschen fürchten*. Frankfurt am Main: Fischer Taschenbuch.

Renn, O. (2014). *Stakeholder Involvement in Risk Governance*. London: Ark Group.

Renn, O., & Schweizer, P. J. (2009). Inclusive risk governance: concepts and application to environmental policy making. *Environmental Policy and Governance, 19*(3), 174–185.

Schweizer, P. J. (2019). Systemic risks–concepts and challenges for risk governance. *Journal of Risk Research*, 1–16.

Welcoming Address

Bärbel Friedrich
German National Academy of Sciences Leopoldina

On behalf of the German National Academy of Sciences Leopoldina, it is a great pleasure for me to welcome you all to the second international conference of the series 'Crossing Boundaries in Science' titled 'The Mystery of Risks – How Can Science Help Reconcile Perception and Assessment?' I am delighted that so many representatives of the scientific community are attending this event here in Potsdam, the capital of the federal state of Brandenburg.

Please let me introduce myself: my name is Bärbel Friedrich and I am a microbiologist by profession and served as Vice President of the Leopoldina for 10 years. As one of the two chairpersons of the Joint Committee on the Handling of Security-Relevant Research, I am involved in the organisation of this meeting. The Joint Committee is a body which was set up by the German Research Foundation and the Leopoldina to raise awareness of dual-use aspects of research and to strengthen the responsible handling of security-relevant research and the sustainable self-regulation of sciences and humanities in Germany in the long term.

In 2008, the Leopoldina was appointed the German National Academy of Sciences. In this capacity, one of its central and most prominent tasks is to provide science-based advice to policy makers in Germany and the public. The Leopoldina also publishes joint statements with other German, European, and international academies on a regular basis. It promotes scientific and public debate, supports young scientists, confers awards for scientific achievements and even conducts research projects. The Academy voices its opinion on great challenges with relevance to our society and identifies major scientific developments that are likely to become important in the future. This includes topics such as how to execute the precautionary principle in the context of emerging pandemics, global climate change, political instabilities and economic globalisation, which are subject of discussion during the next two days.

The conference format 'Crossing Boundaries in Science' of the Leopoldina is meant to stimulate discussions between areas of research that

are particularly dependent on new modes of interdisciplinary cooperation and method transfer. The first international conference, entitled 'Modelling Nature and Society – Can We Control the World?' took place in Weimar in June 2016. Its objective was to provide an overview and discuss current attempts to understand and control complex systems in nature and society using scientific modelling.

This second conference, which was generously funded by the Alfried Krupp von Bohlen und Halbach-Foundation is focussing on the role of science in the perception, assessment and handling of risks in our increasingly complex world. This includes the frequent overestimation of risks associated for example with terrorism, genetic engineering, artificial intelligence or vaccination but also the prevalent underestimation of risks associated with common causes of destruction, illness and death. The scientific community attempting to assess and communicate these risks on the basis of evidence is often confronted with the situation that public risk perception follows more subjective and emotional principles.

During the three-day conference, 18 scientists from areas such as sociology, economy, philosophy, psychology, medicine, meteorology and biology will discuss the following questions:

- Have our lives become riskier or do we simply know too much about potential risks?
- How are risks socially constructed?
- What risks are commonly underestimated or overestimated?
- Does the precautionary principle hinder innovation and progress?
- Do we face more complex risks in times of globalisation?
- What are the origins, probabilities and time scales of certain risks and how can we reliably cope with these risks on a scientific basis?
- How can science help to reconcile the systematic misperception of risks?
- Are scientists responsible for creating new risks when providing new knowledge that may be misused for harmful purposes?
- What are some science-based strategies to mitigate risks and how can we promote risk literacy?

I hope that this meeting provides an opportunity for productive discussions among scientists from many research areas related to risk assessment. I wish all participants a rewarding symposium.

Session 1
How Risks Are Socially Constructed

Chair:
Ralph Hertwig
Max Planck Institute for Human Development

The Paradox of the Risk Society

Martin Schröder
Philipps-Universität Marburg

Abstract: *This presentation shows that we frequently assume that the world is becoming less stable, more menacing and riskier, while in fact both internationally and nationally, almost every measurable indicator of quality of life is improving. As likely reasons behind our faulty perception, it introduces the concepts of negativity bias, a so-called rosy view of the past, a human availability heuristic coupled with a media focus on negative events rather than long-term positive developments, and a so-called prevalence induced concept change, all of which twist our minds into perceiving more risk in the world, even though, objectively, quality of life is increasing in almost every measurable regard.*

The world is getting better in many respects but our perception of the world does not seem to follow these mostly positive trends. We seem to have a completely mistaken view of risks and the tendency behind this tends to be that we perceive the world as worse, to be riskier than it objectively is. I am going to first highlight this with examples. Then I present which mental biases account for the over-perception of risks.

Oxfam asked a representative selection of Germans in 2016 how the share of the world population that lives in extreme poverty has changed in the last 20 years. The choices given were:

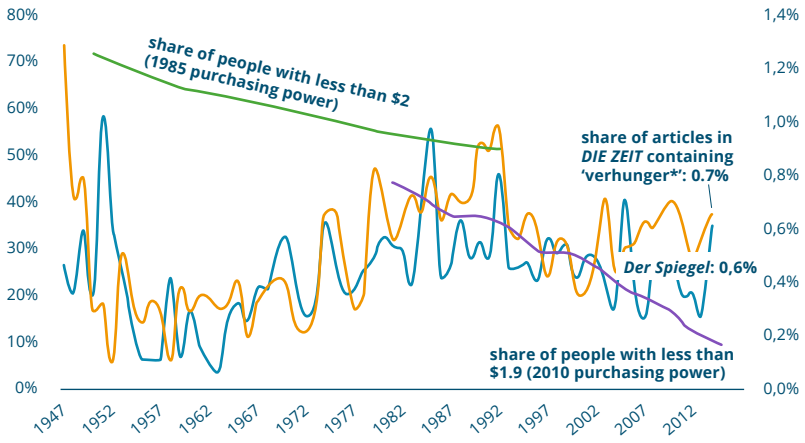
- it increased by 50 %
- it increased by 25 %
- it stayed the same, it was unchanged
- it decreased by 25 %
- or it even decreased by 50 %.

This is what a representative selection of Germans said: 22 % think that poverty had increased by 50 % in the last 20 years. 51 % think that poverty has increased by 25 %. Consequently, you have three-quarters of the German population saying that worldwide extreme poverty has increased in one way or another. You have another 18 % who think it remained the same, 8 % think it decreased by 25 %, and 0.5 % of the population think it decreased by 50 %. The World Bank's current definition of extreme poverty sets the poverty line very low. Everyone who has more than 1.90 US dollars in 2010 purchasing power parity is not extremely poor in this view. Whoever has less than that is considered poor. Imagine how much you could buy in the US with that amount in 2010: you would barely be able to meet your calorie needs. Interestingly, in 1981, the share of the world population that was that poor was 44 %. Even in 2000, it was still close to 30 %, and now it is down to 10 %. Incredible – when I was born, in 1981, almost half of the world population was living in extreme poverty and within my lifetime, this has changed from almost half of the population to 1 person in 10.

Why are people so mistaken about worldwide poverty? To answer this question, I downloaded all of the *DIE ZEIT* and *Der Spiegel* articles from their online databases spanning since the Second World War. This way I could code what percentage of all articles included words such as *Verhungern* (and similar spelling), which translates to 'starvation', to see whether, while world poverty actually decreased, the amount of articles that contain the word *Verhungern* also decreased. The graph (Figure 1) illustrates what I found. The orange line shows the share of articles in *DIE ZEIT* that contain the word *Verhungern*, and the blue line shows the share of articles annually in *Der Spiegel*.

While worldwide poverty strongly decreased, the share of articles that contain stories on starvation did not. The actual share of newspaper attention on the topic of starvation remained the same or even – depending on how you want to measure it – increased.

FIGURE 1



Decreasing share of extreme poverty in the world but steady share of German media coverage (*DIE ZEIT*/*Der Spiegel*) of the topic. Articles selected based on whether the word starvation or similar (therefore marked as 'verhunger*') were included.[6]

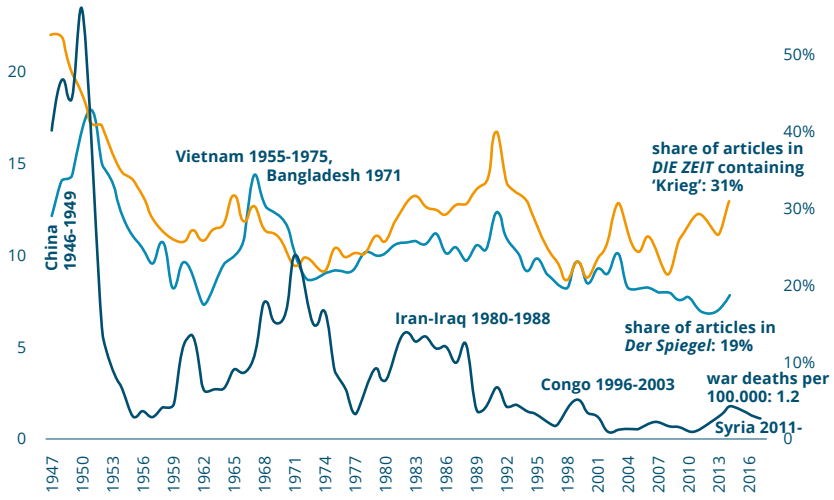
1. Armed Conflicts and their Media Attention

The same can be illustrated with the topic of war. Figure 2 shows the share of people by 100,000 population worldwide that die in wars annually. In 1951, 25 out of 100,000 people died in wars annually and note that these numbers are post-Second World War. About 400 out of 100,000 people died in an average year during the Second World War. In comparison, only about 1.7 died at the peak of the conflict in Syria. Currently, 1.2 out of 100,000 people die in wars. Obviously, I am not saying that 500,000 people a year dying in wars is not a problem. Every single person is one too many.

But I would guess that most people are not aware that the conflicts we are talking about are much less deadly than conflicts such as the Iran-Iraq War, Congo, Vietnam, Bangladesh, which were associated with a much higher death rate (Figure 2).

6 Bourguignon, F., & Morrisson, C. (2002). Inequality among world citizens: 1820-1992. *American Economic Review, 92*(4), 731f; Archives of *DIE ZEIT*/*Der Spiegel*.

FIGURE 2



Development of war deaths as a share of 100,000 population and media coverage measured by the share of articles where the word 'war' appears in *DIE ZEIT* and *Der Spiegel* magazine. While the actual proportion of people who die in wars has decreased by about 95 %, the media report as much about war today as they did at a time when the likelihood of dying in wars was 20 times greater.[7]

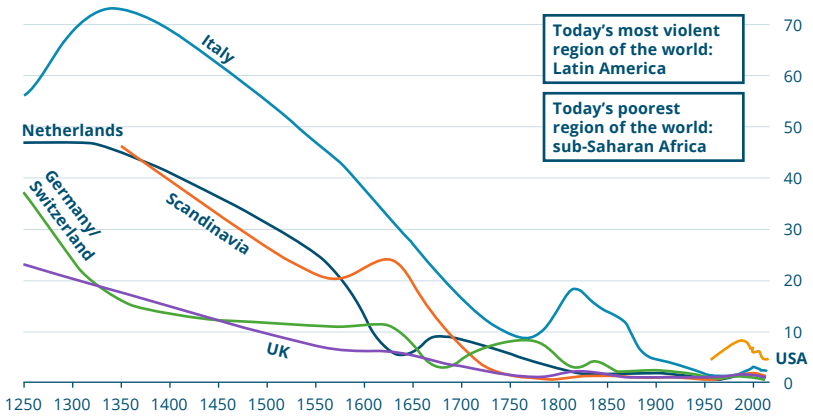
The numbers look different if you look at the total number of casualties. Obviously, if 1.2 out of 100,000 people die in a world with seven billion people, that is more in absolute numbers than in a world with two billion people. What we see here, however, is a 95 % reduction in the probability of being killed in a war if you are born on planet Earth. If you look at empirical data, attention to the concept of armed conflict is not at all lower now than it used to be. This total disjunction between actual risk development and the attention media is paying to these risks, and accordingly also the fear that people have about it, is not only something you can see for war, but for murder rates.

7 Gleditsch, N. P., Wallensteen P., Eriksson, M., Sollenberg M., & Strand H. (2002). Armed Conflict 1946–2001: A New Dataset. *Journal of Peace Research* 39(5): 615–637. Archives of *DIE ZEIT*/*Der Spiegel*.

2. The Development of Homicides over Time

In the late Middle Ages in Italy, 70 out of 100,000 people were killed by someone else every year (Figure 3). How can you reconstruct this? Many cities and regions have good archives with data on how many people were killed annually. If you know the size of the population of a region, you can estimate the share of violent deaths, manslaughter and murder in each year.

FIGURE 3



Homicides per 100,000 inhabitants, years 1250–2000. In the territory of present-day Italy, more than 70 out of 100,000 people died a violent death every year in the Middle Ages. In the territory of present-day Germany and Switzerland, it was almost 40 out of 100,000. Today, in almost all developed countries, less than one in 100,000 people are killed each year.[8]

By now, in pretty much all developed countries in Europe, you have a chance of 1 out of 100,000 – in Germany, it is currently even less – of being murdered every year. The US is known for their gun violence, but still, you are much better off living in the US today than in any other place a while ago. Today's poorest region is sub-Saharan Africa, and today's most violent region is Latin America. Even in these least developed and most violent places the

8 Eisner, M. (2003). Long-term historical trends in violent crime. *Crime and Justice, 30*, 99; Baten, J., Bierman, W., van Zanden, J. L., & Foldvari, P. (2014). Personal security since 1820. In van Zanden, J., et al. (Eds.), How Was Life?: Global Well-being since 1820 (pp. 139-158). Paris: OECD Publishing.

risk of getting killed violently is lower than in pretty much any developed place a couple of hundred years ago.

While this is the case, hardly anyone thinks that we are living in a situation where little violence occurs. 71 % of Germans say that terrorism is a serious threat, yet most cannot tell you how many Germans die in terrorist attacks.

3. Comparison of Fatalities due to Terrorism and Car Accidents

The number of road traffic deaths in Germany has drastically decreased from about 20,000 in 1970 to 3,000 in 2019.[9] By comparison, in 2016 26 people were killed in terrorist attacks in Germany. Nevertheless, it was dubbed by media as 'The Year of Terror'. They could have called it 'The Year of the Bathtub', because in the same year, twice as many people drowned in their own bathtub, yet I do not see anyone who is afraid of them. You have to live two million years in Germany to even have a 50/50 chance of dying in a terrorist attack. What might be even more interesting is that terrorism did not increase. In the almost 20 years since 2000 there were fewer terrorism-related deaths than in the 1970s, 1980s or the 1990s alone. Every 10-year period of the past thus saw more terrorism-related deaths than Germany since 2001.

Terrorism might be the poster child for making an argument that risks are not as bad as we tend to think they are, but what about more ordinary crimes? Next to terrorism, these are actually Germans' second largest concerns. In 2016, 64 % of all Germans feared becoming the victim of a crime, and 82 % thought the risk of becoming a crime victim had increased. The three most feared crimes were burglary, criminal assault and robberies. I used police crime records to have a look at these three types of crimes. Using solely the records to extract that information is a bit of a problem because it leads to a bias. If someone does not report a crime to the police, then it is not going to be prosecuted. The actual numbers might therefore be higher than the official ones. Moreover, for most people, the possibility is much lower because the likelihood, for example, of being assaulted is

9 Statistisches Bundesamt (Destatis). (2020). *Verkehrsunfälle Zeitreihen 2019*. Retrieved 20 November, 2020 from https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/Publikationen/Downloads-Verkehrsunfaelle/verkehrsunfaelle-zeitreihen-pdf-5462403.pdf?__blob=publication-File

clustered in small parts of the population. If you are a bouncer on Hamburg's Reeperbahn your risk is highly increased.

But how prevalent are crimes that Germans are afraid of? In 1993 there were 2.8 domestic burglaries per 1000 inhabitants, currently this is down to 1.4. The risk of being assaulted is 1.7 per 1000 inhabitants.[10] If we take that number, this means that the risk of not being assaulted in a given year is higher than 99.8 %. This means you have to live about 400 years to even have a 50/50 chance of being assaulted once. You have a 50/50 chance of becoming a burglary victim about every 500 years in Germany. To become a victim of a robbery, you have to live about 1,500 years. For being murdered, your chance is 1 in 100,000 – it is really not something you should worry about. Yet most people would say that burglary could happen to them every 10 years, not every 500 years.

4. Rosy View of the Past and Negativity Bias

The last part of my talk addresses why we perceive an increase in risk if in fact life becomes less risky. The first idea is best described by a term used in psychology literature, which is the so-called 'rosy view of the past'. An experimental study sent people to an amusement park and asked them how they felt while they were there. Typical answers went something like, 'Well, yeah, I really have to pee, and it just rained, and the kids are screaming, and I had to throw up after the last rollercoaster ride, but basically, it is a fun day.' But if you asked the same people two weeks later how their day in the amusement park went, the typical answer was, 'Oh, that was just one of the nicest days of my life. Everything was perfect.' There seems to be a bias inherent to us that we tend to remember good things about the past, whereas smaller things that annoyed us are swept under the rug. That is problematic because the present, which we do not see through rose-tinted glasses, often cannot keep up with the past that we systematically see through a positive bias.

10 Source until 2011: Rahlf, T. (Ed.). (2015). *Deutschland in Daten: Zeitreihen zur Historischen Statistik.* Bonn: Bundeszentrale für politische Bildung; Source from 2013: Official crime statistics (per 100 inhabitants, extrapolated to 1000 for a better understanding).

Another bias is the so-called negativity bias. Telling you that the likelihood of a marriage not making it through the first 10 years is 40 % or telling you 60 % of all marriages survive the first five years, is exactly the same information. Nonetheless it is easier to remember the first phrasing, the negative one. A number of experiments have shown that it is easier for us to remember negative information rather than positive information. That does make sense from an evolutionary perspective. If the positive information that there is a piece of cake and you should have it, escapes you, you are just missing a piece of cake. Yet if the negative information, beware of that sabre-toothed tiger next to you,' escapes, your genes might not make it into the next generation. We are very attuned to negative information, and that is a good thing, but the problem is that this is coupled with what is called an availability heuristic and a problem-oriented media coverage.

What is this availability heuristic? We are incredibly bad at judging risk through data. Imagine you receive information about murder statistics, but then on your way home, you see someone being murdered. That sensory input is going to undermine everything you have been told about murder statistics. You are going to be much more convinced that a murder is likely when you have actually seen one. That is the so-called availability heuristic. We think that something is more probable if we can recall it more easily. This would not be such a problem if media coverage were not problem oriented. But it becomes very problematic because we want journalists to tell us about problems.

Imagine that worldwide poverty, which – even if it concerns only 10 % of the world population – is still 700 million people, decreases by another staggering 99 %. On the one hand, you could say, that is great. On the other, it would mean that there are still seven million people living in horrible circumstances. If journalists report about those people that is not 'fake news'. The problem is, while it is true, it tells us only about an ever smaller part of the world.

5. Prevalence-induced Concept Change and Sensitivity

A possible solution for a more accurate media coverage is to tell us about every plane that crashed, but also about the trend behind it. Is it even more worrying that another plane crashed because more and more planes seem to crash, or is it actually even more surprising that a plane crashed because fewer and fewer planes are crashing? Media should tell us about each terrorist attack, but also whether one incident of a terrorist attack means that terrorist attacks are generally becoming more likely. Unfortunately, even that is not going to change the last problem, which is the so-called 'prevalence-induced concept change'.

In an article that appeared in *Science* in 2018, Levari et al. showed people more or less threatening faces on some cards. Unsurprisingly, the more threatening faces they showed, the more people thought there was a high number of threatening faces being shown to them.[11] In a second round, they reduced the number of threatening faces. People saw fewer threatening faces, but they also started to perceive faces as threatening on a continuous scale that appeared harmless to them before. This means that the fewer threatening faces you show to people, the more sensitive people become to perceiving a face as threatening. They then tried the same with research proposals asking whether these were unethical. In a second round, they reduced the number of actually unethical research proposals. What happened is that people started to classify research proposals that they found ethically unproblematic as ethically problematic. This means that the less you are confronted with injustice or what can be perceived as unethical, the more sensitive you become to exactly these phenomena. If that is actually a bias or a mechanism that you can generalise, then it means that, in a world where risk declines, where dangers decline, where problems decline, people simply become more and more sensitive to those problems, to those risks, to those dangers that remain.

11 Levari, D. E., Gilbert, D. T., Wilson, T. D., Sievers, B., Amodio, D. M., & Wheatley, T. (2018). Prevalence-induced concept change in human judgment. *Science, 360*(6396), 1465–1467.

Risk as Feelings and Perception Matters

Ellen Peters
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Abstract: *Risk is presumably about probability, the odds that something may happen in the future. As a result, it appears objective. However, risk is not a 'hard fact' waiting to be perceived and known by individuals or calculated by risk analysts. Instead, it is 'constructed' in the psychology of individuals and through interaction with social influences. In this talk, I will focus primarily on the role of feelings (aka affect or emotion) in perceiving risks. When faced with a complicated judgment or decision, we simplify our task by relying on the heuristics of our experiential minds. One common heuristic, the affect heuristic, concerns our reliance on feelings to inform our perceptions of risk and benefit. Affect has other functions as well, however, and 'emotional' is not the opposite of 'factual.' Instead, affect acts as a cue to inform risk perceptions (the affect heuristic), motivate behaviours, and encourage greater scrutiny of risks.*

Today's talk concerns in particular how affect influences how we perceive risks and what actions we take when it comes to those risks. When we are faced with complicated judgments or decisions, we often try to simplify the task by using a heuristic of our experiential mind. The use of affect is one of those heuristics. In addition, I will address how the public apprehends risk through those feelings.

Affect is often described as causing irrational reactions and decisions among laypeople. I will give you some examples that might point in that direction. I will also provide some examples illustrating that affect actually helps us most of the time and that it is, in fact, quite rational in how it helps us make our way through a complex world in which we cannot possibly take into account all the information. Let us start off with the idea that feelings cause irrationality. Risk is presumably about outcome severity and also its probability, the odds that the negative outcome might happen in the future. As a result, it appears to be objective, and it appears to be understandable.

The problem is that the public often does not understand numeric risks since many people are innumerate. In fact, according to the OECD, about 18 % of German adults can do only very simple processes with numbers (Table 1). They can count, sort, and do simple arithmetic. They can also use simple percentages. However, they can only do these operations if there are minimal text and distractors around the numbers. You might consider the next 33 % of German adults as being innumerate, too. They can use simple tables or graphs, but they cannot use the kinds of complex information that is often required to truly understand risks.

TABLE 1

Key abilities estimated by the Organisation for Economic Cooperation and Development (OECD) for Germany in 2013.[12]

NUMERACY LEVEL	% OF ADULTS*	KEY ABILITIES ASSOCIATED WITH LEVEL
Level 1 or below	18 %	*Simple or basic one-step* or simple processes (counting, sorting, simple arithmetic, simple percentages such as 50 %). Little text and minimal distractors.
Level 2	33 %	*More complicated math* with two+ steps, percentages and fractions, simple measurements, estimation; simple tables and graphs.
Level 3	35 %	*Less explicit and unfamiliar numeric tasks* that require several steps, problem solving, interpretation and basic analysis of data and statistics in texts, tables and graphs.
Level 4/5	14 %	*Complex, abstract, unfamiliar contexts*. Multiple steps, analysis and chance, change, formulas.

* The proportion of Germans who fell into five numeracy performance levels. Individuals at each level of quantitative numeracy are thought to have the skills identified at that level but not the skills at levels above their own.

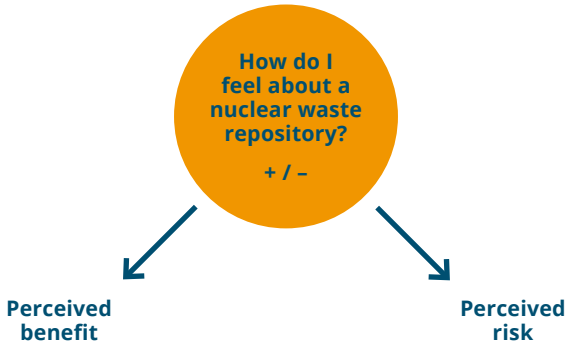
12 Organisation for Economic Cooperation and Development (OECD). (2013). *Survey of Adult Skills First Results* (Country Note Germany). Retrieved 20 November, 2020 from https://www.oecd.org/skills/piaac/Country%20note%20-%20Germany.pdf

1. The Inverse Relation between Risk and Benefit Perception

It turns out that people's risk perceptions are not based on these hard facts, or at least they are not based only on these hard facts. Instead, risk perceptions are constructed through the psychology of the individuals and through their interactions with social influences. Instead of only using facts or figures, the public often uses different information than what experts might expect. In the real world, risk and benefit tend to be positively correlated. Objects and events that provide more benefit can be either higher or lower in risk. However, if it is very high risk (think about a prescription drug with very serious side effects), it has to also be high in benefit for it to survive the marketplace. Otherwise, it simply does not exist.

In people's minds, however, this relation between risk and benefit is different. Risk and benefit perceptions are negatively correlated instead. Objects and events that are perceived as high in benefit tend to be perceived as low in risk, and those that are perceived as being very risky tend to be perceived as lower in benefit. The strength of the negative correlation between perceived risks and perceived benefits depends upon its affect or the feelings that people have about the object or event. Objects and events that feel good tend to be perceived as high in benefit and low in risk. Those that feel bad, that an individual feels negatively towards, tend to be perceived the opposite, as high in risk and low in benefit. This inverse relationship between risk and benefit perceptions can be explained by the *affect heuristic* (Figure 4). The affect heuristic predicts and explains how good and bad feelings about things from nuclear waste repositories to prescription drugs are associated with perceptions of their risks and its benefits. It predicts that we look at our feelings as simple cues, as pieces of information themselves, to infer how much risk a hazard poses or how much benefit it offers. Affect is used as a quick and efficient mental shortcut that helps us cut through the complexity of the world and to quickly and efficiently figure out what to approach and what to avoid.

FIGURE 4



The Affect Heuristic Model. The public uses their feelings as information to 'figure out' risk and benefit perception whereas they have an inverse relationship. Objects and events that feel good tend to be perceived as high in benefit and low in risk. Those that an individual feels negatively towards tend to be perceived the opposite, as high in risk and low in benefit.[13]

Not only is affect correlated with risk perceptions, it is also causal of them. In one paper, participants who read a negative story (e.g., about a homicide) estimated the frequency of death from fire, flood, disease, terrorism, and other risks as about 74 % higher as those people who read just a neutral story.[14] The authors further found that people who read a positive story (e.g., about the success of a student) felt better and had lower risk perceptions by about the same amount.[7] Prominent events that you might read about in the paper or social media or see in a movie can modify our feelings and, through those feelings, shape our risk perceptions and a wide variety of risk-related behaviours.

13 *Figure 4*. The Affect Heuristic Model. Adapted from "Rational actors or rational fools: Implications of the affect heuristic for behavioral economics," by P. Slovic, M. Finucane, E. Peters, & D.G. MacGregor, 2002, *The Journal of Socio-Economics, 31*(4), 329–342. Copyright 2002 by Elsevier.

14 Johnson, E. J., & Tversky, A. (1983). Affect, generalization, and the perception of risk. *Journal of personality and social psychology, 45*(1), 20.

2. Affect Acts as Information, Motivator, and Spotlight

Affect is used as information to inform our risk and benefit perceptions, but that is not the only function that affect plays in judgment and decision processes. In addition to that, affect works to motivate action. Any time we have a feeling, the core part of that feeling is an action readiness. When we are angry, we want to strike out; when we are fearful, we want to avoid or flee. In addition, affect acts as a spotlight and changes our cognition, either by how much we think and/or about what we think. First, the quality of the affect, for example, whether it is more positive or more negative, can focus the decision maker on other information in the situation. Then that new information, rather than the experienced affect, is used to guide the judgment. Alternatively, affect can act as a spotlight on certain information about which decision makers think harder.

The question then becomes: If affect works in these multiple ways, is it good or bad? Does it produce irrational or rational thought? The answer is likely more nuanced. Let us turn next to two examples from studies in my lab. One study concerns smoking, the other breast cancer treatment decisions. People tend to have low or superficial knowledge in both examples.

3. The Prevention of Smoking

The Canadian Barb Tarbox was a model in her teens and early 20s in Europe. Once she was done with modelling, she settled down, got married, and had a daughter. At the same time, back in seventh grade – she would have been about 12 years old – she started to sneak cigarettes from her mum's handbag. She thought it made her look cool and, by ninth grade – about 14 years old – she was smoking a pack of cigarettes a day. Barb was diagnosed with Stage 4 lung cancer at the age of 40. She was given about three months to live. She actually lived quite a bit longer than that. We know that because Barb decided not to live out the rest of her life quietly. She decided to fight back. What she really wanted was to talk with kids who were the age she was when she started to smoke. She wanted to help them understand smoking diseases and to convince them not to smoke. In the end, she spoke to millions of people because she went out to schools and appeared on radio and television programmes many multiple times. She ultimately spoke to millions of Canadians. She had a simple message: If you smoke, quit. If you do not smoke, do not start. After one junior high school visit, she received 750 letters

from teens. Many of them handed over their cigarette packs to her, vowing never to smoke again. Her story was emotional, compelling, and effective. In fact, she agreed to let them use her image on her deathbed in graphic warning messages in Canada after her death (Figure 5). Thus, her story influenced millions more Canadians and perhaps even you.

Recently, I have been interested in evidence-based methods to inform smokers about the health risks of their habit and reduce smoking prevalence among people who do not want to continue smoking. Health-related risks of smoking are quite high, but those risks are preventable. In addition, smokers often want to stop smoking and/or they wish they never started. The average smoker dies 10 years earlier than the average non-smoker, and smoking harms nearly every organ of the body. For every one smoker who dies of a smoking-related death, about 30 people live with some serious smoking-related disease. Those diseases range from cancer to heart disease, lung disease, diabetes. But smokers have relatively superficial knowledge about smoking. They know that smoking can kill them. What they do not know is the large range of smoking-related diseases. They can usually name about one to four of those diseases when dozens of them exist. They also do not understand disease likelihoods, what the experience of having those diseases would be like, and which ones are curable versus not curable.

One potential route to smoking reduction is through the use of affect-inducing graphic warnings as shown in Figure 5. Canada introduced such warnings back in 2001. They are now in use in more than 100 countries around the world. These warnings may be important when it comes to informing smokers about the risks of smoking because pack-a-day smokers – they smoke 20 cigarettes a day – are exposed to warning messages on their own packs as many as 600 times a month, 7,200 times a year. Consequently, it is a very frequent risk communication.

We started to think about why the affect and the emotion from these graphic warnings might be impactful to smokers. We knew from prior research that graphic warnings elicit greater negative affect to those warnings. We also knew that greater negative affect to the warnings generalises to greater negative affect towards smoking itself.

FIGURE 5

Former Model Barb Tarbox agreed in her attempts to prevent others from smoking and to fight lung cancer for her image to be used in Canadian risk communication as affect-inducing graphic warnings on cigarette packages. The image was taken by Photographer Greg Southam and later used by Health Canada as campaign against smoking. Material republished with the express permission of Edmonton Journal, a division of Postmedia Network Inc.

We decided to conduct a risk communication clinical trial. We recruited 244 adult smokers and exposed them over four weeks to nine text messages on their cigarette packages. We purchased their cigarette packages for them each and every week, and we replaced the warning labels with our experimental labels over them. In the study, half of our smokers got text-only messages. We simply put another sticker with the text-only messages over the current warning label on their packs. The other half got the exact same text messages augmented by a pictorial image that depicted the risk in the text message. We found that the graphic warnings indeed elicited greater affect to smoking than the text-only messages.[15] This negative affect acted as information

15 Evans, A. T., Peters, E., Shoben, A. B., Meilleur, L. R., Klein, E. G., Tompkins, M. K., Romer, D., & Tusler, M. (2016). Cigarette graphic warning labels are not created equal: They can increase or decrease smokers' quit intentions relative to text-only warnings. *Nicotine & Tobacco Research: official journal of the Society for Research on Nicotine and Tobacco, 19*(10), 1155–1162; Lazard, A. J., Byron, M. J., Vu, H., Peters, E., Schmidt, A., & Brewer, N. T. (2019). Website designs for communicating about chemicals in cigarette smoke. *Health communication, 34*(3), 333–342.

enhancing risk perceptions, suggesting that graphic warnings were better at transmitting the risks of these products. It also acted as a motivator, encouraging smokers to attempt to quit smoking.

In another study, graphic warnings increased quit attempts from 34 to 40 % in only four weeks of a clinical trial.[16] Furthermore, affect acted as a spotlight, as we expected, encouraging smokers to scrutinise the information contained on the graphic warnings, thus playing a cognitive role. Affect causes more cognitive activity, hence doing more than just evoking emotion. Overall and in the case of smoking, affect can be beneficial. Smokers tend to want to quit, and/or they wish they never started, and helping them to feel more negative affect can have positive effects.

Negative affect also has another interesting effect that we just started testing recently in breast cancer treatment decisions. Negative affect can act in a motivating way. As you will see in the next section, it appears to encourage approach of some behaviours that are seen as risk reducing, even when perhaps they are not.

4. Breast Cancer and the Choice of Surgery

One of the more emotional decisions that a woman can face concerns breast cancer and its different surgical options. Women with breast cancer are often offered the choice between a lumpectomy, a mastectomy, or a double mastectomy. With plastic surgeon Doctor Clara Lee, we have been studying treatment decisions associated with a remarkable increase in the use of contralateral prophylactic mastectomy (CPM). CPM is a procedure to remove the non-diseased breast in a woman who has cancer in the other breast. CPM rates in the US grew from 2 % in 1998 to 17 % in 2003, just five years later, and the largest growth was seen among women for whom CPM confers no survival benefit.[17] However, having CPM, of course, means more surgery, and, consequently, it offers substantially more risk.

This trend toward more invasive breast cancer surgery is a major reversal from US trends in the 1980s and 1990s, when invasive surgeries

16 Brewer, N. T., Hall, M. G., Noar, S. M., Parada, H., Stein-Seroussi, A., Bach, L. E., Hanley, S., & Ribisl, K. M. (2016). Effect of pictorial cigarette pack warnings on changes in smoking behavior: a randomized clinical trial. *JAMA Internal Medicine, 176*(7), 905–912.

17 Wong, S. M., Freedman, R. A., Sagara, Y., Aydogan, F., Barry, W. T., & Golshan, M. (2017). Growing use of contralateral prophylactic mastectomy despite no improvement in long-term survival for invasive breast cancer. *Annals of surgery, 265*(3), 581–589.

had reduced. The surgeons who are doing CPM have expressed intense concern about this increase in rates, even describing an epidemic of mastectomies. Among women who are considering these different surgical options, we know that knowledge about the risks and benefits of the surgical options is relatively low. They are informed about the risks but their knowledge, when tested, is fairly low. We also know that emotional reactions are high. In particular, women tend to misunderstand the risks and benefits of the surgical options, and they tend to misunderstand that CPM is risk reducing, even though they are explicitly told that its survival benefit is the same as the other two less invasive options.

Patients who have CPM versus those who do not report more anxiety about future breast cancer. They also say that they want this procedure because they have a desire to achieve peace of mind, and they believe that getting CPM will help them emotionally in some way. These data suggest an important role for affect in these decisions, but we have no causal evidence of it.

As a result, we recently conducted a hypothetical pilot study of about 1,000 women aged 30 to 60 years old.[18] In past data, this age group was more likely to get CPM. We asked our participants to imagine that they were diagnosed with breast cancer, and we walked them through a story about it. Then, we gave them one of two stories in an attempt to manipulate affect towards breast cancer. In one group of women, we attempted to elicit more negative affect towards breast cancer; in another group, we attempted to elicit less negative affect. We then gave them information about the different treatment options in both conditions. We also explicitly told them that CPM offered no additional survival benefit over other options and that it conferred substantially more risk. Then we measured emotional responses, risk perceptions, and choice (i.e., 'Would you choose CPM or one of the other options?').

Our results mostly supported our hypotheses. First, our affect manipulation worked. The more negative narrative caused more negative affect towards breast cancer. That negative affect was associated with greater perceptions of future cancer risk. Thus, affect acted as information, informing their risk perceptions (in line with the affect heuristic). Additionally, the more negative narrative also produced different choices through what appeared to be a motivated spotlight effect. Those in the more negative condition experienced

18 Silverstein, M., Lee, C., Scherer, L., Phommasathit, C., Merrill, A., & Peters, E. (2020). *Negative affect toward breast cancer and choices of double mastectomy treatment*. Presented at the annual conference of the Society for Behavioral Medicine, San Francisco, CA.

more negative affect to breast cancer, and they were more likely to choose CPM. Even though they are explicitly told that their chances of survival were the same with CPM versus with the other options and that CPM caused more adverse events, inducing more negative affect to breast cancer caused them to be more likely to choose an option that they falsely believed offered more benefit. In this case, I would claim that affect produced a negative effect.

5. The Construction of Risks

Risk is constructed in the psychology of individuals and through interaction with social influences. Affect is used as information about risks and we can change that affect and alter how risks and benefits are perceived. Affect also motivates action, and it can act as a spotlight, provoking greater thought about risks. Ultimately, it underlies risk perceptions, behavioural intentions, behaviours, and also increased knowledge through thoughtful as well as heuristic paths. Affect and risk are socially constructed, influenced, for example, by movies and advertising, by popular media, and even by social communities that form around certain choices, like in the case of breast cancer.

Affect is also constructed through characteristics of the individual person. People who are more emotionally reactive, for example, report greater risk perceptions across a variety of different domains. Our political ideologies, too, can influence our feelings and, through them, our risk perceptions. For example, studies have shown that people who are more conservative and hierarchical experience more positive affect to nuclear power whereas more liberal and egalitarian people experience more negative affect; their risk perceptions follow the expected pattern from their affective reactions. Psychological theory can help us to understand risk perceptions and inform better risk communications.

Affect is not always good or always bad. It is nuanced. The multiple ways through which it acts poses challenges, however, to the scientific community, manufacturers, and regulators to track, understand, and manage those sources of affect. It further has implications for media, social media, marketing, and risk communications as well as other communications. Informing the public about risk is not about just the facts. Risk perceptions are socially constructed from cues that exist in the situation and from characteristics of the individual that ultimately alter how people feel about risk and how much risk they perceive. Policymakers help to control some of those cues, although not all of them, and they have a responsibility as a result.

Session 2
Limits of Assessing and Communicating Risk

Chair:
Alfons Bora
Bielefeld University

Foundations of the Precautionary Principle and What is Wrong with Empirical Psychology

Nassim Nicholas Taleb
New York University, Tandon School of Engineering

Abstract: *We discuss two flaws in conventional risk analyses when translated to the real world: 1) missing dynamics and ergodicity, 2) using thin-tailed distributions. We show that under multiplicative dynamics, many psychological biases seen negatively, such as mental accounting, become rational and optimal. We also show that asymmetric reactions such as paranoia (and overestimation of tail probabilities) are entirely justified under the right conditions.*

1. Introduction and Definitions

Definition 1: The general (non-naive) precautionary principle delineates conditions where some actions must be taken to reduce risks of ruin, and where traditional cost-benefit analyses must not be used. These are ruin problems where, over time, continuous exposure to tail events leads to a certain eventual extinction.

Precaution is scale-specific. While there is a very high probability for humanity surviving a single tail risk, *over time*, there is eventually zero probability of surviving continuous repeated exposures to such a class of events. While some classes of such repeated risks can be taken by individuals with limited life expectancy, ruin exposures must never be taken at the systemic and collective level. In technical terms, the precautionary principle intervenes when risks methods are not *ergodic*, that is yield different results when seen over time than over state-space outcomes (see Appendix).

Definition 2: Thick-tailed distributions are characterised by the dominance of a few number of events over the total statistical properties. Conventional statistical methods fail to work in fat-tailed domains (dubbed *Extremistan*) – they work only under thin tails (dubbed *Mediocristan*). There is a crisp demarcation between the two domains.

2. Different Probabilities: Assessing Risks Across Time not Space

I am going to start with the concept of time probability (in real life) as an extremely different animal distinct from ensemble probability (used in decision theory). We will see the difference intuitively.

First, consider path dependence. If I wash my shirt and then iron it, visibly, it would be a very different outcome than if I iron my shirt first and then wash it. This may seem trivial, but if we look at it from a risk standpoint, some truth can emerge by introducing a sequence. As Warren Buffet says: 'In order to succeed, you must first survive!', which leads to some inseparabilities – you cannot separate returns from risks of ruin. You cannot say an investment strategy is a great strategy if it does not first guarantee survival. Cost-benefit analysis breaks down under some environments – those entailing ruin.[19] That point can be easily seen in the following thought experiment (Figure 6). We select 100 people, give them an endowment, each one of them, and send them to a nearby casino to figure out their expected return from the casino, which may be positive. The 100 people proceed to gamble eight hours a day at a certain pace. Then person number 28 goes bust. Will it affect person number 29? Of course not. That is what we call vertical (state-space) probability. The total return that we are going to get that way will be an arithmetic average of the returns – standard expectation operator. By the law of large numbers, we can figure out what the expectation of that return would be and infer how the casino fares.

The story would be markedly different if we send one person for 100 days to the casino, instead of 100 people each for one day. So, one single person speculates across time, and of course, if on day number 28 the person is ruined, there is no more day 29, unlike in the other experiment.

19 For more technical, at length discussions, and precise definitions, see: Taleb, N. N. (2020). On the statistical differences between binary forecasts and real-world payoffs. *International Journal of Forecasting 36*(4), p. 1228-1240.

As a consequence, we individuals have to evaluate our risk process across time, not across space; that is completely different. This is what has been recently rediscovered and formalised by Ole Peters along with the late Murray Gell-Mann[20]; they realised that there is something a little shaky in the foundation of the way we treat probability because these are completely different probabilities. We traders dismiss averages with the expression 'never cross a river if it is on average four feet deep' – and traders and business-persons have a deep intuitive understanding of the notion.

Now if I take the expectation of something horizontally (over time), I get a completely different result. For example, if a gambler is exposed to a small probability of ruin, they will be eventually ruined no matter how small the probability. Why? Because over time it is a geometric average since you are multiplying, and if you multiply something by zero, you get zero. So, the two probabilities are not the same, but they have been treated the same in the literature. The point was not fully formalised until Peters and Gell-Mann did so in 2016. Another way to see it is that, in the presence of an absorbing barrier, these had all the same return, but the paths are very different. To compare or equate time probability and the other one, of course you need some kind of function.

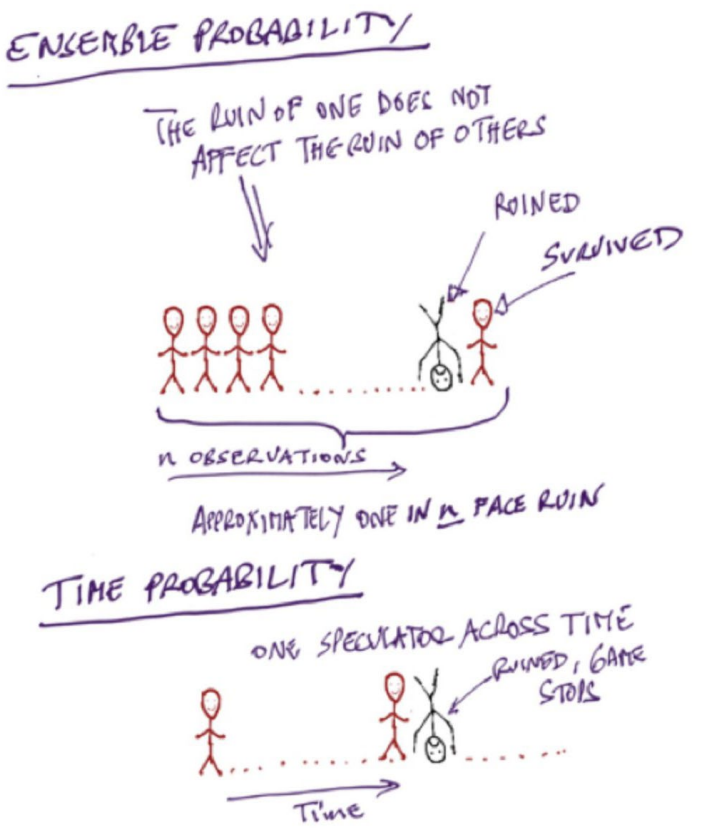
Visibly, the logarithm operator works well because it gives you the same payoff on both sides. It can translate between arithmetic and geometric because when a state corresponds to ruin, the log equals negative infinity, no longer zero. People mistakenly believe that the log is used for risk aversion; it is not. It so happens that the log operator maximises things over time, using simple parameters such as growth – and what maximises things over time also prevents ruin because this business of multiplying by zero causes absorption at zero.

Contrary to what is said in the literature, the law of large numbers does not work over time (what we call horizontally). If you looked at your future outcomes (in a multiplicative way) on a binomial tree, you will realise that you rapidly start diverging from the average, with no eventual pull-back or what is called 'reversion to the mean'. There is no law of large numbers for a single individual that way, no matter the number of periods involved. It is just you – and you are not an average. So, the only way you can start equating strategies is if someone engages in a stream of payoff that sort of

20 Peters, O., & Gell-Mann, M. (2016). Evaluating gambles using dynamics. *Chaos: An Interdisciplinary Journal of Nonlinear Science, 26*(2), 023103.

completely eliminates ruin. There are classes of strategies that dynamically eliminate ruin that are acceptable because they give you the same or some very similar returns across ensemble and across time.

FIGURE 6



The difference between 100 people going to a casino and one person going to a casino 100 times, i.e. between (path dependent) and conventionally understood probability. The conflation has persisted in economics and psychology since time immemorial, particularly with the use of nonergodic cost-benefit analyses.

Let us consider surviving risk takers in the real world. Take for instance the trading firm (and investment bank) Goldman Sachs. They must have engaged in these restricted classes of strategies because these people take monstrous

amount of risk, and they have been doing it for 149 years, and 149 years is a very long time: a small local (daily) probability of blow-up would have ensured total ruin. That something they are doing right is not taking small-tail risk; it is taking no-tail risk (or something of the order of 10^{-8}). They try to be exposed to maximum risk without tail exposure, which is completely different from what people engage in if they follow something like the *Markowitz mean variance optimization* or similar standard business school methods. The only strategies that make you avoid the gambler's ruin are part of the classes that have some specific properties either by using logs or by using dynamic hedging and/or the Kelly criterion, things that come from information theory rather than from standard economics or decision theory.[21]

To rephrase: owing to gambler's ruin, eventually, you are going to go bust no matter what your space expectation is. If you have a small probability of going bust, you are going to go bust. At the stopping time, you are going to go to zero regardless of your return, unless you have zero probability of ruin. Consequently, if we start using these concepts exposed above, then you must start evaluating risk not by incident, like what is your risk of falling off a mountain or something, but by integrating over your lifespan. We do it intuitively – see the works of Gerd Gigerenzer and the ABC group for the validity of intuition under some probabilistic representation.[22]

3. Dynamics vs Statics

We know not to do a risk analysis on smoking based on the risks of a single cigarette; basically, if you enjoy cigarettes, your benefit may vastly outweigh the risk for a single smoking episode. A single cigarette probably has zero risk (since, owing to convexity, exposure to harm has increasing effects). But we know that you have got to analyse things over time. In other words, put some dynamics in it. If you enjoy that cigarette, you are likely to do more. Thus we do not consider smoking as one event, but an activity. There is no independence between decisions – if you survive, you will take more of the same risk. Your analysis needs the following approach: if you continue that activity over time, by how much does it reduce your life expectancy? This cancels out the real-world validity of psychological experiments based on a single exposure.

21 Cover, T. M., & Thomas, J. A. (2012). *Elements of information theory*. New York: John Wiley & Sons.

22 See for instance Gigerenzer, G. (2000). *Adaptive thinking: rationality in the real world*. New York: Oxford University Press.

4. Multiscale Survival

Precaution must be considered at a multiscale level, never at a single scale, that is, for a single individual. If I engage in crossing the street regularly, I have 1 in 47,000 or so chances of death per lifetime. It does reduce my life expectancy just a tiny little bit because I do not cross the street that often.

The pedestrian's risk of death is controlled; it is in addition a well-known probability. However, I do not want the whole of humanity to cross the street at the same time. As you go up the layers here, you realise that there is a worst-case scenario than your death by accident. It is you plus your friends and pets, you plus your tribe. As we go up the scale, we have to exert more precaution because my life expectancy is probably another few decades, but the life expectancy of humanity should be more, and of course, that of the ecosystem should be even more. The more life expectancy is at stake, the less one can perform standard cost-benefit analysis. You have got to consider every activity as if we are going to do it forever or do it over a long period of time, which affects the expectation monstrously.

You cannot really afford to use the scientific consensus for risk. You just have to say, 'I want a zero error rate,' regardless of probabilistic structure, because even a 0.1 of a percent error rate would mean that there would be no pilots and flight attendants at all in existence because they fly so often. Nor can we use P values because they are not quite scientific.[23] People do not realise that, one, they are not useable. Two, they are very stochastic, and worse, researchers do not realise they are stochastic because they think that the *n*, the number of subjects in experiments, disappears from the P value, they are sort of numbed by that. In fact, with P values, if you repeat the same experiment from the same statistical ensemble, many times, you get different values.

23 Taleb, N. N. (2016). The meta-distribution of standard p-values. *arXiv preprint arXiv:1603.07532*.

5. How to Look at Paranoia

In the literature researchers typically assume the agent will never again take the same risks in their lifetime – and that they do not aggregate risks. These analyses are not organic because as we saw they conflate time and ensemble probability. Cost-benefit analyses for risk management do not work. Now take for example the error or mental bias called 'mental accounting' in the literature – where people behave differently depending on the source/target of the funds at risk. Statically, to consider that mental accounting is an error attributable to framing, makes sense. But we do not live in a static world and Richard Thaler's results can in fact be interpreted backwards. The notion of 'gambling with the house's money' is deemed to be a departure from rationality; it is considered in that literature that it is irrational to treat money coming from the casino differently from your own initial endowment.[24] In other words, you do not do a cost-benefit analysis at a business school exercise without the path independent zero cost budgeting, or something like that.

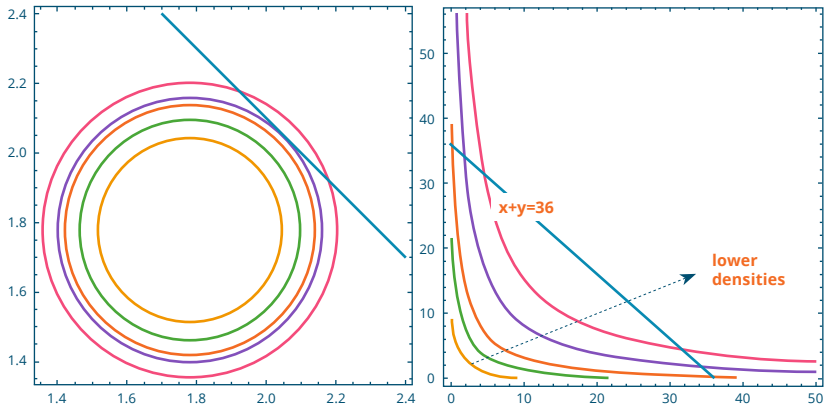
But in reality, if you do not engage in mental accounting, you will go bust – with near certainty. The most robust methods in gambling require you to be path dependent in the way you gamble because if you make money from a casino, you can afford to get more aggressive, and you will thus be able to survive – and grow (assuming you have the edge). Dynamics have not been put in Thaler's argument. Effectively, once you put time (and multiplication) into the argument, you realise many things that are considered departures from rationality, assuming we can define rational decisions in this concept as those that *condition on survival*, become very rational. To repeat, the law of large numbers does not work the same way under multiplication.

Paranoia can thus be a blessing. Therefore, the way to look at paranoia is not per event, rather per payoff for the attitude over a sequence at a specific scale. How did humanity survive? Can we survive without paranoia? The question becomes really, are we paranoid enough? In fact, the asymmetry is such that a slight decrease in paranoia might blow us up.

So far, I have explained the problem of path dependence and time probability and how, when you use dynamics, you get different results. Let us look at the story of fat tails now.

24 Thaler, R. H., & Johnson, E. J. (1990). Gambling with the house money and trying to break even: The effects of prior outcomes on risky choice. *Management science, 36*(6), 643–660.

FIGURE 7A AND 7B



A) Iso-densities for two independent Gaussian distributions. The line shows x + y = 4.1. Visibly the maximal probability is for x = y = 2.05.

B) Iso-densities for two independent thick tailed distributions (in the power law class). The line shows x + y = 36. Visibly the maximal probability is for either $x = 36 - \varepsilon$ or $y = 36 - \varepsilon$, with ε going to 0 as the sum x + y becomes larger.

6. The Statistical Consequence of Fat Tails

Fat tails are not trivial; there are two different classes of distribution that are very distinct. In fact, when you are in a fat-tailed world, the consequences for statistical inference and decision making are vast.

Say I randomly select two people from the population, and I have an outlier: I have in my sample a total combined height of 4.1 metres. Of course, the probability is very small, but in the Gaussian world, which is a thin-tailed distribution, it is vastly more likely to have the combination at 2.05 metres each, rather than have a combination of 0.1 and 4 metres, or even 1.7 and 2.4 metres. It is vastly more likely to have two times three-sigma events in a row than one time a six-sigma event. As the deviation gets bigger, the divergence becomes even stronger.

Now say I play out the same thought experiment but with monetary wealth, that is, I select two people randomly from the population, and I get an outlier in my sample. The two people have a total net worth of 36 million. What is the most likely combination? Very different, the most likely combination

is going to be either 36 and 0, or 0 and 36. It is very, very unlikely to get 18 and 18 (see Figure 7A and B for the reasoning). The difference between the two environments is huge and the thought experiment we just played out presents the so-called *catastrophe principle*. Say an insurance company loses 500 million US dollars over a five year period. If its risks are thin tailed, they must have had a high number of claims and accidents. If you are in a fat-tailed environment, which is the case of reinsurance, odds are it came all from a single event – just one.

If you start ranking probability distributions, the principle above determines the demarcation between them. Insurance is based on the following concept: you have a sort of bathtub, and the equivalent of money coming steadily into the bathtub, with lumps occasionally going out owing to claims. Now there exists a strategy with almost zero probability of never going bankrupt if your risk is thin-tailed. As with the allocation of height, a six-sigma event is much, much less likely than two three-sigmas in a row – the exact opposite of the situation with fat tails. There is a very big difference between one world and the other, between a world of fat tails, where the small probabilities always matter, no matter what they are, ruin can always hit, but it is very easy to hedge yourself. You just make sure that you do not have negative exposure to these fat-tailed events – if there is a risk of ruin of the type we saw earlier.

Another simple example to illustrate the difference between thin tails and fat tails is as follows. Consider a plane crash. It is a tragedy; 300 people perished, horrible. But as bad as that is, you are still in Mediocristan because in Extremistan, the event can kill every single person that ever rode a plane before. In finance and banking, we periodically see banks losing more than they ever made before. This was the case in 1982 and 2008–2009.

You know what is currently happening to Deutsche Bank. The people who create risk can cash their bonuses then go home, and nobody is going to own these catastrophic losses. Not only can lose you a lot of money, you could lose every penny ever made in the whole industry in one period.

Now when it comes to risk analysis, let us call it fake empiricism to compare potential pandemics, such as Ebola, which is multiplicative, hence very fat-tailed, to tobacco, car accidents or alcohol (thin-tailed) and say, 'Oh, Ebola's not killing as many people.' That is the wrong approach. You should never mix fat-tailed things with things that have existential risk for the planet and are multiplicative, like Ebola or another virus. Maybe you do not have to obsess over Ebola, but you cannot use the same tools of analysis. You would do

the following mental experiment, 'Say 100 million people died in Europe. What is it more likely to come from, Ebola or alcohol abuse?' You know it is more likely to come from Ebola. Hence tail events are a different story, and using and comparing averages naively is very bad because Ebola would have a distribution that is closer to the so-called *Pareto 80-20 principle*[25], whereas alcohol deaths per year have variations that are very close to those of a Gaussian.

To repeat, the variables are not in the same class, and you cannot compare them. This is done very often in the press. People sometimes claim that it is irrational to worry about terrorism, given past data. No, it is not irrational to worry about terrorism, even if terrorism does not kill a lot of people. In fact, if you are not paranoid about terrorism, you are going to be a victim of it, as a person or as a nation.

7. Prediction and the Perceived Miscalibration in the Tails

We are going to see under fat tails that there is something about these probabilities used in calibration – they become completely useless.[26]

First, consider what we call a characteristic scale. There are three types of random variables. For the first one, the limit of x conditional and x being higher than K as K goes to infinity, is going to be proportional to K. That distribution will have fat tails. To give a very simple example, if I tell you an event killed *more than* 100 million people, what is the expected number? You would say it is going to be 200. If it kills more than 500 million, it is going to be one billion. Thus, it is always proportional to K, the conditional expectation. But in a thin-tailed world, it is not so. Say, if someone is taller than four sigma, how tall are they? Well, 4.01 sigma. In other words, there is a characteristic scale.

So in that world, there exists a 'large' deviation. So, one can say 'this is a large deviation'; it is well defined, something more than four sigma because the payoff of more than four sigma does not keep going as with fat-tailed payoffs. But in a fat-tailed world there is no representative large deviation. And between the fat-tailed and the thin-tailed world there is a category, the borderline one.

25 The Pareto 80-20, common in popular parlance but largely ignored in psychology, is a representation of a typical fat-tailed distribution; it originates from the observation that 20 % of the people in a region in Italy owned 80 % of the land, and vice versa. This recurses to 1 % of the people having 50 % of the total.

26 This exposition is from: Taleb, N. N. (2020). On the statistical differences between binary forecasts and real-world payoffs. *International Journal of Forecasting 36*(4), p. 1228-1240.

More formally:

Let X be a random variable that lives in either $(0,\infty)$ or $(-\infty,\infty)$ and E the expectation operator under 'real world' (physical distribution). By classical results:

$$\lim_{n\to\infty}\left(\frac{1}{K}E(X\,|_{X>K}\right)=\lambda,$$

- If $\lambda=1$, X is said to be in the thin-tailed class D_1 and has a characteristic scale
- If $\lambda>1$, X is said to be in the fat-tailed regular variation class D_2 and has no characteristic scale
- If

$$\lim_{n\to\infty}\left(\frac{1}{K}E(X\,|_{X>K}\right)-K=\mu$$

  where $\mu>0$, then X is in the borderline exponential class.

The substitution made in the literature is as follows:

Let $K\ \backslash in\ \backslash mathbbm\{R\}^{+}$be a threshold, f(.)a density function and p_K \in [0,1] the probability of exceeding it, and g(x)an impact function. Let I_1 be the expected payoff above K:

Let I_1

$$I_1=\int_K^{\infty}g(x)f(x)dx$$

and let

$$I_2=g(K)\int_K^{\infty}f(x)\,dx=g(K)\,p_K.$$

The substitution comes from conflating I_1 and I_2, which becomes an identity if and only if g(.)is constant above K (say g(x)=\theta_K(x), the Heaviside theta function). For g(.)a variable function with positive first derivative, I_1 can be close to I_2 only under thin-tailed distributions, not under the fat-tailed ones.

Next the math shows us the effect of the conflation:

Convergence of $\frac{I_1}{I_2}$:

If X is in the thin-tailed class D_1,

$$\lim_{K\to\infty} \frac{I_1}{I_2} = 1$$

If X is in the regular variation class D_2,

$$\lim_{K\to\infty} \frac{I_1}{I_2} = \lambda > 1.$$

TABLE 2

Gaussian pseudo-overestimation.

p	K_p	$\int_{K_p}^{\infty} x\, f(x)dx$	$K_p \int_{K_p}^{\infty} x\, f(x)dx$	p*	$\frac{p^*}{p}$
$\frac{1}{10}$	1.28	1.75×10^{-1}	1.28×10^{-1}	1.36×10^{-1}	1.36
$\frac{1}{100}$	2.32	2.66×10^{-2}	2.32×10^{-2}	1.14×10^{-2}	1.14
$\frac{1}{1000}$	3.09	3.36×10^{-3}	3.09×10^{-3}	1.08×10^{-3}	1.08
$\frac{1}{10000}$	3.71	3.95×10^{-4}	3.71×10^{-4}	1.06×10^{-4}	1.06

TABLE 3

Paretan pseudo-overestimation.

p	K_p	$\int_{K_p}^{\infty} x\, f(x)dx$	$K_p \int_{K_p}^{\infty} f(x)dx$	p^*	$\frac{p^*}{p}$
$\frac{1}{10}$	8.1	8.92	0.811	1.1 (sic)	11.
$\frac{1}{100}$	65.7	7.23	0.65	0.11	11.
$\frac{1}{1000}$	533	5.87	0.53	0.011	11.
$\frac{1}{10000}$	4328	4.76	0.43	0.0011	11.

Let us discuss Table 2 and Table 3 , which show the conflation under the two different domains. When you say people overestimate tail probabilities, your tools might inaccurately specify the payoff because you are giving them a fixed outcome. A lot of these experiments, such as the seminal Kahneman-Tversky's Econometrica paper[27], are inspired by a simple experiment where you give someone a simplified outcome where probability is separable from the integral. The results work well but are limited to that type of exposure. You are not giving the person an open-ended payoff – ignoring the large error of making general statements from a static experiment. You are testing for a certain payoff thinking it is representative. That only works for thin tails. Even then, the approach makes you underestimate probability in the tails, for example, by a little bit, something like somewhere between 6 and 36 % (see Table 2).

On the other hand, if you apply the same approach, by what I call *pseudo-overestimation of probability*, it can be 11 times, as you can see in Table 3 (pseudo-overestimation means erroneous overestimation). Thus, the tails play such a role that you should not talk probability without associated conditional expectation because most researchers appear to be using probabilities as a proxy for expectation, and the two diverge.

8. Conclusion

In this discussion, I have made two central points. The first one is that you do not study probabilistic risks and returns statically. You should consider them dynamically and, dynamically, you get a different story. Effectively, if you start applying this idea, you will see much that is called irrational is in fact not irrational at all. It is very rational the way we humans have handled it – and survived. The second one is that there is a difference between thin tails and fat tails and the literature makes a huge mistake by conflating their properties and generalising from experiments, creating what we called here *pseudo-overestimation*.

Of course, we may be paranoid about something, and it might be irrational, but we should consider paranoia as a general attitude, not paranoia as a local property. Whether one is locally wrong or not is irrelevant. Whether someone is calibrated in probability or not is meaningless: I myself

27 Kahneman, D., & Tversky A. (1979). *Prospect theory: an analysis of decision under risk*, 263–292.

have traded for a long time, and I make money once per 1,000 trades – so being 'wrong' and miscalibrated did not bother me. Probability is part of a kernel and cannot be separated and to be discussed as its own item, particularly under fat tails. Hopefully, research will correct these misinterpretations that put society at risk.

Appendix

Next we present the derivations between the lack of equality of time and ensemble probability (even without a multiplicative setting). Consider the extremely simplified example, the sequence of independent random variables $(X_i)_{i=1}^{n} = (X_1, X_2, \dots X_n)$ with support in the positive real numbers ($\mathbb{R}^+$). The convergence theorems of classical probability theory address the behaviour of the sum or average: $\lim_{n\to\infty} \frac{1}{n}\sum_i^n X_i = m$ by the (weak) law of large numbers (convergence in probability). As shown in the story of the casino, n going to infinity produces convergence in probability to the true mean return m. Although the law of large numbers applies to draws i that can be strictly separated by time, it assumes (some) independence, and certainly path independence.

Now consider $(X_{i,t})_{t=1}^{T} = (X_{i,1}, X_{i,2}, \dots X_{i,T})$ where every state variable X_i is indexed by a unit of time t: $0<t<T$. Assume that the 'time events' are drawn from the exact same probability distribution: $P(X_i)=P(X_{i,t})$.

We define a time probability as the evolution over time for a single agent i. In the presence of terminal that is, irreversible, ruin, every observation is now conditional on some attribute of the preceding one, and what happens at period t depends on $t-1$, what happens at $t-1$ depends on $t-2$, etc. We now have path dependence.

Next, what we call *failure of ergodicity*:

Theorem 1 (state space-time inequality): Assume that $\forall t, P(X_t = 0) > 0$ and $X_0 > 0$, $\mathbb{E}_N(X_t) < \infty$ is the state space expectation for a static initial period t, and $\mathbb{E}_T(X_i)$ the time expectation for any agent i, both obtained through the weak law of large numbers. We have

$$\mathbb{E}_N(X_t) \geq \mathbb{E}_T(X_i)$$

Proof:

$$\forall t, \lim_{n\to\infty} \frac{1}{n} \sum_{i}^{n} 1_{X_{i,t-1}>0} X_{i,t} = m\left(1 - \frac{1}{n} \sum_{i}^{n} 1_{X_{i,t-1}\leq 0}\right)$$

where $1_{X_{i,t-1}>0}$ is the indicator function requiring survival at the previous period. Hence the limits of n for t show a decreasing temporal expectation:

$$\mathbb{E}_N(X_{t-1}) \leq \mathbb{E}_N(X_t).$$

We can actually prove divergence.

$$\forall i, \lim_{T\to\infty} \frac{1}{T} \sum_{t}^{T} 1_{X_{i,t-1}>0} X_{i,t} = 0.$$

As we can see by making $T < \infty$, by recursing the law of iterated expectations, we get the inequality for all T.

We can see the ensemble of risk takers expecting a return $\mathrm{m}(1 - \frac{1}{n}\sum_{i=1}^{n} X_{i,j-1=0})$ in *any* period t, while every *single* risk taker is guaranteed to eventually go bust.

Principle of Probabilistic Sustainability

Principle: A unit needs to take any risk as if it were going to take it repeatedly – at a specified frequency – over its remaining lifespan.

The principle of sustainability is necessary for the following argument. While experiments are static (we saw the confusion between the state-space and the temporal), life is continuous. If you incur a tiny probability of ruin as a 'one-off' risk, survive it, then do it again (another 'one-off' deal), you will eventually go bust with probability 1. Confusion arises because it may seem that the 'one-off' risk is reasonable, but that also means that an additional one is reasonable (see Figure 6). The good news is that some classes of risk can be deemed as having a probability of practically zero: the earth survived trillions of natural variations daily over three billion years, otherwise we would not be here. We can use conditional probability arguments (adjusting for the survivorship bias) to back-out the ruin probability in a system.

Now, we do not have to take $t \to \infty$ nor is permanent sustainability necessary. We can just extend shelf time. The longer the t, the more the expectation operators diverge.

Consider the unconditional expected stopping time to ruin in a discrete and simplified model: $\mathbb{E}(\tau \wedge T) \approx \mathbb{E}(\tau) = \sum_{i=1}^{\lambda N} i \left(\frac{p}{\lambda}\left(1 - \frac{p}{\lambda}\right)^{i-1}\right)$, where λ is the number of exposures per time period, T is the overall remaining lifespan and p is the ruin probability, both over that same time period for fixing p. Since $\mathbb{E}(\tau) = \frac{\lambda}{p}$, we can calibrate the risk under repetition. The longer the life expectancy T (expressed in time periods), the more serious the ruin problem. Humans and plants have a short shelf life, nature does not – at least for t of the order of 10^8 years hence annual ruin probabilities of $O(10^{-8})$ and (for a tighter increment) local ruin probabilities of at most $O(10^{-50})$. The higher up in the hierarchy an individual-species-ecosystem is, the more serious the ruin problem. This duality hinges on $t \to \infty$; hence requirement is not necessary for items that are not permanent, that have a finite shelf life.

Scientific Diagnostic of Global Financial Markets and Economies: What Risks and Growth Does it Bode for the Future?

Didier Sornette
ETH Zurich

Abstract: *Based on the investigation of more than 500 catastrophic failures in critical infrastructures and large technological companies, we have determined that, before a disaster, some employees/collaborators of the affected organisation were aware of dangerous conditions that had the potential to escalate to a critical level. But for a variety of reasons, information about these risky conditions was not delivered to decision-makers and vice-versa. Consequently, the organisation continued moving towards the catastrophe, unaware of the possible threat – despite the fact that some of its employees clearly understood the likelihood of an impending disaster. We dissect the causes and mechanisms of such behaviours. We then suggest recommendations and practical solutions for the efficient and timely transmission of information about technological risks within large industrial companies: transmission of information on risks, risk analysis, accumulation of knowledge about risks, decision-making. We also differentiate the risk prioritisation approaches needed in different industrial sectors. This presentation is based on two books.*[28, 29]

I am a theoretical physicist by training but I also hold the Chair of Entrepreneurial Risk and I am a Professor of Finance at the Swiss Finance Institute. I am also associated with the department of Earth Sciences at ETH Zurich and lead a research group on the physics and prediction of earthquakes.

28 Chernov, D., & Sornette, D. (2016). *Man-made catastrophes and risk information concealment*. Switzerland: Springer International Publishing.

29 Chernov, D., & Sornette, D. (2020): *Critical risks of different economic sectors. Based on the Analysis of More Than 500 Incidents, Accidents and Disasters*. Switzerland: Springer International Publishing.

My area of focus is the analysis and prediction of large and extreme risks in many different systems, and in particular financial risk and financial upside risk, therefore I am a specialist on financial bubbles and crashes in particular.

What I am going to talk to you about concerns the question of how catastrophes, crises and big disruptions in society and industry occur. This is research performed in close collaboration with Doctor Dmitry Chernov. We started to investigate a number of cases progressively over the years. In the analysis of up to 500 catastrophes in all sectors, we have tried to understand if there are commonalities and if there are differences in industry sectors. I am going to walk you through some of the evidence, some stories, narratives, insights, and then draw some conclusions.

When dealing with the management of critical infrastructures, technological systems and so on, I am very interested in looking at the failures. As von Bismarck once said, 'The stupid person learns from his failures. The intelligent person learns from the failures of others.' This is the goal, to learn from the failures of all the others. What are the reasons for failures? First, we lack imagination. I always like to say that nature is much more imaginative than any mathematician, physicist, engineer or economist. Nature finds vulnerabilities much better than any expert. Moreover, we often lack courage, and we are lazy in addressing problems.

There is also the issue of luck versus skill. In the paper, we state a new problem, it is called the *fair reward problem*.[30] The fact that most successes are due in large part to luck depending on the disciplines, and because it is success that is in general rewarded, it follows by transitivity that society rewards luck. A key open problem is to develop a management system, a reward system in society, in organisations that reward the process and not just success. This is a very important aspect of the conversation about understanding the root cause of failures.

I will come back to the issue of understanding the nature of complex systems. Complex organisations go beyond our natural ability to grasp complex systems. Here, I am going to look more closely at the issue of communication. Looking at the cases mentioned earlier, we wanted to examine the axiom of management theory that says that managers oversee people by means of information. There are dozens, even hundreds of books dealing with crises or even managing crises, which are based on the axiom that the manager or

30 Sornette, D., Wheatley, S., & Cauwels, P. (2019). The Fair Reward Problem: The Illusion of Success and How to Solve It. *Advances in Complex Systems, 22*(03), 1950005.

decision maker has all the necessary information. These books are concerned with how to find the best response to the crisis within the organisation, how to manage it and how to communicate with the public. We are going to challenge this approach since the main point of the talk will be that information is not generally in the hands of the managers and we are going to try to understand why this is so. A possible reason for distortion could be because information is very hard to obtain but also there will be a very strong component associated with intentional concealment of information.

1. The Challenger Disaster in 1986

After a few seconds of flight, the O ring, which is a rubber system on the booster on the side of the main rocket, broke and led to the explosion, killing seven members of the Challenger Shuttle in 1986. What is very interesting in terms of information transmission is the conclusion of the celebrated Richard Feynman, Nobel Prize winner in physics. He was called to be a participant of the Presidential Commission to try to understand what was going on, and he pointed out, based on the interviews that he carried out among technicians and engineers at NASA, that there was a big discrepancy between the reported probability for an accident of 1 in 100,000 by the management of NASA compared to the 1 % probability derived by the engineers. How is it possible that the engineers had this estimation, and not the management?

It is very interesting to look at the complexity of the management structure and the complexity of the different providers, private industry and more. It is also fascinating to look at the decision process on the day before the flight. Essentially, the engineers of the company Thiokol were trying to do everything to stop the flight. There was a power struggle between the management of Thiokol with the NASA management, the importance at the political level, the accumulated delays, the pressure from the US Congress, and so on, which eventually bypassed the concern of the engineers that there was a problem, allowing the flight to take place. Actually, this is also another failure. Not only is the message that many knew there was a problem, and it was not passed on clearly enough to the top management, or you could say the reverse is that overarching political consideration, monetary consideration, reputation consideration took over rational risk management.

It is our responsibility as scientists and technician engineers to clearly and powerfully communicate the conclusions extracted from data. The engineers failed in this case because they only showed tables of statistics of

previous damage of the rubber of this booster. It is a O-ring rubber structure that ensures good airtightness between elements of the boosters. The engineers failed to show a graph where a trend is clearly visible, where you can see the intensity of the damage increasing as the temperature at take-off decreases. I call it the 'evidence of the dog that did not bark', which is to plot all the cases, including those that had no damage. The trend was that, at high temperature or room temperature, there is no damage. When you start to decrease the temperature, damage appears. Framed in this way, I would claim they would have been able to convince top management not to launch. Some of you might remember that Feynman came in front of Congress in his testimony with a glass of water with ice cubes, put this rubber inside the glass, and was able to break it to show that it is brittle at sub-zero temperatures, and indeed, it should not have flown as the temperature at take-off on that day was -2 degrees Celsius. It was a big failure of communication. In conclusion, there were many issues at the origin of the disaster, in particular the problem of lack of trend analysis, complacency, problems of reporting, and others.

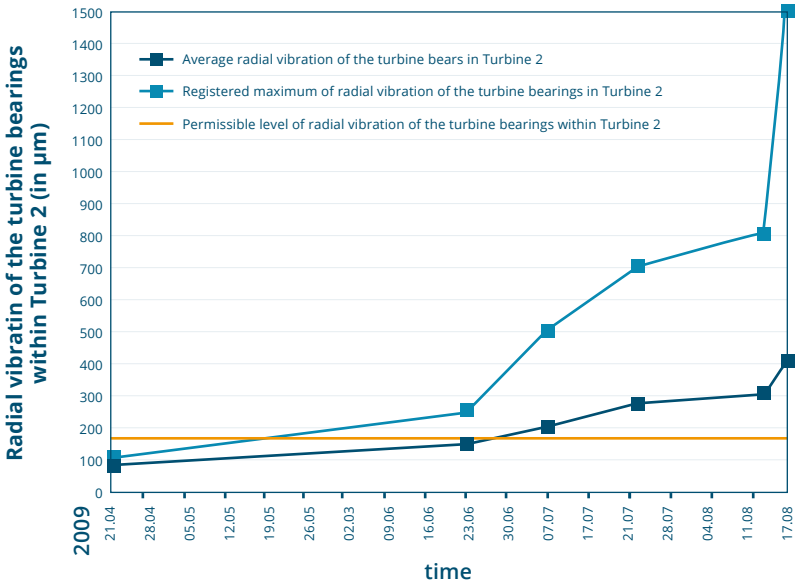
2. Failures of Communication and the Deficit of Information

Similarly, the accident at the Piper Alpha platform in 1988 was a failure of communication and a blatant disrespect for safety regulations. The cause of the disaster was a shift between two teams and a lack of transfer of information between them. The first team did not inform the second team about the removal of a pressure safety valve for routine maintenance. This was also associated with other aspects of the company.

Another notable case is the accident in 2009 at the Sayano-Shushenskaya hydropower station. One turbine failed and killed 75 people and incurred several billions of dollars of damage. It was the stud bolt responsible for holding the turbine that failed. Was this accident caused by a failure of information transmission? In 1983, a similar accident occurred in the USSR. All the details of the problem were communicated to the ministry in charge of the energy provision at the time, in particular with a recommendation to perform regular ultrasonic tests of the stud bolts. Yet, over time, this information was progressively forgotten, and the tests were abandoned. Even more shocking in this case was the increasing level of radial vibration of the turbine (Figure 8). A thing that is rotating vibrates a little bit due to slight unbalanced masses with respect to the rotation axis, and of course, any vibration, for example, if you drive your car and you feel vibration, is not good. It means that the wheel

is not correctly balanced and the cumulative effect of vibration is eventually going to lead to a failure and an accident.

FIGURE 8



A man-made catastrophe and risk information concealment of the Sayano-Shushenskaya hydropower station incident in 2009. The amplitude of radial vibration in Turbine 2 is plotted as a function of time from 21 April 2009 to 17 August 2009, the day of the accident. One can observe unsafe high vibration levels months before the accident, with a clear upward trend. The acceleration of the vibration amplitude is a characteristic signature of the criticality of rupture.[31] Still, there was no warning passed on from RusHydro security service to RusHydro senior management about abnormal vibrations in Turbine 2.

The safety level had already been exceeded six months before the catastrophe. Thus, several months and even weeks before, the workers were essentially shutting off the alarm, using anti-noise to continue the routine operation of

31 Johansen, A., & Sornette, D. (2000). Critical ruptures. *The European Physical Journal B-Condensed Matter and Complex Systems, 18*(1), 163–181; Sornette, D. (2002). Predictability of catastrophic events: Material rupture, earthquakes, turbulence, financial crashes, and human birth. *Proceedings of the National Academy of Sciences, 99*(suppl 1), 2522–2529; Zhou, W. X., & Sornette, D. (2002), Generalized q-analysis of log-periodicity: applications to critical ruptures, Physical review. *E, Statistical, nonlinear, and soft matter physics, 66*(4 Pt 2), 046111.

the plant, ignoring the approaching finite-time singularity[32], as I call it mathematically, the fact that indeed something is going to rupture. Information was there, ignored for various reasons.

The Deepwater Horizon was an offshore drilling rig that exploded in 2010, and the responsibility is shared by the trio of associates, British Petroleum (BP), Haliburton, and Transocean. In that case, a lot of information concealment was documented in the post-mortem analysis. In particular, Halliburton concealed from BP and Transocean the results of the test on the concrete that would actually ensure the safe operation at depth. BP also concealed information from Halliburton about the centraliser and so on.

The Tohoku earthquake on 11 March 2011 is not obviously a human failure; it is a natural catastrophe. This earthquake occurred close to Japan on what we call the Ring of Fire along the plate tectonic boundaries around the Pacific Ocean, associated with a lot of geodynamic activity that makes our planet so lively and so beautiful. It was a very long rupture of 400 kilometres at depth. The Japanese experts were representing the risks of earthquake along that coast by what is called a segmentation approach. This approach is done in all countries, including the US, Europe, and Japan. It consists in identifying the discontinuities and bends between faults, in order to identify segments on which characteristic earthquakes are supposed to occur and be the largest possible events associated with a given fault. In other words, the size of the fault determines the size over which the rupture can propagate and thus the size of the earthquake. The problem is that the Tohoku earthquake ruptured half-a-dozen of such segments, in a domino effect that was supposed to be impossible. This was a surprise for them, but the sad truth is that scientists had known about the fact that earthquakes can jump from segment to segment for at least 15 years before the Tohoku earthquake. There was a failure of information transmission from scientists to hazard specialists and decision makers. It is probably due to the inertia with which scientific knowledge is transformed into risk assessment and risk management implementation, but also to laziness and complacency. This is another example of a risk information deficit.

The earthquake led to a large tsunami and I want to jump directly to the consequence of the Tohoku earthquake, which is the Fukushima-Daichii nuclear plant disaster. As you know, the earthquakes did not kill anyone

32 Ide, K., & Sornette, D. (2002). Oscillatory finite-time singularities in finance, population and rupture. *Physica A: Statistical Mechanics and its Applications, 307*(1–2), 63–106.

because the buildings held thanks to their engineering quality. Nevertheless, about 12,000 people died due to the tsunami. The flooding of the Fukushima-Daiichi nuclear plant is well known, and it led to the melting of three cores, and a large release of radiation. There are still thousands of engineers there and large efforts to clean and decommission this plant, with a timetable extended over the next 75 years. The problem that was uncovered is a culture of complacency and concealment by TEPCO, the owner of the nuclear plant.

My own reaction, when the Tohoku earthquake and the Fukushima disaster occurred, was of course first shock, but then a relative sense of relief that this occurred in a highly technical, organised and cohesive country that would address the disaster efficiently. That is exactly the Achilles problem or vulnerability that we all discovered. The Japanese had become accustomed to outperforming the West so much that this is one of the rare developed countries that were not learning the lessons of all the accidents in the world's nuclear fleet. They thought that their technology was superior to that in the US or in Europe. TEPCO was actually forging information to the regulators on the different tests that they had to do for the regular maintenance of their nuclear plants. There is another side that also shows the deficit of information where the Prime Minister learned about the event from the TV. He had to form his own team of experts because the Nuclear and Industrial Safety Agency, the regulators, and TEPCO, the company owning the plant, refused to communicate information to him.

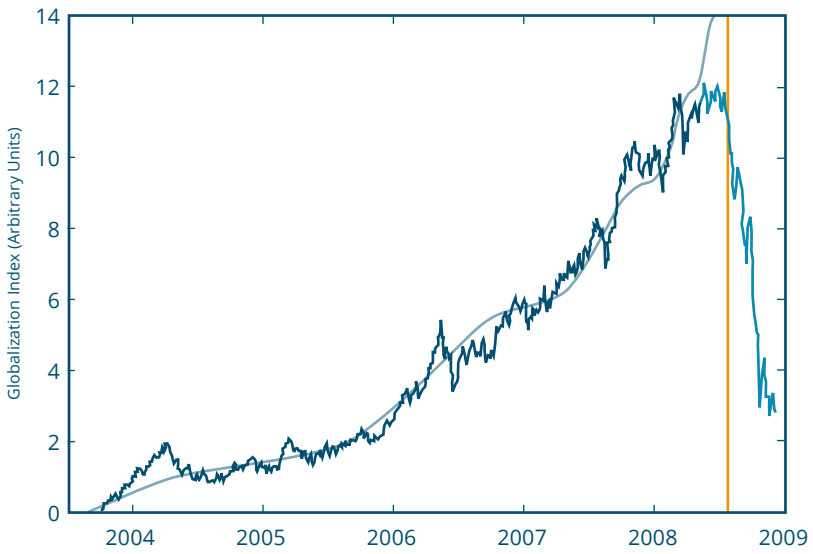
Japan was arguably at the top in terms of nuclear power and technology, however they failed miserably. Therefore, this may be one of the best examples to suggest that, when you do risk management, do not assume you have all the relevant information. The lessons of past crises indicate that the decision makers rarely have it.

3. The Financial Crisis in 2008

I propose that the financial crisis of 2008 (known as the GFC, global financial crisis) is an example of a huge information deficit or information distortion. You may remember Alan Greenspan himself giving a testimony in front of Congressman Waxman, and saying, 'Yes, I have been functioning for the last 35 years on the basis, on the belief, on the conviction that financial management of banks and so on left to themselves by optimising their own selfish utility function would make the whole world better, and I have to reconsider this question.'

So why is it information concealment? Figure 9 below shows the time dependence of a global financial index, which is essentially measuring or quantifying the excess of the financial markets, the inflation of prices over the five years before the crisis. You have the acceleration of valuation, which develops on an unsustainable basis, and then it ruptured in a big crash. There is a long list of major bubbles that developed concomitantly, such as the real estate bubbles, the stock market bubbles, debt bubbles and others, that developed over the years from the 1980s to the crash.

FIGURE 9



The global bubble (2003–2008) marked by the real estate bubble 2003–2006, the mortgage-backed security (MBS) and collateralised debt obligations (CDOs) bubble as well as the stock market bubble 2004–2007, the commodities and oil bubbles 2006–2008 and the debt bubble all developing jointly and feeding on each other until 2008 – finally leading to deterioration of the 'perpetual money machine'.[33] The time series represent a proprietary index of emerging markets equities and currencies, freight prices, soft commodities, base and precious metals and energy. The vertical yellow line is the best estimate of the correction time.

33 *Figure 9*. The deterioration of a global bubble. Adapted from "The illusion of the perpetual money machine and what it bodes for the future," by D. Sornette & P. Cauwels, 2014, *Risks, 2*(2), 103–131. Licensed under CC BY-NC-SA 3.0.

Maybe some of you have heard the term *Great Moderation*. It was promoted by a Nobel Prize winner, by the policymakers, the bankers, and so on as characterising the two decades and a half before the GFC. The Great Moderation means that, over the 25 years before the crisis, the world was much better due to financial innovation, deregulation, the repeal of the 1933 Glass-Steagall Act and others. As a consequence, GDP growth in the US in particular was solid for 25 years. It is the best 25 years ever in the US with very low volatility. Inflation was on a downward trend, very controlled also with low volatility, unemployment also controlled and predictable and lastly low financial volatility. Historically, it has been impossible to have all these four elements performing so well simultaneously. However, we got it for 25 years, and this was called the Great Moderation. After the GFC occurred, I was at a conference in 2011 organised by the Federal Reserve, and the European Central Bank in Frankfurt. The same economists who were self-satisfied saying, 'Hurrah, we got it. We have mastered the economic biz,'(as summarised by the Great Moderation) were now saying, 'This was so abnormal.' Of course, this was abnormal and this is a very good example of a bias called *hindsight bias*. When you look back after the catastrophe, it becomes obvious that the system was bizarre. You see the price skyrocketing, doubling, tripling in just a few years, and then crashing. The returns on the real estate growing in an accelerated way associated with what we call in mathematics *finite-time singularity*, means the story looks very good until the prices are ascending vertically and this cannot continue. The information was present, prevalent, everywhere that this 'Great Moderation' was an aberration yet this was ignored by most policymakers and even academics.

This is the essence of the cause of the global financial crisis. Elaborating further is another talk, but I have accumulated a large set of evidence showing that it is actually the change around 1980 that was the source of the financial crisis. There has been a deficit of attention to the relevant information, where you could see the change in productivity, in the stock markets, in financialisation, in debt skyrocketing, in monitory policies, in fiscal policies, and in inequality, which bottomed in the 1970s and has grown and accelerated since then. The GFC should not have been a surprise and was predictable. But stopping a booming economy, even if fuelled by unsustainable financialisation, is political suicide and against the vested interest of most financial and economic actors.

4. External and Internal Environments of the Organisation

I would like to finish by trying to consolidate the information presented to you until now, obtained by analysing all these case studies and looking at the cause of this deficit of information that we find to be the major mechanism. We have found approximately 30 causes which we organised into what we could call an external environment of the organisation and what is more an internal environment. In the external one, you have, for example, the global deregulation, which is very well illustrated by what I was describing for the GFC. You have weak control over complex organisation. You have unfortunately, in many cases, like in the case of Japan, the cosy relationship between the government and the industry. An ongoing problem is the low qualification of representatives of the government regulators: If you are not very competent, you become a regulator while, if you are good enough, you are more likely to go and launch your hedge fund. Very strong difference in incentive and even general competence need to be considered.

In the internal environmental organisation, you can also separate the mechanism in terms of the internal ecology of the organisation, for example, the case of habituation that I was mentioning for NASA leading to the Challenger disaster and then later to the Columbia disaster in 2003 that we also analysed. Furthermore, Enron is a very good case of a permanent rush work culture – success at any cost, and no bad news policy. Wishful thinking, self-deception and also the fragmented perception of the risks and if there is not a will from the top leading managers to build a complete picture, nobody will have it. Personal features of the employees are another factor, such as looking good in the eye of the superior. Fear of criminal prosecution, unrealistic projection of personal performance, illusion of control, illusion of skill, and you have the components leading to failures of risk assessment and risk knowledge management. Another important problem is the unwillingness to share information and experience, even within a given sector across different companies and then the absence or deficit of communication channels.

In conclusion, while we advise risk specialists to not blindly and hastily follow the response and experience of other sectors, there is still something to be learned from them.[34]

34 Chernov, D., & Sornette, D. (2020). *Critical risks of different economic sectors. Based on the analysis of more than 500 incidents, accidents and disasters*. Switzerland: Springer International Publishing.

Session 3
Commonly Over- and Under-estimated Risks

Chair:
Thomas Lengauer
Max Planck Institute for Informatics

Between Phlegm and Panic – Underestimated versus Overestimated Risks

Gaby-Fleur Böl
The German Federal Institute for Risk Assessment

Abstract: *The term risk refers to the likelihood of damage resulting from a potential hazard, as well as the likelihood of exposure to such a hazard. These expert assessment criteria differ from those of laypersons, who turn to parameters such as the probability of a risk, controllability, potential for catastrophe, the voluntary principle, as well as the severity. Thus, perceived risks seem to result from risks that have not been communicated clearly and at the same time, in a differentiated manner. Therefore, risks are often under- or overestimated by the public, leading to disinterest or fear. Risks should be communicated in such a way that the type, extent and significance of a risk can be adequately assessed, both by experts and laypersons. A clear understanding of how risks are perceived and what factors influence risk perception are crucial for adequate risk communication.*

Today we are going to talk about under- and overestimated risks in the field of consumer health protection as well as in other fields. At first, it should be reconsidered as to whether we are afraid of the right things, e. g. taking the example of nuclear power, nuclear energy, or obesity. Peter Sandman told us that the risks that can kill you are not necessarily the risks that anger and frighten you. Therefore, we are afraid of nuclear energy and not of obesity, but the opposite of this would be more logical. Underestimated risks could include heat, car accidents or even cancer. Why is this the case? And why are risks over and underestimated? There are several mechanisms at play here.

The scientists Müller-Peters and Gatzert asked whether the following risks would more likely be over- or underestimated.[35] At first, they dis-

35 Müller-Peters, H., & Gatzert, N. (2016). Todsicher: Die Wahrnehmung und Fehlwahrnehmung von Alltagsrisiken in der Öffentlichkeit. *Schriftenreihe Forschung am IVW Köln, Bd, 12*.

cussed terrorist attacks, motorcycle accidents, being suspected of a criminal offence, and fire in a house or flat. The result was that the first two were overestimated. Terrorist attacks are often overestimated in risk perception because they are horrific and have a high casualty rate. But maybe you are surprised that motorcycle accidents are overestimated because it is more dangerous to ride a motorcycle compared to driving a car. Nevertheless, the basic rate is also important to consider, as there are 10 times more cars here in Germany than there are motorcycles. In addition, with cars, you tend to drive for significantly longer distances. Therefore, the objective risk, if that exists, is lower in terms of having an accident in a car than on a motorcycle. Being suspected of a criminal offence or a fire happening in a house or flat is often underestimated in risk perception. They both happen frequently, but you tend to believe that they happen to other people, and never to yourself. As a result, one of the aims of risk communication is to consider the discrepancy between experts and laypersons. The objective risk comes from the expert review, whereas gut feelings come from the general population. It would be desirable to close, or at least reduce this gap between experts and laypersons. The *Information Deficit Model* fosters the idea that there may be a lack of education of laypersons, leading to irrational reactions and misinformation. If you provide people, the media or journalists with the right information, perceptions will then align with scientific judgment. Unfortunately, this viewpoint is all too simplistic and is not realistic.

Therefore, I would also raise the question, 'Does objective risk even exist?' Who defines if a risk is over- or underestimated? It is always important to ask, 'Who profits from classifying people as scared or relaxed?' 'Does the media have an interest or an ulterior motive, leading them to classify people and create panic, or not?'

1. Challenges in Risk Communication: Factors of Risk Perception

One of the biggest challenges in risk communication is the *single-study syndrome*. This is where some reporters, NGOs and the media in particular, cherry pick, meaning that they select one piece of literature to publish, but ignore other results or viewpoints. The answer according to Steven Pinker is to stop reporting single studies, no matter how appealing they may be.

Instead we should report literature reviews and meta-analyses.[36] Yet it is difficult for journalists to accurately show all of the data, as they do not necessarily understand it all. Therefore, institutes such as the Science Media Centre in London and Cologne can offer a lot of support.

The relation between perception and fact is often problematic. If you compare the risk between catching a flight that ends in fatality to driving a car, the catastrophic potential is considerably different (Figure 10). For example, there are a large number of fatalities or injuries in every flight crash, opposed to only a small number of people in a car. And what about controllability? You have no control on an aeroplane. Therefore, there is little to no personal control over the risk. There is some – and maybe you think there is a lot – of personal control over risk when driving a car. And what about media attention? There is a lot of media attention surrounding aeroplane crashes, but no or little media attention regarding car accidents. The figures from 2018 say there were 523 air traffic fatalities worldwide, in comparison to 25,100 road accident fatalities in the European Union alone. This suggests that it is not as dangerous to catch an aeroplane as people think.

There are several reasons for the overestimation of risks. For example, when you are on an aeroplane, there is no freedom of choice. Therefore, you may perceive it as being very high risk. There are lots of challenges in risk communication, as well as different factors of risk perception. We have already considered controllability, the severity of an event and the risk-benefit relationship. Is there any benefit to all this? People still typically underestimate risks. There are also other factors including who provides the information about a risk, how trustworthy the person or institution providing the information is. Then the risk is perceived in a different way. What about your personal concern surrounding the risk? If there are headlines about risks regarding children and you do not have children yourself, there is no personal connection.

36 Pinker, S. [@sapinker]. (2014, August 1). Lesson for sci journalists: Stop reporting single studies, no matter how sexy (these are probably false). Report lit reviews, meta-analyses [Tweet]. Retrieved 20 November, 2020 from https://twitter.com/sapinker/status/495077560787927040

FIGURE 10

Characteristics	HIGHER Risk Perception	LOWER Risk Perception
Catastrophic potential	Fatalities or injuries grouped in time and space	Fatalities or injuries distributed randomly in time and space
Severity of consequences	Large numbers of fatalities or injuries per event	Small numbers of fatalities or injuries per event
Controllability	Little personal control over risk	Some personal control over risk
Media attention	Much media attention	Little media attention

2018: **523** air traffic fatalities worldwide ⟷ **25.100** road accident fatalities in the European Union

Problematic relation between perception of risks versus facts in air and motor traffic leading to an over- and underestimation of actual risks. Influential factors are characteristics such as the catastrophic potential, controllability or media attention.[37]

Keeping an eye on perceived risks means that risk perception is always situated in a cultural and societal context. Disparities between experts and laypersons cannot be resolved by the provision of information alone. Most people believe that natural substances are safer than synthetic ones. This is merely a perception. Natural is often viewed as being synonymous with safe. Yet, the reality is that nature produces a lot of different poisons. For example, mouldy food is the easiest way to develop liver cancer. The myth of nature being benign means that interventions in nature and

37 International Air Transport Association (IATA). (2019). *Safety Fact Sheet*. Retrieved 20 November, 2020 from https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet---safety/; European Commission (2019). *Road Safety*. Press release 04/2019. Retrieved 20 November, 2020 from https://ec.europa.eu/transport/modes/road/news/2019-04-04-road-safety-data_en

health risks stemming from deviations of the natural are both perceived as very problematic. Therefore, people typically overestimate the risk of cancer due to pesticides. In comparison, they underestimate the risk of cancer from natural substances, as most people believe that natural chemicals are safer than their synthetic counterpart.

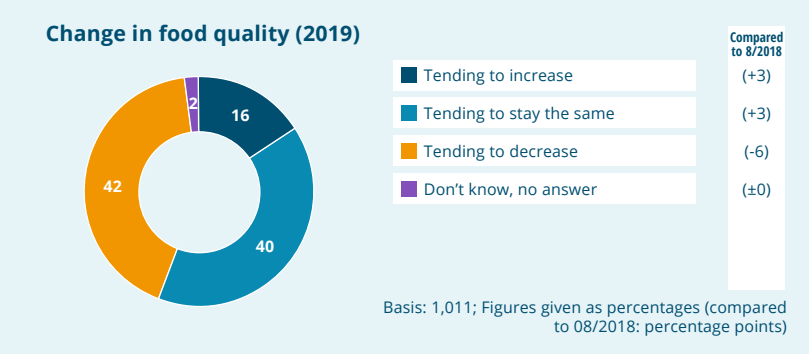
We completed a representative population survey on comparative risk estimation. Maybe you remember the EHEC outbreak here in Germany in 2011, a crisis that lead to 53 deaths and left nearly 4,000 people extremely ill. Yet within the same year, dioxin gained major media attention despite there being no health-related issue. The question is, how would you estimate your own personal risk of damage to your health when you compare these two incidents? Out of all of the people asked, 40 % told us that both risks are equally as high, and the rest told us that there is slightly or much more risk with dioxin. To clarify, dioxin is a chemical substance, and EHEC is a bacterium. Therefore, it may well be a consequence of intuitive toxicology, because if you have bacteria in your body, you do not necessarily feel unwell.

Regarding underestimation, lifestyle risks in particular are underestimated. There is, for example, freedom of choice. You can eat whatever you want to, therefore the risks are not so daunting. Maybe you are gaining weight, but there does not appear to be an imminent risk. Maybe there even seems to be more benefits than risks. Maybe you are passionate about food, or you enjoy smoking. You think you have the risks under control. Similarly, the risk of driving a car seems to be a higher risk when thinking about others, but not for yourself. In the cases of UV light and obesity, possible consequences on your health seem to be in the distance. As you grow older, you will encounter these problems, but not in the present.

Based on the 2010 Eurobarometer report, the majority of people in Europe associate food and eating with pleasure.[38] Yet when you are talking to a natural scientist, they will tell you about mercury, sulphate, and acrylamide among other things. Therefore, people are sometimes afraid of what is really in their food. In a representative survey from February this year, we asked people 'Do you believe that the quality and safety of our food tends to increase, decrease, or stay the same?' Figure 11 shows that 42 % of the participants believed that the safety as well as the quality of food tends to decrease. 40 % believed that it stays the same and only 16 % believed that it tends to increase.

38 Special Eurobarometer Report (EFSA). (2010). Food-related risks. Retrieved 20 November, 2020 from https://www.efsa.europa.eu/sites/default/files/corporate_publications/files/reporten.pdf

FIGURE 11



Representative consumer survey (n = 1.011) on the quality and safety of food asking, 'Do you believe that the quality of food tends to increase, decrease or stay the same?' Please note that 42 % of the respondents believe that the quality and safety of foods tend to decrease.[39]

To what extent are you personally concerned or not concerned about the following food safety topics? If we ask these questions, especially from the angle of a natural scientist, the things that you have to be afraid of include food hygiene at home or Campylobacter and Listeria. Surprisingly, people are not too concerned about this. But again, from the angle of a natural scientist, residues from plant protection products such as glyphosate and also genetically modified foods, are not very dangerous, yet people are afraid of them. People are afraid of chemical substances but not of other things. So, is analytical sensitivity boon or bane?

It is very difficult to tell people, especially journalists, that just because you can measure things, that does not necessarily mean that it is dangerous for you, as exposure and concentration must be taken into account. If you ask people, 'To your knowledge, are pesticide residues generally allowed in food in Germany?', 66 % think that these pesticide residues are generally

39 *Figure 11*. Consumer survey on change in food quality. Adapted from Consumer Monitoring 02/2019, by The German Federal Institute for Risk Assessment (BfR), 2019, Retrieved 20 November, 2020 from https://www.bfr.bund.de/cm/364/bfr-consumer-monitor-02-2019.pdf. Copyright 2019 by the German Federal Institute for Risk Assessment (BfR).

not allowed in food.[40] Yet in reality, very small amounts are allowed, but people are afraid of the topic.

2. Uncertainty or Certainty Level in Health Risks

How can risk to human health be measured in principle? This is actually easier than you may think. Risk is the product of hazard and exposure, yet most people think that risk is the same as hazard. This means that if you detect any substance which could be dangerous, people do not think about it in terms of how much of it is safe to eat, or how much contact they have with it.

It is interesting to talk about exposure and concentration of a possible hazard in terms of contact and ingestion. The typical way to calculate these risks is from animal experiments to so-called limit values. This means that you have a certainty or uncertainty level of around 10 for the interspecies difference, as it measures the hazard on animals, then calculations will determine if it is also dangerous for people. There is another factor of 10 in intraspecies difference, and that is the fact that we are all different. Therefore, you also have to divide the result, which is of no effect in the animal, finally by 100. Then you end up with the acceptable daily intake (ADI). That means – and this is critical – that limit values do not characterise a boundary between toxic and nontoxic, nor the difference between dead or alive. Limit values only dictate whether a food product can be traded freely, and nothing more. This is not widely known to the public, nor by journalists. Consequently, when assessing health risks, there are several sources of uncertainty.

To summarise, when we have a hazard identification, we then complete the dose-effect relationship. Next, we assess the degree of exposure. Finally, we have a risk characterisation. But at the same time, we have to think about the uncertainties of each measurement. So, what about different results? What about the extrapolation of the human population? What about the relevant doses for humans in comparison to the dose used in the original experiment? And what about the model selection? Is the model selection correct, or could there be a better model? We have to discuss and think about different contamination scenarios and identify the target group, as it makes a great difference if you end up with one result for older and younger

40 The German Federal Institute for Risk Assessment (BfR). (2016). *Consumer Monitoring 2/2016: Special Plant Protection Products* (n = 1.004). Retrieved 20 November, 2020 from https://www.bfr.bund.de/cm/364/bfr-consumer-monitor-2016-special-plant-protection-products.pdf

people, one for people with allergies, and another for pregnant women. Therefore, there are a lot of uncertainties during a risk calculation. Ultimately, it is rare to have an objective risk. In my opinion, it does not even exist. Uncertainty is an uncomfortable position, as Voltaire once stated, but certainty is an absurd one.[41] Karl Popper states that we owe our best knowledge to science.[42] It is important to put emphasis on this in a time where science is attacked from every angle. But even scientific knowledge is only hypothetical, as it is based on assumptions and nothing more. Thus, scientific knowledge produces no absolute truth, and is not static. There are many sources of uncertainty, meaning that dealing with it is of the utmost importance in the communication of scientific knowledge. If you miss this, telling journalists and also the public that there are uncertainties, no matter how difficult it is to admit, means that it is really no surprise that people over- or underestimate risks.

3. Strategies for Communicating Uncertainty and the Choice of Words

To communicate uncertainty is an extremely difficult thing. There are some recommendations from Peter Sandman, suggesting that we should not wait to be confronted and should acknowledge uncertainty upfront.[43] We should acknowledge in which areas there is uncertainty and make it clear that you are more certain about some things than others. We should explain exactly what has been done so far and what will be done in order to reduce uncertainty. We should also communicate the implication of remaining uncertainties, as there will still be some at the very end of the process. We should provide advice on what people can do, give them some hints on controllability so that people can protect themselves. We should acknowledge that information may change as we gain new knowledge. For example, in the first few days of the EHEC crisis, it was thought that the cause was salad, cucumbers and tomatoes. After several days, together with other institutions including the Robert Koch Institute, we found out that it was due to a specific form of sprouts.

41 Letter to Frederick William, Prince of Prussia, 1770 Nov 28. In S.G. Tallentyre (Ed.) (1919). *Voltaire in His Letters*. (p. 232). New York: G.P. Putnam's Sons.

42 Popper, K.R. (1982). Interview 1982, published in *Aufklärung und Kritik 2*/1994 (p. 38 ff.).

43 Sandman, P. M. (1993). *Dealing with Uncertainty*. Retrieved 20 November, 2020 from http://psandman.com/handouts/sand13.pdf

In addition, rhetorical aspects are of great importance. For example, how word choices can influence perception and also interpretation. If we are talking about plant protection, the word 'protection' has positive connotations. Yet if we are talking about a weed killer, that carries more negative connotations. It is very similar with climate change as the phrasing is fairly neutral. But, if you are talking about climate crisis, that of course has different, more troubling connotations. It is similar with the 'refugee problem'. Is it a problem? Or would it be better to refer to the 'refugee situation' or the 'topic of refugees'? Again, it is the same if you talk about a 90 % survival rate opposed to a 10 % mortality rate; people react to phrases very differently.

There is an interesting study by Song and Schwarz called, 'If It's Difficult to Pronounce, It Must Be Risky'.[44] It explores how things that are complicated to explain usually lead to people being afraid of them. One clear example of this was in 1998, when the following question was posed: 'Should dihydrogen monoxide be banned or regulated in the European Union?' By comparison, it seems extremely serious when you add that dihydrogen monoxide is routinely used by the industry, that it is found in rivers and food, that it is a major component of acid rain, that it can potentially kill you and it has been found in tumours of terminal cancer patients. However, dihydrogen monoxide is water. 76 % of the Europeans answered, 'Yes, it should be banned or regulated,' because it sounds so harmful. This leads us to believe that if you ask people a question in a complicated or complex way, the result will be fear. Yet if you try to explain that to them, they will have a different risk perception.

4. Risk Perception and Social Conformity

To conclude, I would like to add how social factors can influence risk perception as the risk perception of social conformity. The social influence effect can be seen in all age groups, but it tends to decrease with age, meaning that when you are younger, social influence in peer groups is particularly strong. Especially when we are talking about social media, which is used by institutions like ours, but especially by younger people, there are lots of opportunities to influence and to be influenced. Dissemination of information happens in seconds and it can result in a kind of correction to public communication.

44 Song, H., & Schwarz, N. (2009). If it's difficult to pronounce, it must be risky: Fluency, familiarity, and risk perception. *Psychological Science, 20*(2), 135–138.

You can directly address specific target groups, although this entails many challenges as it is nearly impossible to correct messages that have been communicated incorrectly. Group actions can be initiated spontaneously, making everybody a self-made expert. Therefore, social media is an interesting topic in regard to risk perception.

Our daily bias is that most risk assessments in daily life happen intuitively and without conscious effort. Therefore, when you meet a person for the first time, you already have a list in the back of your mind. The list may include ideas on their neighbourhood or their baseball cap, if they are black, male or female, or aggressive. Hence, at the end of the encounter, you will decide whether or not to shake their hand.

How to Advocate for Vaccination in a Climate of Science Denial

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Abstract: *In many countries, the success of misinformation, alternative facts or fake news is promoting a climate of science denial, where false claims such as 'vaccination causes autism' can spread. Learning lessons from behavioural studies can help advocate for vaccination in light of vaccine refusers and deniers. In this talk I will show where fake news come from, why they stick in our heads, and what we can do to get rid of them.*

Vaccinations protect those who are vaccinated – and have a social benefit – which makes vaccination a social decision. Here in Germany, it is claimed that those who do not want to vaccinate against measles are antisocial, and will now be forced to do so by law. Other countries in Europe have decided to do this already, and mandates are being implemented. If we look at this kind of decision, it is really important to focus not only on medical and epidemiological research, but also on behavioural research. Because there is some research showing that, if you make only specific vaccines mandatory, this could actually threaten or damage a well-functioning vaccination programme. This should not be a big surprise: If just some vaccines are mandatory, those that are still voluntary might not be taken up anymore because people get reactant. People get angry and claim back their freedom of choice. Thus, it is important to take a close look at the science to understand the reasons why people do not vaccinate and to implement policies that match these reasons.

The main idea behind the new measles law in Germany was that people just do not want to vaccinate and that, in this context, fake news and misinformation are the major reasons. For the vaccination debate, this is not the whole story, but still, a very important one. Knowing about misinformation and what we can do about it will help us in other areas too because it seems that this misinformation pollutes our information environment. Hence, I would like to think about it as the 'cockroach' in it. As with cockroaches, we wonder: where do they come from? Why do they stay forever? How can I get rid of them?

1. Science Denial and Misinformation

Learning about misinformation can help us to deal with and get rid of it and maybe save lives because it matters not only in the area of vaccination but also when it comes to the climate crisis, tobacco, HIV and many other scientific areas.

In 1998 there was an MMR vaccine scare which originated in the UK when a doctor with vested interests put forward the idea that vaccination against measles could lead to autism. So the uptake of measles vaccine went down and, consequently, measles cases went up and death due to measles increased.[45] Vested interests is one of the aspects where fake news can come from.

The other one is the motivated rejection of science, which has often been connected to world views. Free market endorsers will say that an economic system based on free markets automatically works best to meet human needs, so they will want to reject the science that might lead to regulation. The same is true for people who think that we have gone too far in pushing equal rights in this country; they think that having hierarchies in society is a legitimate thing. Likewise, these people would rather reject science because they do not want to be regulated.

2. Fake News as Pollutants of our Information Environment

Why does fake news stick? It seems easy to provide facts, to tell the truth, to talk about risks, for example, with a pictograph. This is an easy-to-understand way of putting risk information forward which should help you understand that just a very small number of vaccine side effects occur so you might decide to do it. However, then you hear from your neighbour that, after her vaccination, she suffered from insomnia – this makes you question your decision. Such information is very powerful: We ran lots of studies where we varied the statistical risks and gave people narrative information, stories, about what could happen after vaccination. We found that stories have a much stronger

45 For more detailed information see: Ruling on doctor in MMR scare (2010, 29 January). National Health Service. Retrieved 20 November, 2020 from https://www.nhs.uk/news/medical-practice/ruling-on-doctor-in-mmr-scare/

effect than the statistical information because we see stories as relevant.[46] They are very strong in changing risk perceptions and intentions. We also tend to bias our perceptions more into the direction of increasing risk: when the narratives tell us it might be risky, we tend to believe them more.

Why should we listen to others? We rely on social learning and social information when the costs of acquiring or implementing personal knowledge are high and when we are uncertain about the optimal behaviour.[47] Therefore, we wonder if we should vaccinate our kids and we think it might be a bit costly to just give it a try, meaning: if you think your child could die from vaccination, you do not give it a try.[48] You just look at what your neighbour's experience might be. This is a very basic principle which – in the verbatim way it is described here – actually pertains to fish. Fish and humans do the very same thing when there is some risk in acquiring the information themselves.

As we have also heard before, people are not very good at estimating risks. We are not interested in asking how *likely* something is, we want to know *how* something actually feels. Thus, this mixture leads to the very good effect of stories.

Moreover, when parents wonder if vaccination is dangerous, they probably type exactly that in their Google search. If you count the numbers of pro- or anti-vaccination results, you might end up with more anti-vaccination than pro-vaccination websites. And while the pro-vaccination websites mostly talk about safety, parents want to know if it is dangerous. It might seem the same, just a matter of framing, but for somebody who is looking up information, it makes a difference. Thus, there is a problem in the question of what people find and how the search results are presented. We call this the *confirmation bias*: I want to look up stuff that I already know and I want to be confirmed in my preconceptions. That is guiding our search.

This is even more obvious in social media, where we are much more connected to people who are like us, who think the same things, who are posting similar things. This drives this process even more. On social media,

46 Betsch, C., Haase, N., Renkewitz, F., & Schmid, P. (2015). The narrative bias revisited: What drives the biasing influence of narrative information on risk perceptions? *Judgment and Decision Making, 10*, 241–264; Betsch, C., Renkewitz, F. & Haase, N. (2013). Effect of narrative reports about vaccine adverse events and bias-awareness disclaimers on vaccine decisions: A simulation of an online patient social network. *Medical Decision Making, 33(1), 14-25*.

47 Kendal, R. L., Coolen, I., van Bergen, Y. & Laland, K. (2005). Trade-offs in the adaptive use of social and asocial learning. *Advances in the Study of Behavior, 35*, 333–379.

48 Webster, M. M., & Laland, K. N. (2010). Reproductive state affects reliance on public information in sticklebacks. *Proceedings of the Royal Society B: Biological Sciences, 278*(1705), 619–627.

we can share information. This is another problem in the fake news universe because the way we are sharing is also very critical. There has been an analysis of a large number of tweets. What the researchers found was that tweets with false information were more likely to be retweeted than tweets that contained correct information.[49] These tweets were analysed, and they were more emotional in terms of disgust, surprise, and fear. We want the tweets that we retweet to do something in the reader.

The bad news here is: fake news are not cockroaches. It's us. It is not ignorance; it concerns features that are inherent in our minds. Usually, they help us through this busy world. They allow us to make good decisions in a short amount of time, but still, we created this mess, and now we have to get out of it. So the way we digest the information, the way we select information, process it, or share it, pollutes our information environment and makes it really hard to separate facts from fakes.

3. Approaches to Conquer Science Denial

There are several ways of fighting misinformation. The regular approach is the debunking approach. The first idea is to remove what is wrong. It is like trying to get the false piece out of the puzzle and removing the information from people's mental models. But as you will remember from your childhood, it feels really bad having a full puzzle with just one piece missing. That is exactly how it is in our minds. We do not like incomplete puzzles. Therefore, it is important to put something back into the gap, and at the same time it is difficult to do so.

The second possibility is just to add what is right by giving people the correct information. We tend to say that there is this myth, this misinformation, and then we provide the science. For example, vaccination leads to autism is the myth. Then we have thousands of studies which are saying the opposite and using them, we write a very complicated text to make sure the person understands that this is false. However, this is too complicated because the myth is very simple and easy to remember. Therefore, this is also not the best way to do it.

49 Vosoughi, S., Roy, D., & Aral, S. (2018). The spread of true and false news online. *Science, 359*(6380), 1146–1151.

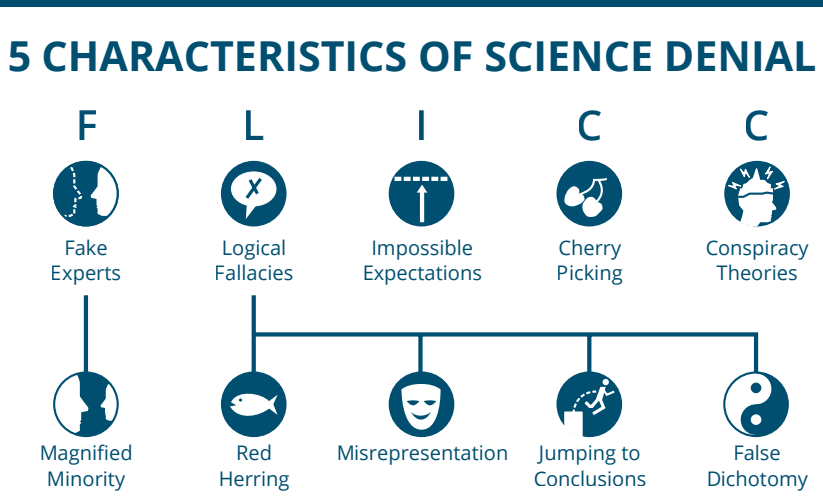
There are two other possibilities. Instead of correcting the myth afterwards, you could also provide a rebuttal during the process, when the person actually receives the misinformation, for example, in public debates. Imagine a typical debate, where there is a pro and a con person, and in this rebuttal it is possible to correct the facts. The third possibility, and that is a very new and fancy way of doing it, is to do an inoculation, to vaccinate people against misinformation before the actual misinformation occurs. As in a vaccination, you just give them pieces of misinformation so their informational immune system learns what misinformation looks like and can then react when it encounters it.

4. Training to Recognise Science Denial Techniques

Science denial is something that occurs in various areas; vaccination, climate change, and others. Interestingly, the techniques used to put forward the misinformation are usually very similar across domains (Figure 12).

Technique 1) is logical fallacies, e.g. natural things are positive, vaccination is not natural; so vaccination is not positive. 2) Conspiracy theories, which are always an easy win because every attempt to debunk them can be interpreted as evidence for it. 3) Cherry picking is also a very common technique. From the plethora of scientific papers you just pull out one single paper, the one paper that shows a slight association between vaccination and autism, for example. Then you just do not talk about the iceberg of papers that show the opposite. 4) You raise impossible expectations. Regarding climate change, for example, you could say, 'Oh, it is just models, and models are not 100 % correct,' or for vaccination, you say, 'Oh, I am not against vaccination. It just has to be 100 % safe.' 5) The last one is fake experts. Here you use people who are not actually experts in the field but still argue publicly, e.g. against vaccination.

FIGURE 12



FLICC: An easy to remember acronym of five commonly used techniques of science denial. Being familiar with those techniques helps to conquer science deniers in debates and therefore reduce the negative impact they have on the audience.[50]

There is a guideline from the World Health Organization (WHO) that my PhD student Philipp Schmid developed.[51] It suggests training spokespeople (e.g. of governments) to recognise these techniques and gives support in how to respond to vocal vaccine deniers in a public debate, e.g., a one-on-one debate. I think what gives people the greatest relief with this training is that they learn that it is not about convincing the denier, it is about protecting the audience from the denier's impact. You cannot change the denier's mind, but you can try to mitigate the denier's effect on the audience by pointing to the techniques: One possibility is to de-mask the techniques while they are being used.

When looking at the universe of misinformation, e.g. in the area of vaccination, there is a typical range of topics from addressing questions of safety, denying the threat due to the disease, suggesting alternatives to

50 *Figure 12*. FLICC: Acronym of five commonly used techniques of science denial. Adapted from *SkepticalScience*, by J. Cook, 2015, Retrieved 20 November, 2020 from https://skepticalscience.com/inoculating-against-science-denial.html. Copyright 2015 by John Cook.

51 World Health Organization. (2016). Best practice guidance: How to respond to vocal vaccine deniers in public. Retrieved 20 November, 2020 from https://www.who.int/immunization/sage/meetings/2016/october/8_Best-practice-guidance-respond-vocal-vaccine-deniers-public.pdf

vaccination, putting forward distrust in the regulators or the governments, and questioning vaccine effectiveness. Then there are the said typical techniques (Figure 12). In the WHO/Euro training and in our experiments, we decomposed each argument according to these 5x5 categories.[52] The basic idea is: when the spokesperson knows which techniques are used (i.e. usually the same five) they can prepare counter arguments. For example, if a denier stresses the lack of safety, stating that 'I would vaccinate if it is 100 % safe,' a spokesperson can say that the science denier requests 100 % safety and this argument is called impossible expectations, as you can never guarantee 100 % safety. This is an example of technique rebuttal.

Our work has shown that both after technique rebuttal (pointing to the technique of science denial) or topic rebuttal (correcting the content), the audience's attitudes are more stable, i.e. the science denier has less damaging influence. In control groups where none of these rebuttals were applied, the science denier had a negative effect on attitudes. For this reason, we suggest studying the five techniques in particular because you can use them independent of the topic area. The topics might be very specific, but it seems to be a very economical way of learning to recognise these five techniques if you are in a debate with a denier. Yet again, it is important to know that this is not meant to change the denier's mind but to address the audience that is watching.

The second study was conducted by Sander van der Linden and puts forward the idea of inoculating people against fake news.[53] It is based on an online game called 'Bad News' (Figure 13). Your task is to be a fake news producer earning more followers. You have several options; what kind of fake news you want to create and your task is to earn several badges. You can earn a badge by using a certain technique. For example, you could polarise groups, take somebody's personality and target their position. You can raise emotions, control people, put forward conspiracies, or discredit people. Whenever you apply something successfully, your number of followers rises, and you earn one of these badges.

52 Schmid, P., & Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. *Nature Human Behaviour*, 3(9), 931-939.

53 Roozenbeek, J., & van der Linden, S. (2019). The fake news game: actively inoculating against the risk of misinformation. *Journal of Risk Research, 22*(5), 570–580.

FIGURE 13

The online game 'Bad News' (www.getbadnews.com) designed to make people more aware of fake news techniques by taking on the role of a fake news producer. The task is to use those techniques in order to receive more followers and win badges for conspiracy, trolling and other similar actions.

The research team had tweets rated for their reliability before and after the game and found that the fake tweets where one of these techniques was used were rated as less reliable after playing the game. So again: knowing the techniques seems to be a very economical way of fighting misinformation.

It might be possible to draw an analogy here between cockroaches and science deniers. They are growing stronger. They are becoming immune or resistant against all sort of insecticides. So, once you think you have a solution, the enemy adapts. On an anti-vaccination website, I found a very long list of what you could do if mandates really are introduced here in Germany. One of the suggestions was to find people whose children are damaged from vaccination and to tell their stories very vividly. That is basically what we did in our experiments and it showed how 'effectively it enhances fear of vaccination'. They read our papers and said, they say this works, so let's do it.

Darwin said, 'It is not the strongest nor the most intelligent that survive. It is the one that most adapts to change.' We have changed our information environment and now we need to adapt to it. So it seems that we need some kind of further metacognitive strategies to be developed that help us in our automatic information processing, but we all know that this is a very long process.

Meanwhile, we could try these five simple questions. So, whenever we find some information, we should ask

- Who holds interest in this?
- Who is behind it?
- Who else said so? Could it be an effect of our echo chamber?
- What do the experts say?
- Is there a consensus?

Consensus is a very important variable. We could try to do the anti-confirmation bias, just look for the opposite. If we use social media, we could fact check before sharing. We should make ourselves aware of typical techniques that are used by science deniers.

Can China Trigger a Crisis of Globalisation?

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Abstract: *The trade conflict between China and the USA may well lead to a deep crisis of globalisation. China's economic policies, in particular the opaque financing structures for state-owned companies, appear to be incompatible with an open trading system. If that pillar of globalisation is damaged, the concept of globalisation might be replaced with a more inward-looking, less open version of international economic relations. Is that going to happen? China is currently confronted with a coalition that has never existed before. The US, Japan and the EU are exerting joint pressure on Beijing to achieve changes in China's economic system. The European Union may not share Donald Trump's rhetoric, but it agrees with some key elements of his economic policy goals. The crucial requests of this unprecedented alliance are the abolishment of hidden subsidies and of forced technology transfer. Will that be possible? Can China accept the conditions imposed by the US and its allies while maintaining its current economic system?*

My topic does not exactly fit in with the previous discussions because it is on a completely different range of subjects. I will be talking about political risk and I will be trying to examine the future of globalisation and the risks that are associated with that. Of course, this is quite different from health risks and other risks we have previously discussed. Nevertheless, I do think it affects quite a few of us.

The first question is: Why do we discuss globalisation in 2019? What has happened to put it back on the agenda? I think it is important to recognise that globalisation, which was very popular in OECD countries in previous phases of economic development, has lost broad support not in the Global South, but in OECD countries. Many people in OECD countries are asking if globalisation is providing the benefits we were told it would provide. When we then talk about political responses to this change, people ask themselves if

today's beneficiaries of globalisation are living in Shanghai or in Ho Chi Minh City rather than in Birmingham or Detroit. These are questions that are shaping the debate on globalisation. China is in the title of my presentation. The question is, can China trigger – trigger, not cause – a crisis of globalisation? My argument is no, it cannot, but the current clash between China and the United States of America and, to a degree, with the European Union is not only a clash between a rising and an established power. It is a conflict within OECD societies. China exposes the weaknesses of the current form of globalisation. Therefore, the integration of China into the global economy has sped up the process of debate on globalisation, but it has not caused it.

I have three questions to answer and the first question is, what are the reasons for this increasing unpopularity of globalisation? Are there Chinese economic policies that fuel existing resentment against globalisation? Finally, I will look at the future of the conflict between Mr Trump and Mr Xi and at how the conflict between the West and China will develop.

1. Globalisation and its Division of Popularity Among the World

The headline of our session here is, what are potentially underestimated risks? There might be the risk that we underestimate the risk that globalisation may end. For a long period of time, this was considered to be rather silly talk, but if you look back at the history of international economic relations, we of course had a collapse of globalisation. Harold James, the economic historian, wrote about it.[54] In the 1930s, it collapsed. This is a serious and potentially underestimated risk and it may lead to unintended consequences for security.

Before that global financial crisis in 2007 and 2008, there was broad support for globalisation in the Global North and South, if I may use those two terms. People assumed that globalisation was inevitable. Bill Clinton said, and I quote, 'Globalisation is the economic equivalent of a force of nature, like wind or water.' This was a very common perspective. It was seen as a higher force that could not be influenced by policymakers and moreover they were unwilling to do anything about it.

Of course, even then, there were some sceptics and Dani Rodrik from Harvard is one of them. A few years ago, he asked, 'Has globalisation gone

54 James, H. (2009). *The End of Globalization: Lessons from the Great Depression*. Harvard University Press.

too far?' A very well-known American economist, Paul Samuelson had already published in 2004 a piece on the fundamental question of whether the trade economist David Ricardo might be wrong.[55] This was, of course, no less than a shock. Paul Samuelson, who was the first American to receive the Nobel Prize for economics in 1970, questioned the very pillar of modern trade theory. He suggested that the theory of comparative advantage is perhaps no longer valid, and he suggested that the productivity gains – and this is, of course, China – in other countries have resulted in a change of the terms of trade. Hence the consequence is, that the entire economies, and not just parts of them, might be negatively affected by the deepening of the international division of labour. Back in 2004, Samuelson looked at those negatively affected by globalisation. This very group was labelled subsequently in 2016 by Hilary Clinton as 'deplorables'. Samuelson's point was that unrestricted trade has the same effect as the mass immigration of unskilled workers to the United States of America. When we look back at this 15-year-old text of Paul Samuelson, it helps us to understand the declining popularity of globalisation in the old industrialised countries. Today, we find a North-South divide regarding the perception of globalisation. Globalisation is unpopular in the Global North and is popular in the Global South, and this is quite surprising.

The least support for the concept of globalisation we find in France with 37 %, followed by the US with 40 % and Britain with 46 %, Germany 60 %, India 83 %, Philippines 85 %, and in Vietnam a full 91 % of the population supports the idea that globalisation is a good concept. In our part of the world, it is very difficult to find support for anything at that level, 91 %.[56] Where do you get that level of support?

My assessment is globalisation's perception has changed. In the North, it is less popular and in the South it is more popular than it has been in the past. So, what characterises this form of globalisation that might be in danger? Of course, the main characteristics for an economist are the barriers for the exchange of goods, services, and capital are lowered or dismantled. Everybody knows about the dismantling of barriers for trade. Today's applied tariffs in the United States are 2.5 %, in the European Union 3.5 %.

55 Samuelson, P. A. (2004). Where Ricardo and Mill rebut and confirm arguments of mainstream economists supporting globalization. *Journal of Economic perspectives, 18*(3), 135-146.

56 *International survey: globalisation is still seen as a force for good in the world.* (2016, 17. November). YouGov. Retrieved 20 November, 2020 from https://yougov.co.uk/topics/politics/articles-reports/2016/11/17/international-survey

Thus tariffs are low and consequently we have relatively unrestricted trade. Less frequently discussed, and I am mentioning it because this might be a reason for the unpopularity of today's form of globalisation, are the effects of unrestricted capital flows.

2. Untaxed Profits Cannot Contribute to Countering the Negative Effects of Globalisation

Economists have told us time and again that unrestricted capital flows result in a more efficient allocation of capital. Therefore, capital goes where returns are highest and that is considered to be a good thing. However what economists often fail to mention is that the dismantling of barriers for capital flows also results in a disability of states when it comes to taxing corporate profits. They are much more difficult to tax if you have unrestricted capital flows. Before the tax reform in the United States of late 2017, there is one figure which I would like to mention. Apple parked 250 billion dollars of untaxed profits in offshore financial centres. That is, of course, something that is very problematic because it deprives governments of being able to counter the negative effects of globalisation.

Just as a footnote, you would, of course, think that Germany is in a better position because we tax corporate profits. When I look around, many people assume that taxation rates on corporate profits are higher in Germany than in the United States. Correct me if I am wrong, but I give you the data. Germany is characterised by a falling share of taxes on corporate profits. They fell from 6.1 % of total taxation in 2006 to 4.7 % in 2015. The figure for the United States was 8.1 % in the same year. Thus, these liberal Americans have been taxing corporate profits much more intensely than us Germans. However, Donald Trump's tax reforms have resulted in lower taxes in the USA. Nevertheless, the OECD average in 2018 is 8.8 %. In the OECD, the share of taxes on corporate profits is only lower in three countries. That is France, Hungary, and Slovenia.[57]

To me, it is a bit of a puzzle that Germans accept that corporate profits are not very intensely taxed while individuals are taxed quite highly. What I would like to suggest is that this declining ability of governments to tax corporate profits together with the harsh effects of the 2007–2008 financial

57 Organisation for Economic Co-operation and Development (OECD). (2020). *Tax on corporate profits (indicator)*. Retrieved 20 Nov, 2020 from https://data.oecd.org/tax/tax-on-corporate-profits.htm

crisis has led to widespread criticism of globalisation in OECD countries. In plain English, banks are bailed out, but big business pays little taxes.

Even the godfather of globalisation, if you want to call him that, Klaus Schwab, the Founder of the World Economic Forum in Davos, today calls for a new form of globalisation. Smart globalisation he calls it. Schwab suggests that globalisation should be altered in a way that the preferences of societies are considered.

3. Chinese State Capitalism and the Global Market Economy

I come to my second point, to China. The question here is whether Chinese economic policies fuel existing resentment against globalisation. My argument is that this conflict had to happen and this conflict will not be a short economic war, instead it will be a lasting conflict for years. Of course, this is a surprising statement. First of all, one should consider that China's integration into the global economy went smoothly for something like four decades. For four decades, nobody was afraid of China. Today, this mood has changed, and there is increasing concern that China does not accept the rules of the liberal economic order. My witness here is Pascal Lamy, the French socialist, former European Commissioner for Trade, and subsequently for many years Director of the World Trade Organization. Lamy says that the biggest problem here is that Chinese state capitalism is threatening the existence of a global market economy. Now the simple question here is, will the Chinese Communist Party be willing to change the existing system? Is it possible to have the Communist Party in China in power of the country and, at the same time, alter the influence of the state on economic development? I do not think it will be possible to maintain the current influence of the Communist Party on the economy on state-owned enterprises, and it will be difficult to alter that without reducing the influence of the Communist Party. Now this is, of course, the threat. When we look at that conflict, one of the points to consider is, how strong is the Chinese economy? Is the Chinese government in a position to have a decade-long economic conflict, or is the Chinese economy weaker than most observers assume? I am sceptical when it comes to the sustainability of the Chinese economic model. The situation in China reminds me of the situation in Japan 30 years ago. China may be struggling with a combination of debt and hostility towards its economic model.

In the 1980s, many people were afraid of the Japanese influence on the global economy. Japan was considered to be a rising economy that would

dominate the 21st century. Today, there are similarities between Japan and China. What we can observe is that debt in China is rising as fast as debt was rising in Japan in the 1980s. Since 2008, debt to GDP has risen in China from 160 % of GDP to almost 300 % of GDP within a decade. No matter what you think of debt, the speed of the rise of debt in China is simply too fast. The International Monetary Fund (IMF) examined this rising debt of China in a 2018 working paper, and they asked whether it is a dangerous development in China and if they should consider factors that would result in a more benign evaluation of the situation there. The IMF gave an unambiguous answer. They said that there is no case in history in which such a rapid increase of credit has not resulted in a financial crisis, which is a worrying sign. The IMF says that the only solution is a reduction of growth and/or a stabilisation of debt. Any postponement will make the eventual crisis even worse.

What we can also observe today is that Chinese citizens are starting to lose faith in their own economy. They want to get rid of their Chinese currency. They want to export their capital. This is, of course, something we know from financial history. The countries to mention here are Argentina and Greece. As we know, these have not been very stable economies. The trade conflict between the United States and China comes at a very inconvenient time for President Xi. It may further erode confidence in Chinese economic development.

I come to the last point, the conflict between China and the West. I dare to suggest that the conflict between China and OECD countries will shape international economic relations for at least the medium term. This conflict will affect the entire world. Of course, we should not ignore that conflict between the United States and other countries in the economic domain are nothing new.

4. US Trade Policies as Accelerating Power for the Great Depression

In the 1930s, US policies contributed to the deepening of the Great Depression. The Hawley-Smoot Tariff in 1930 added fuel to the fire. In this context here, it is important to recall that it was visible. People realised that this was an ill-conceived piece of legislation. There was a resolution of 1,000 economists in the United States of America that warned the US government not to implement this higher tariff on the importation of goods to the United States of America. That Hawley-Smoot Tariff contributed – and here, we do have a collapse of

globalisation – to a decline of world trade by two-thirds in four years, from 1929 to 1933. It was rather short-sighted to implement that tariff because the rest of the world, including Germany, owed money to the United States. If those countries are not able to export to the United States and earn dollars, they cannot pay back their debt. It is as simple as that. Therefore, a certain rashness in US trade policy is nothing new. That is what I want to say, but we have more examples in the late 1960s and 1970s. The United States had problems with Japan and Germany at the time. Nixon implemented a 10 % tariff in 1971. In the 1980s, Ronald Reagan heavily criticised the Japanese. In July 1987, nine congressmen used a sledgehammer to crush a Toshiba radio on Capitol Hill, demonstrating their anger towards the Japanese. Today, China dominates that discourse. President Trump irritates us all but at the same time, not all of his tweets are wrong. China is increasingly perceived as an aggressive player. Nevertheless, it is very easy to criticise Mr Trump. He is very unpopular in this part of the world, in Germany in particular. At the same time, people ignore that Mr Obama's policies towards China were characterised by rather harsh policies. Obama tried to create the Trans-Pacific Partnership, which was an anti-Chinese project in the Pacific. It was a project that aimed to exclude China from trade in the Asia-Pacific. Therefore, Trump is continuing a policy that Obama had initiated. What has changed is that the US economy is in much better shape today than it was under Obama, not that Obama has anything to do with the initial weakness of the US economy. Today, the US economy is characterised by the lowest level of unemployment since 1969. For women, unemployment in the United States today is the lowest since 1953. This is why Mr Trump is able to engage in a conflict with China because the US economy is doing extremely well, and he does not need allies to confront China. Of course, in Europe, we ask ourselves if he is right in confronting China. Does he have allies? Are the Europeans united or divided on China?

Last year a very surprising new situation emerged and China today is confronted with a constellation and with coalitions that never existed before. The US, Japan, and the European Union together put pressure on China to change the economic model, to change the influence of the government on state-owned enterprises with, in my regard, little hope for success.

Last summer, outgoing EU Commission President Juncker went to Beijing and told Chinese Premier Li Keqiang that while the European Union does not share the rhetoric of Mr Trump, the European Union does share some of his economic policy goals, namely the abolition of hidden subsidies and forced technology transfer.

Finally, on a German response to China for Germany, China played a very promising role in our economic relations for too long. Companies were happy to invest in China. Those that were not doing business in China were pitied and that has changed. The Confederation of German Industry (*short in German: BDI) published a paper early this year in which China is labelled a systemic competitor. The BDI says that a convergence of systems is now unrealistic. The BDI claims that Europe should counter China's economic policies. Minister Altmaier suggested that European industries should be strengthened against those competitors from China and the US. Hence why I think the conflict with China will continue. We may see a further deterioration in the support for globalisation. I do not think that we will see a collapse of world trade similar to the collapse in the 1930s, but I think there is an obvious risk that globalisation may go into reverse and that instead of seeing a further deepening of globalisation and international economic exchange, we will see less of it.

To conclude very briefly, I think it is appropriate to label the relationship of China with the West as being at a turning point. China, by the way, is actively seeking that challenge. The rhetoric of Chinese diplomats and policymakers has changed. President Xi has a much more robust rhetoric than all his predecessors. The West is responding with different voices, but, I think, increasingly united. Unless China changes its economic system, this conflict will persist. The clash can well result in less emphasis on deeper globalisation. China exposes the faults in today's form of globalisation, therefore fuelling this discontent with globalisation. Mr Trump put it on the agenda, but he did not create it.

Session 4
Assessing Existential Risks

Chair:
Julius Weitzdörfer
Cambridge Centre for the Study of Existential Risks

Student Rapporteurs

Rapporteurs on Session 1 'How Risks Are Socially Constructed'

Nils Haneklaus
RWTH Aachen University

Professor Schröder explained the paradox of the risk society. While we live in an increasingly safe society, we feel increasingly afraid. We are afraid of car accidents, which have declined since the invention of the car. We are afraid of wars, homicides, genetically modified plants, probably non-existing zombies, and definitely the spaghetti monster, but most importantly, of terrorists. The good news is we should not be afraid of all these things. As Professor Schröder rightfully pointed out, the masked murderer of the 21st century is not going to wear a beard. The masked murderer of the 21st century will come in the form of bathtubs, slippery kitchen floors, ladders, and chocolate bars.

Why do we perceive increasing risks while there is actually little risk that exists? Professor Schröder looks at four points here. He mentions a rosy view of the past, a negativity bias, an availability heuristic, and the problem of media-oriented attitude, and lastly, a prevalence of induced concept change. So what should we do about our irrational selves? Should I not wish you a safe drive home because I know it will be the safest drive home that ever existed in history? Probably not. Professor Schröder suggests that it is up to the media to induce changes. He appeals to the media, saying that they have a responsibility to put things into perspective. What does that mean? So while a headline might have read in the past, 'Aeroplane crashes,' a new headline should read, 'One aeroplane crashes today; 20,000 others did not, and flying is more safe and comfortable than it has ever been in history.' However, when you buy your holiday snacks for your next flight somewhere, watch out for cancer and diabetes because these are the ones that might get you. Nonetheless, according to Professor Schröder, it is unlikely that this way of communication is going to happen because media, politicians, and maybe even scientists themselves have an agenda that prevents it. Maybe it is in their interest to not communicate in this way and also too complicated to present facts this way. Maybe we as readers and listeners will not be interested in always going through the very difficult and complicated statistics, right?

Moritz Bielefeld
UMIT TYROL – The Tyrolean Private University

Ms Ellen Peters spoke about risk as matters of feeling and perception. She pointed out that feelings guide us and she presented the negative correlation between perceived risks and their perceived benefits, which also follows consistency. One focus was on the affect heuristic, meaning that emotions function as cues, actions, and a spotlight on important information, as illustrated by the studies on deterrent advertising on cigarette packs and the story of Barb Tarbox. Another case was the increase of CPM, a risk without objective health benefit. Ms Ellen Peters showed that negative emotions lead to greater perception of future risks and more CPM choice, but also to more thought and gain of knowledge. Furthermore, the limited effect of emotional cues was discussed, which highlights the importance of variation and involvement. In addition, the statement that risk communication should make consequences experienceable convinced us. To conclude, we were particularly fascinated by the contrast between the talks of Mr Schröder and Ms Peters. While he argued for more cognitive solutions, for example, by considering trends, Ms Peters illustrated the benefit of emotions when tackling complexity. Obviously, emotions or affect as well as information and objectivity are both powerful tools in dealing with risks, but it also shows the importance of risk context and that we really should be aware of addressed risk, its character, and our aim.

Rapporteurs on Session 2 'Limits of Assessing and Communicating Risks'

Zhongzheng Zhang
Ruhr-Universität Bochum

The Skype lectures topic from Professor Nassim Nicholas Taleb was 'Foundations of the Precautionary Principle and What is Wrong with Empirical Psychology'. First of all, he quoted from Warren Buffet that you have success after you are able to survive, which means that he wants to avoid obvious high risks. The second point he indicated was the fat tail and thin tail corresponding principle, which is the 'catastrophe principle'. It says, regarding the sequence of events, catastrophe is likely to happen in the single events rather than the normal other 90 % of events. There is also the example of

the one guy who has a daily in-take of fast food and alcohol and is afraid of contracting Ebola. That means that while a cost-benefit analysis of single events is not relevant, those daily events and therefore daily risks should be considered. Thus, we have to make the issue relevant and take into account the lifespan or the time as an important factor when thinking about how we perceive those risks and the small ones.

Janina Lüders
Universität Bielefeld

Big issues and the big risks are devastating, and that is what Didier Sornette talked to us about yesterday. He informed us about risk information transmission and critical infrastructure. We heard that there is a difference between learning from mistakes and learning from others' mistakes. Consequently, we should look back in history to see what went wrong to improve on that. We heard about many examples of catastrophes, including the Challenger explosion, Sayano-Shushenskaya 2009, and the financial crisis in 2008. What did they all have in common? The common thread was that there was an issue in risk information transmission. It did vary across the examples though. In the Challenger explosion, the information was given but not taken into account by the management. In the financial crisis, we saw warning signs in retrospect, but everybody thought they would get out before the crash. That was, of course, not possible.

There is a deficit in information channels and there is also a problem in the industry-government relationship that needs to be improved on. What can we do about that? We have to establish sustainable communication. That is one big issue because, if the crisis happens, it is on everybody's minds, and everybody is thinking about it and remembering it, but this effect wears off. What also has to be done is improving the management. There is a lack of imagination, a lack of initiative to reward success instead of luck. Finally, what we also got from this talk is that early warning systems seem to be very difficult. So, what we all can do is to be prepared for unexpected tipping points.

Julia Lemp
Heidelberg University (Mr Löfstedts contribution to the conference could not be published.)*

Mr Ragnar Löfstedt emphasised the importance of trust, transparency, and proactive communication for the relationship between the public and policymakers. He gave us illustrative examples from typical risk communication failures, especially from UK and Swedish agencies. Those examples hinted to quite some ignorance from the side of the regulatory agencies. It was especially astonishing that there was a lack of consideration of already existing evidence. It was not taken into account, and they all relied on their own judgment calls. As a way forward, Mr Löfstedt, apart from a more general focus on transparency, suggested strengthening social science expertise in regulatory agencies as well as establishing an academic risk communication advisory board. We wanted to stress that this also calls for action from academia's side. Maybe we should ask ourselves if we are already providing the tools which are necessary for a quick response to such events and if academia scientists in risk communication are ready to serve on those expert boards.

To wrap up, as a common theme, we identified that both Mr Löfstedt and Mr Sornette's talks raised the question of how many failures do we really need to finally get it right? We think it is a really brave endeavour to synthesise already existing evidence and what went wrong in the past to potentially guide future actions. Remember, learn to fail small, and always pre-test your risk communication message.

Rapporteurs on Session 3 'Commonly Over- and Underestimated Risks'

Lea Ballenberger
Heidelberg University

Session 3 was very rich in applicable examples and insights on how risk perception works and what risks are frequently over- and underestimated. We have learned, for example, that riding a motorbike is less dangerous than we might think. We found it particularly interesting that the topic of objectivity has been picked up again, and there is a gap between experts and laypeople and that pure objectivity is a very hard thing to find. The prominent example of

GMOs shows us that people tend to limit the focus to one aspect of risk, which is hazard, but they tend to forget the degree of exposure to the hazard that plays an important role as well. Media in general plays an important role in the way risks and scientific results are communicated since they impact perception and therefore also public opinion. We heard about the recommendation for an ever-closer dialogue between scientists and generalists to work on ways to leverage risk-communication approaches. That is also what we as future scientists have to keep in mind to work on as well. At the same time, it has to be clarified that there is no 100 % certainty in science, that new results do not mean that the scientists did wrong before. Loss of trust in science can lead to dangerous developments, like we see nowadays as people turn towards people and groups who promise a clear and easy-to-understand reality. This fact has been very well highlighted in the session, but more must be done to make transparent that science also deals with uncertainty. The groups that we address are not tied to trust or science. They have much more perfidious ways to make sure that their stories stick with the audience, and we have learned during the session how the five techniques of science denial can work. What we heard more than once in the conference is that the relevance of bias and risk management, decision making, our gut feeling and the laziness of our minds all play a role. The good news is that we have seen that scientists have a fairly good understanding of the mechanisms behind fake news and have identified ways to deal with these. The shocking news, on the other hand, is that the distributors of alternative facts do not even have to convince their audience entirely. It is obviously sufficient to seed a tiny little doubt about the expert's opinion.

Running up the portfolio of risks on the global radar, we have now been entering a tier in Session 3 where objectivity and truth are even less clearly identifiable, namely politics and economics. Here, the perception of risk and in particularly China's willingness to participate in the global arena have been long underestimated by the world. Acting very self-confidently, this self-confidence is already increasing the likelihood of unintended security risks. Also, looking at the dramatic increase in debt in China, we asked ourselves the question, and maybe someone from the audience has the answer, whether China and its economics policy is itself a systemic risk.

Opening of the Chair

Julius Weitzdörfer
Cambridge Centre for the Study of Existential Risks

This session entitled 'Assessing Existential Risks' matches this conference's theme of the mystery of risks, as it is likely a topic not yet familiar to most people. As an interdisciplinary, serious field of enquiry, 'existential risks' are a relatively young research area. So I think it was a wise and farsighted decision to include such an emerging topic into this conference.

It is also a field that requires crossing boundaries in science because it has become highly interdisciplinary, involving topics ranging from climate science, engineered pandemics, AI safety to nuclear disarmament. What all of these topics have in common is that they think about very unlikely but not impossible scenarios that could lead to human extinction.[58]

I should provide a very brief introduction to the research on existential risks. Such risks display many of the characteristics that have been highlighted in previous sessions of this conference, particularly Professor Renn's session on systemic risks. The Centre for the Study of Existential Risk (CSER) at the University of Cambridge is one of the few centres in the world founded with a dedication to the study of these risks. We concentrate on the identification, management and mitigation of global risks associated with emerging technological advances and human activity, especially high-impact risks, that might result in global catastrophe or threaten human extinction, even with very low probability.

An indeed intriguing question for this conference is how to discern science fiction and purely hypothetical scenarios from very real, yet underestimated threats. This is difficult, also because media bias can easily distort the picture towards, say, a zombie apocalypse or Terminator. However, we do know, for instance, that large asteroid impacts are relatively rare in geological history, as are super-volcanic eruptions and thus it is quite unlikely that they will occur this century. So, in the nearer term, human actions and technological advances would be a more probable cause of human extinction.

58 For an overview, see Avin, S., Wintle, B. C., Weitzdörfer, J., O hÉigeartaigh, S. S., Sutherland, W.J. & Rees, M. J. (2018). Classifying global catastrophic risks. *Futures, 102*, 20–26.

One of the main motivational drivers of these questions is a long-termist utilitarian argument. It relates to the tendency of us humans to overestimate our own importance in time and to the notion that future generations will by far outnumber us. If you think about two billion years of planetary future, there is a lot of potential for wonderful things to happen, and thus we in our brief moment in time would be well-advised to take good care of this planet responsibly. But the field is also grounded in hard science, and distinguished scientists have disseminated these concerns, most prominently among them Martin Rees and Max Tegmark. Globally, there are currently four main groups of researchers in this field, at CSER in Cambridge, the Future of Humanity Institute in Oxford, and at the Future of Life Institute and the Global Catastrophic Risk Institute, both in the United States. We have different focus areas, but we all work explicitly on the area of existential risk.

While you might think that this topic is exotic, we would argue it is an extremely understudied one. When the Oxford philosopher Nick Bostrom examined how prominently various topics feature in scientific journals, he found over 800 papers on the dung beetle, over 200 papers about Star Trek, and only 12 on human extinction.[59] It is intriguing that we do thousands of probabilistic safety assessments for, say, oil rigs and nuclear reactors, but there are, for example, hardly any probabilistic models on the accidental occurrence of nuclear war. This is one of the areas where we had an alarming number of near-misses and serious close calls in the past that should induce us to realign our research priorities.

Towards the end of this brief introduction, I would like to mention methodological approaches that our teams use. We have geneticists, ecologists, mathematicians, philosophers, and economists. I am a lawyer by training and so we adopt various strategies, including knowledge sharing with industry and policy engagement. We very much stress that this kind of research must be translated into political action because, in many areas, it is scientific uncertainty that has to be worked on, but in more areas it is political action that really is the bottleneck.

59 Bostrom, N. (2013). Existential risk prevention as global priority. *Global Policy, 4*(1), 15–31.

The Challenge of Climate Change

Jochem Marotzke
Max Planck Institute for Meteorology

Abstract: *The ongoing and expected anthropogenic climate change creates a complex mélange of expert-assessed and publicly perceived risks. Owing to this complexity, experts struggle to find the right balance between avoiding false alarms and avoiding missed alarms. I will use the coverage of sea-level change in recent reports by the Intergovernmental Panel on Climate Change (IPCC) to illustrate how this struggle has unfolded in practice. Elements of this struggle are the striving for scientific rigour, the psychological anchoring effect of high numbers quoted for expected sea-level rise, and the perceived effects of errors of commission versus errors of omission by IPCC authors.*

I am not an expert on risk research in the way that most people in this room are. Furthermore, if you are expecting a story of doom on what might happen because of climate change, you will be disappointed. Suffice it to say that I take it as a given that, if climate change proceeds in an unmitigated fashion, this will present unacceptable risks worldwide. I will focus on one specific aspect of the interaction of expert assessment of risk and the social construction of risk. I will thus be doing a piece of social science although I have no formal training in it, and I will present a mix of solid and anecdotal evidence.

First, I will introduce what is the most remarkable global assessment process in any field of science, the Intergovernmental Panel on Climate Change (IPCC). Second, I will walk you through a case study, the assessment of future sea-level change. And third, I will talk about the dichotomy between avoiding errors of commission – doing something that is wrong – and errors of omission, i.e. not having done something that would have been right.

1. Systematic Assessment of Risks posed by Climate Change: The Intergovernmental Panel on Climate Change (IPCC)

The IPCC was founded in 1988 as a joint venture of the United Nations Environment Programme and the World Meteorological Organization. The IPCC has 195 member states, almost all the countries in the world; the 'I' in IPCC stands not for international but for intergovernmental. Every six to seven years, the IPCC assesses the state of knowledge about anthropogenic climate change as expressed in the published literature; the IPCC does not conduct its own research.

There are three major draft stages for each IPCC report, and the drafts are reviewed by both experts and governments. Each report receives many thousands of review comments, and each of them must be responded to by the authors. It is one of the hallmarks of the report's quality that the review is so thorough. Each of the three IPCC working groups prepares a full report, which is between 1,000 and 1,500 printed pages long. The full report is subsequently condensed into a 25-page summary for policymakers. This summary is deliberated in the final IPCC plenary, where about 500 government delegates and the authors go through the summary, sentence for sentence, until agreement is reached on each sentence. The authors can veto if something is incorrect. This final plenary is a painful process but also very powerful, because the end result is owned by both the scientific community and the governments. One consequence is that the statements in the summary for policymakers are accepted as scientific fact in all UN climate conferences without any further discussion. Furthermore, the IPCC assessments form the scientific basis of climate policy in many countries, for example Germany. The IPCC reports are thus very influential and in general of very high quality.

There have been five assessment reports (AR) so far, 1990, 1995, 2001, 2007 and 2013.[60] I had no involvement at all prior to the 2013 report and was in charge of one chapter in AR5, and I am again in charge of one chapter in the upcoming AR6. A chapter is typically written by about fifteen authors and is some 30 to 100 printed pages long.

As a rule, every statement in an IPCC report has to come with a characterisation of our confidence in it. For example, are there independent

60 Intergovernmental Panel on Climate Change. (2006-present). *Assessment Reports*. Retrieved 20 November, 2020 from http://www.ipcc.ch/reports

lines of evidence that point to the same result, say, are model simulations and observations in agreement with each other? Also, is there a dispute in the published literature, or do the published papers largely agree on a topic? All of this enters a statement of confidence.

Where possible, IPCC reports provide assessments in probabilistic terms, by specifying how likely it is that a stated outcome will occur within a given range. But there have been criticisms of this approach by two very distinguished colleagues of mine. Ted Shepherd, fellow of the Royal Society in the UK, has criticised that the IPCC reports emphasise what we are confident in, things that are likely to happen. Behind this emphasis lies the desire to avoid false alarms, but he argues that this language and approach carry a built-in bias such that we do not pay enough attention to avoiding missed warnings, because we draw attention to outcomes in the centre of probability distributions. Back in 2007, James Hansen, a member of the National Academy of Sciences in the USA, called it 'scientific reticence' that scientists tend to be averse to sounding the alarm very clearly. So there is on the one hand the IPCC approach of emphasising confidence and likelihoods of occurrence, but on the other hand there is fundamental criticism of this approach.

2. Case Study: IPCC Assessments of Sea-level Change

There are a few background elements I need to go through. Climate projection is a standard term in my field, referring to a simulation of the future (usually until 2100) with comprehensive climate models. Each projection is conditioned on a scenario, in turn based on assumptions about how the world's societies will decide on political and technological issues as they relate to climate change. The world might take very effective mitigation measures or none at all. These decisions result in certain emissions of greenhouse gases and other substances. Conditioned on each scenario, we use our climate models to simulate how the climate will evolve.

Global sea levels will rise for two main reasons. One is that the ocean warms and expands; the other is that ice on land will be transferred to the ocean as liquid water, and the ocean will gain mass. Sea-ice melting has practically no influence on sea-level rise because sea ice already floats on the ocean. Among the many uncertainties about future sea-level change, the future of the two large ice sheets on Greenland and Antarctica is the largest.

The IPCC third assessment report (AR3) from 2001 stated in its summary for policymakers only this: 'Global mean sea level is projected to rise by

0.09 to 0.88 metres between 1990 and 2100, for the full range of [...] scenarios. This is due primarily to thermal expansion and loss of mass from glaciers and ice caps.' This whole range arises from the least-warming model in the most effective mitigation scenario to the opposite end, a very sensitive model in the highest emission scenario. Note that the AR3 made no statement about the contribution made by the ice sheets on Greenland and Antarctica; 'glaciers and ice caps' refer to all land ice apart from these ice sheets.

When the fourth assessment report (AR4) came out in 2007, I and some of my colleagues received a fact sheet from the German government summarising the main findings. That fact sheet contained the sentence (my translation): 'Models show throughout the [21st] century a sea level rise of 18 to 38 centimetres for a low scenario and 26 to 59 centimetres for a high scenario.' I remembered the previous range, 9 centimetres to 88 centimetres, and understood immediately that the new numbers would be interpreted as, first, that the uncertainty range had gone down substantially, and second, that the worst-case scenario was much more optimistic than it had been before. But I also knew that these interpretations could not reflect the true state of uncertainty. Something had gone wrong.

Table SPM.3 in the AR4 summary for policymakers details sea-level rise for various future scenarios, stating 'Model-based range excluding future rapid dynamical changes in ice flow.'[61] Hence an important element leading to sea-level rise was not included in the numbers in the table. The text goes on: 'For each scenario, the midpoint of the range in the table is within 10 % of the AR3 model average.' Largely, this sentence says we are not too different in our average projections from the last assessment report. However, the numbers quoted give a wholly different impression, namely that the expected sea-level rise is much lower than in the AR3.

The next paragraph begins with, 'Models used to date do not include uncertainties in climate-carbon cycle feedback, nor do they include the full effects of changes in ice sheet flow.' We thus have a topic sentence announcing a paragraph on carbon cycle feedbacks, but then the text goes back to ice sheets, continuing 'The projections include a contribution due to increased ice flow at the rates for 1993.' With this extrapolation, the upper ranges shown

61 Intergovernmental Panel on Climate Change. (2007). *Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved 20 November, 2020 from https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-spm-1.pdf

would increase by 10 centimetres to 20 centimetres. 'Larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise.' The 10 centimetres to 20 centimetres would have to be added to get the full estimate, but the total number resulting from '59 centimetres plus 10 centimetres to 20 centimetres' was not quoted in the report.

I have been told that guessed numbers were excluded from the report. But this audience here knows of the anchoring effect of a number quoted. For sea-level rise, the most powerful anchor is always the highest number thrown around. The anchoring effect of the highest explicitly quoted number combined with the poor organisation of the writing had the result that, even though some of the additional information was there, it was lost on everyone but the most persistent reader.

A few months later, Stefan Rahmstorf from Potsdam published a paper in which he argued that sea level would rise by much more than assessed in the AR4, 0.5 to 1.4 metres by 2100, conditioned on the same scenarios.[62] That paper was heavily disputed, but we had the IPCC report on the one hand and a very prominent paper in *Science* saying the numbers are much higher. We have an effective word in German, *Deutungshoheit*; its approximate translation is 'interpretative authority'. The IPCC lost its interpretive authority on sea-level rise in 2007, and the narrative was born that the IPCC underestimates the risks of sea-level rise. This narrative has never fully vanished.

The IPCC fifth assessment report in 2013 set the record straight; there was very little debate about sea-level change after the report came out. However, as any internet search shows, the narrative still exists that sea-level rise is worse than expected or worse than assessed by the IPCC. I think that much of this is due to failed communication of the AR4 – straight A for the science, C-minus for the communication. The question is, should the AR4, in addition to clearer communication, have been less conservative in its assessment to help avoid this interpretative vacuum? Because of what I am exploring next I am not sure.

62 Rahmstorf, S. (2007). A semi-empirical approach to projecting future sea-level rise. *Science, 315*(5810), 368–370.

3. Errors of Commission Versus Errors of Omission in IPCC Assessments

There were several highly publicised errors, mostly in the Working Group 2 part, in the 2007 AR4, and the climate change deniers immediately latched onto them and gave them names such as 'Himalayagate'. Himalaya glaciers are massive; when an AR4 draft stated that Himalaya glaciers might vanish by 2035, Georg Kaser, an expert on glaciers, logged a review comment 'This can't be true.' He was ignored. In the end, it turned out to be a typo; the correct year 2350, quoted from a report, had been turned into 2035.

There was another error, 'The Netherlands are prone to flooding because 55 % of its area is below sea level', from a report by the Dutch government. It should have said, '26 % are below sea level, and an additional 29 % are prone to river flooding'. Together, 26 plus 29 makes 55 %, but to connect the sentences like this is incorrect.

Thirdly, there was a discussion about exaggerated downturn in African crop yield that was dubbed 'Africagate'. This alleged error was not actually an error at all. The only issue in this case was a non-peer-reviewed source, but the source was a high-quality meta-study that was not disputed.

None of the identified errors were consequential, as none of them touch the foundation of the major assessment results and of the IPCC: climate change is anthropogenic, and much more of it is expected for the future. Still, these alleged errors caused a big fuss and a big reduction in trust in the IPCC. Furthermore, at the same time and maybe not coincidentally, emails among IPCC authors were hacked from a server at the University of East Anglia. Altogether, there was a review by the InterAcademy Council into the IPCC procedures, and they proposed some changes to the review process.[63]

Why did these relatively minor errors cause such a big public debate? An error of commission in an IPCC report seems to be seen as unforgivable. When we wrote the fifth report published in 2013, we were aware of what had happened before and tried to ensure that no errors of commission were made. I have not heard that climate change deniers found any mistakes, and I am absolutely sure that this was not for lack of trying. Apparently, we were careful and thorough enough. But have we made errors of omission, as Ted Shepherd's comment might be read?

63 InterAcademy Council. (2010). *Climate change assessments – Reviewof the processes and procedures of the IPCC*. Retrieved 20 November, 2020 from https://nlslash.nl/climatetheory/iac.pdf

4. Résumé – Be Careful What You Wish For

IPCC assessments face a credibility challenge that comes mostly from errors of commission, not so much from errors of omission. Suggestions that we should emphasise more strongly the unlikely and the uncertain outcomes thus make me feel uneasy – I know that everything I write that is either questionable or false will come back to haunt me. This brings me to my résumé: Be careful what you wish for, in particular, if you wish to explore things more along the fringes of the probability distribution.

The complete and absolute primacy of scientific rigour caused problems in the fourth IPCC report. We have to take into account how our messages are likely to be received. The fourth report perhaps neglected considering the social construction of risk that would follow the publication of the report. I can see why we may have to look more at the low-probability, high-impact events, so as to avoid missed alarms. But this comes with a risk of its own because of the unforgivable nature of errors of commission. I do not claim to have an answer for how to deal with this; all I can say is that we must tread very carefully.

What is the Real Threat of Pandemics?

Lothar H. Wieler
Robert Koch Institute, Berlin

Abstract: *The question we face today is not whether a pandemic will occur but when. Apart from a sound health system on their guard at all times, the time of detection is critical for management-efficacy: the earlier an outbreak is recognised, the more efficient containment will be. When we think about the next pandemic, our greatest concern is an airborne transmitted pneumonic pathogen like influenza and coronavirus or a disease caused by other pathogens, a so-called disease X. The pandemic potential of a new virus variant is hard to predict. Apart from all the measures that have to be taken to prepare for a next pandemic, such as vaccines or therapeutics, early detection by surveillance is at the heart of any public health response due to the unknown nature of the virus. Signal detection by surveillance needs to be based on official as well as unofficial sources. Due to time constraints, I will focus on some current and future surveillance strategies that are developed and hosted at the Robert Koch Institute to best serve public purpose, taking influenza as a prime example.*

My talk will include four sections; beginning with a generic definition of what it is we are talking about and progressing towards some technical tools we are currently developing for our risk assessment to be used as direct interventions in order to mitigate risks.

1. What is a Pandemic?

As you may guess, it is something that basically occurs globally. While preparing for this talk, among other things I found out that Pan, the god of shepherds, apparently evoked panic. His own mother, according to the Greek myth, fled from him after he was born. He seems to have been a rather nasty guy because even his sheep fled from him. Panic, therefore is an integral part of the term pandemic, but I will not talk about panic today. However, it

is really important to understand what generic definitions we have in terms of infection epidemiology.

From a population perspective, there are three kinds of diseases. An endemic disease is defined as 'occurring frequently in a particular region or population, applied to diseases that are generally or constantly found among people in a particular area'. An epidemic on the other hand is defined as 'the occurrence in a community or region of cases of an illness clearly in excess of normal expectancy'[64] or 'an increase of new cases of a disease beyond an expected baseline within a defined period of time'[65]. A pandemic is defined as 'an epidemic occurring over a very wide area, crossing international boundaries, and usually affecting a large number of people'.[66] Thus a pandemic is usually a strong, serious illness with a huge burden of disease.

Although I will talk about infectious disease throughout my talk, at this point I want to make clear that, currently, the actually occurring common pandemics are those causing death due to chronic degenerative diseases like cardiovascular diseases, respiratory diseases, cancer or diabetes, as outlined in Figure 14.[67] These are true current pandemics, therefore we clearly need to put more effort into preventing these, as also outlined in the World Health Organization (WHO) Global Action Plan for the Prevention and Control of Noncommunicable Diseases (NCDs), 2013–2020.[68]

64 Porta, M. (Ed.). (2014). *A Dictionary of Epidemiology*. Oxford University Press: New York.

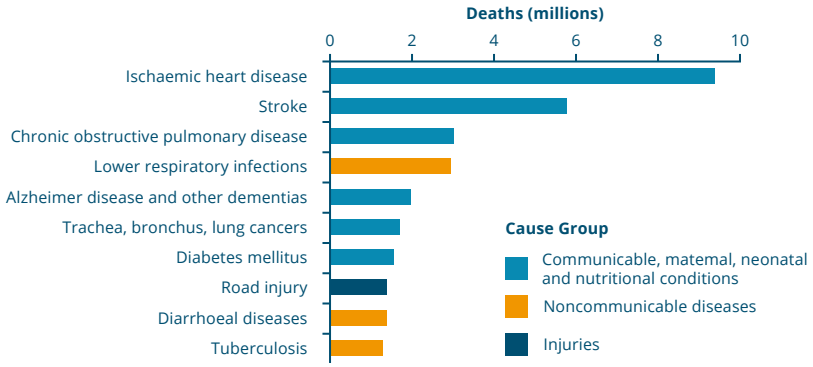
65 Egger, M., Low, N., & Razum, O. (2012). Globale Gesundheit. In Egger, M., Low, N., & Razum, O. (Eds.), *Public Health: Sozial- und Präventivmedizin kompakt* (p. 315). de Gruyter: Berlin.

66 Porta, M. (Ed.). (2014). *A Dictionary of Epidemiology*. Oxford University Press: New York.

67 World Health Organization. (2018). *Global Health Estimates 2016: Death by Cause, Age, Sex, by Country and by Region, 2000-2016*. Retrieved 20 November, 2020 from https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death

68 World Health Organization. (2013). *Global action plan for the prevention and control of noncommunicable diseases 2013-2020*. Retrieved 20 November, 2020 from https://apps.who.int/iris/bitstream/handle/10665/94384/9789241506236_eng.pdf

FIGURE 14



Top 10 global causes of death in 2016. Noncommunicable diseases (NCDs) caused 71 % of deaths globally, ranging from 37 % in low-income countries to 88 % in high-income countries.[69]

2. Influenza – A Pathogen That Has Already Caused Major Pandemics

I will focus on influenza, as this is the prototype model pneumonic disease that we can learn a lot from. Other viruses, like Coronaviruses, causing MERS or SARS, also have to be considered as causes of a putative pandemic, and we have recently modelled a putative outcome of a SARS-like agent. However, there is a breadth of knowledge on influenza and these viruses have already proven to cause several pandemics. Furthermore, various generic approaches established for influenza can be utilised for the management of any pandemic pneumonia. Influenza is caused by viruses that have specific features making them very likely to cause the next pandemic. One reason is their huge antigenic diversity. Influenza viruses are single-stranded RNA viruses with error prone polymerases leading to mutations when replicating the virus genome. In addition, these viruses are made of eight RNA segments, and there is a possibility that these segments are exchanged between

69 *Figure 14*. Top 10 global causes of death. Adapted from "The top 10 causes of death" [Fact sheet], by Geneva: World Health Organization (WHO), 2018. Retrieved 20 November, 2020 from https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death. Licensed by CC BY-NC-SA 3.0 IGO.

certain virus strains during co-infections. This segment re-shuffling is termed *reassortment*. Due to these biological features totally new viruses may pop up all the time in nature, mostly unrecognised and without causing damage. We do not know what kind of virus will appear and in addition it is hard to judge based just on the biological significance of these new viruses.

Furthermore, these viruses have a huge natural host reservoir, mainly waterfowl, but certain virus types can be isolated from various host species. Until 1997, we were pretty convinced that some of these virus subtypes are naturally just transmitted between humans and that other subtypes stick to certain host species. Sometimes, there may be reassortments between animal and human viruses, but transmission of certain virus subtypes between species is still a rare event. However, in 1997, for the first time, a particular H5 virus (H stands for hemagglutinin, an important virulence factor of influenza viruses) was identified that transferred from chickens to humans causing a high level of lethality in humans. Many of the few people that got infected died of this virus but luckily it did not transmit well between humans. Most of you will remember the catastrophic pandemic in 1918 often referred to as the Spanish flu. The numbers vary from publication to publication, but we can estimate that between 25 and 40 million people died during the Spanish flu. Back then, about 40 % of those infected would develop disease and up to 2 % would die of it, which is known as a lethality of 2 %. The seasonal influenza that we see every year usually has an average lethality of around 0.1 %.[70]

However, the Spanish flu happened 100 years ago and the world has seen serious medical and other technological developments since. At that time, due to World War I, people were in a poor physical and mental state, artificial respiration was not yet possible, there were no antibiotics or vaccines available. Spread of disease was much slower, as was the spread of information. It is really important to understand that we should be able to mitigate the risk of a possible influenza pandemic much better today than 100 years ago. Having said this, we have to consider that this is true even though the world population has risen from some 1.8 to 7.7 billion, therefore the possibility of spread is worse, and due to globalisation as well as mobilisation, a putative spread is much faster.

The 2009 influenza pandemic caused by an H1N1 virus subtype was recognised in March and within a timespan of four months, it moved around

70 Armstrong, G. L., Conn, L. A., & Pinner, R. W. (1999). Trends in infectious disease mortality in the United States during the 20th century. *Jama, 281*(1), 61–66.

the globe. This influenza virus was a highly transmissible reassortment of porcine, chicken, and human viruses, but luckily for us, it did not have a high burden of disease, which means that the disease mostly progressed mildly. Nevertheless, this pandemic was met with very challenging discussions and many communication issues. In the end, it is estimated that the 2009 H1N1 pandemic caused the deaths of nearly 300,000 people worldwide[71], having infected billions of people. This shows again how hard it is to predict the outcome of a particular influenza virus infecting humans.

Table 4 and Table 5 illustrate the morbidity and mortality of the four influenza pandemics that occurred during the last 100 years. In 1918, nearly 100 % of those that died of the influenza H1N1 virus were younger than 65. During the 1957 pandemic, that proportion fell to 36 %, and during the so-called Hong Kong flu in 1968 nearly half of those recorded as having died from the infection belonged to this age group. In contrast, in 2009, the number of young people that died, depending on what publications we look at, again was substantially high.

TABLE 4

Global morbidity and mortality of influenza pandemics.[72]

YEAR	MORBIDITY	DEATHS WORLDWIDE	PROPORTION OF DEATHS <65 YEARS
1918	29–43 %*	approx. 50 million	99 %
1957	31 %**	approx. one million	36 %
1968	6–21 %	approx. one million	48 %
2009	18 %	approx. 105,700 to 395,600	62–85 %

* Age group 15 to 64 years
** First wave

71 Dawood, F. S., Iuliano, A. D., Reed, C., Meltzer, M. I., Shay, D. K., Cheng, P. Y., Bandaranayake, D., Breiman, R. F., Brooks, W. A., Buchy, P., Feikin, D. R., Fowler, K. B., Gordon, A., Hien, N. T., Horby, P., Huang, Q. S., Katz, M. A., Krishnan, A., Lal, R., Montgomery, J. M., … Widdowson, M. A. (2012). Estimated global mortality associated with the first 12 months of 2009 pandemic influenza A H1N1 virus circulation: a modelling study. *The Lancet. Infectious Diseases, 12*(9), 687–695.

72 Robert Koch Institute. (2016). Nationaler Pandemieplan Teil II – Wissenschaftliche Grundlagen. Berlin. Retrieved November 2020, 2020 from https://www.rki.de/DE/Content/InfAZ/I/Influenza/Pandemieplanung/Downloads/Pandemieplan_Teil_II_gesamt.pdf?__blob=publicationFile

TABLE 5

Morbidity, mortality and lethality of influenza pandemics in Germany.[73]

YEAR	POPULA-TION*	MORBI-DITY	DEATHS	MORTALITY /100,000	LETHALITY
1918	61,756,930	25 %	426,600	691	2.76 %
1957	72,030,866	31 %	29,100	40	0.13 %
1968	78,069,482	1 %	46,900	60	0.29 %
2009	81,802,257	9 %	350	0.43	0.0048 %

* Population data for 1957 and 1968 include both former West Germany and the former German Democratic Republic

These data reflect the fact that, apart from the biological features of influenza viruses, the host immune system is of great relevance. During each year's seasonal influenza, there is so much interaction between virus and host that makes it very hard for public health scientists like us at the Robert Koch Institute to predict the course of that particular epidemic. Udo Buchholz, a colleague from our institute, published numbers when it comes to deaths in Germany. In fact, the 2009 influenza pandemic caused 'only' 350 deaths in Germany. In 1918, 426,600 people in Germany were killed by the Spanish flu, at that time the German population was roughly 62 million people. This uncertainty of transmissibility and lethality of unknown emerging viruses (reassortments) makes it very difficult to predict what will happen and when. There are various publications, some stating that pandemics cause up to 0.6 % loss of global income, while others say up to 2 %. So they may have tremendous impact on the world economy. In conclusion, influenza as well as other pneumonic pandemics are seen as one of the biggest current threats to global health, and thus economy. From our understanding, it will stay like this.

Despite all that experience, we have to acknowledge the so-called *known knowns* as well as the *known unknowns*. We know the mode of transmission –

73 Buchholz, U., Buda, S., Reuss, A., Haas, W., & Uphoff, H. (2016). Influenza pandemic deaths in Germany from 1918 to 2009. Estimates based on literature and own calculations. *Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz, 59*(4), 523–536

influenza is caused by droplets and aerosols. So this is very important, because an airborne disease that is spread by droplets from person to person can be transmitted very easily. We also know about the incubation period. We have a lot of information about the seasonal pandemic influenza. We know that persons are already infectious before they show clinical symptoms. We know of the positive effect of good hygienic measures. And, finally, we know that transmission will decline in spring and summer depending on temperature zones. This is most likely due to UV light killing off the viruses. We have to soundly analyse all the available data, historical data, clinical studies and modelling studies.

But there are many issues that we cannot assume. We do not know the antigenic type and phenotype. We do not know the susceptibility against antivirals, for example. We do not know which age groups will be most affected and how strong the immunity of this group against that particular influenza subtype will be. This is why we need smart surveillance, technological development in surveillance. This is – apart from storing personal protective equipment and classic infection prevention – the bread and butter of risk assessment and pandemic preparedness. Surveillance allows us to do risk assessment and plan for effective interventions. To stress one point again: this is why we have to collect and analyse all the available data consistently and in a timely manner to be able to steadily get more insight into the biology of this as well as other infectious disease to foster professional prevention and intervention strategies.

3. Surveillance: A Main Pillar of Risk Assessment and Pandemic Preparedness

Surveillance is the continuous systematic collection, analysis and interpretation of health-related data needed for the planning, implementation and evaluation of public health practice. This is a clear public health duty and we have to invest as much as possible into this. We need early warning systems and we need surveillance to document the impact of intervention. How could we judge whether an intervention works or not if we do not survey it? Of course, we have to monitor and clarify health problems to set priorities. Therapeutics as well as vaccines need to be used in a stratified way.

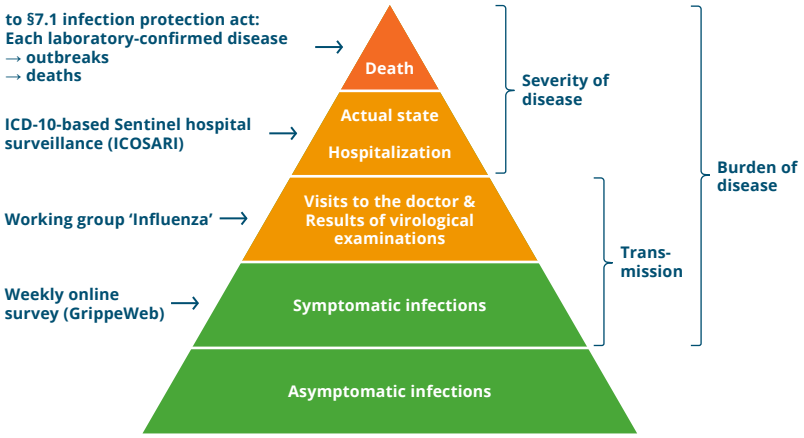
Now I will briefly introduce the surveillance set up by the Robert Koch Institute, which currently consists of four systems (Figure 15). One is a citizen science project we know as GrippeWeb[74], where people have the chance to directly tell us clinical symptoms with regard to influenza-like illness. Currently, around 14,000 people from Germany have registered for GrippeWeb. They give us information about their vaccination status, their age and so on. The second tool is the working group 'Influenza'.[75] Taking on the role of a sentinel, almost 500 practices in Germany send in samples from which we can isolate viruses, culture and characterise them, not only genetically, but also by testing their resistance against antivirals and their pathogenicity. The third is the hospital-based system ICOSARI[76], where particularly strong cases of pneumonia are monitored. Lastly, the fourth one is the mandatory notification of infections according to Section 7.1 of the German Infection Protection Act, which came into force in 2001.

74 See: https://grippeweb.rki.de/

75 See: https://influenza.rki.de/

76 Ibid.

FIGURE 15



Four influenza surveillance systems currently established and hosted by the Robert Koch Institute: the German Infection Protection Act which makes the notification of laboratory-confirmed diseases mandatory, the ICD-10 code based sentinel hospital surveillance (ICOSARI), the working group 'Influenza' and the weekly online survey (GrippeWeb). The central pyramid shows the indicators which the systems deliver, while the right side lists the outcome of the respective surveillance system.

With the mandatory notification system from patients, labs, doctors, hospitals to local health offices, state health offices and to the Robert Koch Institute we provide data to the European Centre for Disease Control (ECDC) and the World Health Organization (WHO). Due to our four surveillance systems we are in the position to give deep insights into the severity and transmissibility of disease, and also the affected age groups. This provides German doctors a sound basis as to how to manage seasonal influenza. We publish weekly reports[77] online which can be accessed by everybody. These reports, for example, give information about the different number of viruses detected in samples and so on. We define a certain threshold when we declare the seasonal influenza epidemic as having started depending on indices that we have developed from clinical pictures.

77 Arbeitsgemeinschaft Influenza. (2008 - present). *Influenza-Wochenbericht*. Robert Koch Institute. Retrieved 20 November, 2020 from https://influenza.rki.de/Wochenberichte.aspx

As mentioned, these four systems are used to analyse influenza epidemics in particular. However, I want to stress that the two syndromic systems Grippe-Web and ICOSARI are more than helpful for every pneumonic disease, as they are based on syndromes and not on the specific detection of influenza.

4. Today and Tomorrow: How Does the RKI use Digitalisation and AI for Surveillance and Risk Assessment?

The 2017–2018 seasonal influenza in Germany was exceptionally severe, with an estimated 9 million cases. Due to our estimations, some 25,100 people have died in the course of this seasonal influenza outbreak.[78] In summary, due to our intensive monitoring we are able to get more insights every single year, hence we are learning every single year and thus our knowledge of risk mitigation is steadily increasing.

However, what we strive for is an even deeper understanding of our data so we are able to better predict the outcome of the disease. The data gained by the surveillance tools I just mentioned puts us in the position to validate machine learning algorithms and further artificial intelligence tools. Due to the mandatory notification systems, we have identified roughly two million outbreaks of infectious diseases since 2011. In the near future, the notification system will be transferred into the German Electronic Notification System for Infection Protection (DEMIS), which will be both less error-prone and faster, thus also supporting the work of the local health authorities.

In addition to the surveillance systems I mentioned, the Robert Koch Institute uses further tools and is continuously developing new ones which will enrich our knowledge tremendously. We run a syndromic real-time surveillance, where through the use of machine learning we try to understand whether particular signals pop up earlier than the notification system can pick them up.[79] We have also implemented two antibiotic resistance surveillance systems – ARS and AVD – where we have data on 17 million samples of resistant pathogens as well as on the use of antibiotics. Again, by means of machine learning algorithms we are able to identify outbreaks earlier than

78 Arbeitsgemeinschaft Influenza. (2019). *Bericht zur Epidemiologie der Influenza in Deutschland, Saison 2018/19*. Robert Koch Institute. Retrieved 20 November, 2020 from https://influenza.rki.de/Saisonberichte/2018.pdf

79 Bartoszewicz, J.M., Seidel, A., Rentzsch, R., & Renard, B.Y. (2019). DeePaC: Predicting pathogenic potential of novel DNA with reverse-complement neural networks. *Bioinformatics*. Retrieved 20 November, 2020 from https://www.biorxiv.org/content/biorxiv/early/2019/05/29/535286.full.pdf

with classical notification systems. In between, we also set up a dashboard for influenza severity that gives us an idea of the age group of people affected by the disease and transmissibility of the virus. This is directly reported to the health authorities giving them an idea about how severe a particular influenza epidemic is. Furthermore, we have developed machine learning tools to predict the occurrence of so far unknown pathogens by next-generation sequencing.[80] And I would like to emphasise here: we have to understand how the algorithms programmed by us deliver their results: we need to understand their decision making, as we cannot rely on a black box.

The Robert Koch Institute is also in charge of health monitoring. Apart from GEDA (Cross-Sectional German Health update) and DEGS (German Health Interview and Examination Survey for Adults), we sample the representative data of some 17,000 children between 0 and 17 years old (KiGGS) acquired by questionnaires and analyses of blood and urine samples, for example. As these biological samples are representative, we can also use them to monitor immunity against influenza and other diseases. We use technology such as next-generation sequencing or mass spectrometry to gain further information and combine all these data in a large health data collection that offers us a huge potential to assess the risk of a particular disease. We can use it for early outbreak detection to rapidly initiate intervention. We will continuously screen these databases automatically and will be able to define certain thresholds, signals that seem to give us the impression that something important is going on. Our notification system includes roughly 80 pathogens. Every year, around 500,000 cases and almost 20,000 outbreaks are reported to us. We can use these as learning datasets to become more precise in prediction and intervention.

It is important to mention that more than 60 % of the signals that relate to epidemics are not from official sources, so we also have to screen for those. We have set up an algorithm to look in certain databases in order to evaluate the importance of signals and – due to our validated data sets – we can check whether these signals are valid. Our newly established Centre for International Health Protection (ZIG) further strengthens these technical developments as it offers us more resources for analysing international databases.

80 Robert Koch Institute, Signale-Projekt. Retrieved 20 November, 2020 from https://www.rki.de/DE/Content/Infekt/IfSG/Signale/Projekte/Signale_Projekte.html

5. Summary

To sum up, we need robust and explainable data to program algorithms for a valid decision-making process. In the long run, we hope that recommendations based on artificial intelligence will have a greater impact on our public health decision making. Clearly, these data must be exchanged and dealt with internationally to foster global pandemic preparedness. Due to our current knowledge, we consider an influenza pandemic to be the biggest threat to the population caused by infectious diseases, but both coronaviruses as well as disease X may hit us. Possibilities for prevention, diagnostics and therapy of influenza should be elaborated. We need scientific breakthroughs both in new therapeutics, pan-influenza vaccines as well as in host-directed therapy.

As Germany's national public health institute, we have both the privilege and the duty to maintain historical data as training data. Three years ago, during the last 'Crossing Boundaries' conference, Dirk Brockmann from our institute presented a model of flight movements during 2015, using data from approximately six billion people moving around. This mobility is clearly a risk factor but one that can easily be managed. We have to understand that the variability of influenza and the known unknowns do not put us in the position to predict how these pandemics will develop. Therefore we are continuously and significantly progressing on an international level to foster cooperation with public health authorities.

Let me finish by quoting the Athenian statesman Pericles: 'It is less important to predict the future than to be prepared for the future.'

Session 5
Coping with Risks

Chair:
Filippa Lentzos
King's College London

How to Cope with Extreme Global Events and Strengthen Societies' Resilience

Garry Peterson
Stockholm Resilience Centre

Abstract: *Humanity and our enterprises rely on the reliable functioning of the natural world, however the growth and success of human activities have simplified and destabilised the natural world. While some changes are gradual and reversible, other changes can be abrupt, substantial and persistent. My colleagues and I have analysed the causes and consequences of these tipping points. I will discuss those for resilience, collapse, and transformation of ecosystems, livelihoods, and societies. Our work shows that while tipping points present new risks for societies, strategies that work with the dynamics that produce tipping points can also enable transformations towards sustainability.*

Resilience describes coping with surprise or unknown risks. We are now living in the Anthropocene, and this means we are living in a time that is unprecedented in earth system history, where we have radically transformed not just the climate, but the entire biosphere, and we can expect surprises.

1. A Complex World - Increased Connectivity and Lack of Stabilising Regulating Processes

Today, a lot of the ways we use for thinking about how the world works are not well suited to its connected complexity. Many of the discussions earlier today are based on a modernist view of a linear world in that the impacts of things dissipate in time and space. For example, one can imagine what happens if a tree falls in the forest. Its biggest impact is right there nearby, and that impact fades away in time. However, the world is full of connected systems in which this type of thinking does not hold. In ecosystems, the biggest impacts of an event can be distant in time and space.

Attempts to improve the human condition, to solve poverty, have modified ecosystems in ways that have often produced distant unintended consequences. Irrigation for agriculture has created new habitats for disease transmission leading to things like river blindness; agricultural runoff from the US Midwest produces a massive dead zone in the Gulf of Mexico. Another example is the how the removal of top predators destabilises ecosystems. The return of wolves to Yellowstone resulted in clearer water there. Wolves scared large elk from rivers, allowing vegetation to regrow, increasing river water quality. This is something where the complexity of these connections is more recently understood.

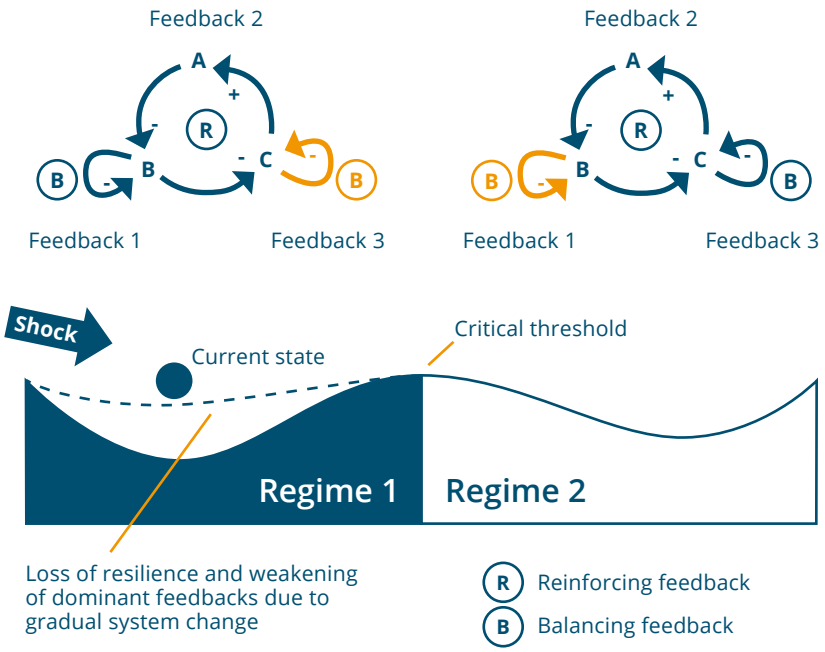
We know a lot about how humanity impacts the natural world, but we know very little about how these changes to the natural world impact human wellbeing, and we know little about how societies, values, interactions with the world change over time. We also do not know much about how the natural world works at the large scales that the world is changing now. We know a lot about one-metre plots, less about hectares and very, very little about hundreds of kilometres. Resilience as a concept focuses on navigating these uncertain areas. This focus on uncertainty is quite different from lots of our modern scientific and engineering expertise, which are based on ideas of optimisation or the optimal balance between risk and reward.

We just heard before that resilience means many different things in different fields. It has different definitions in engineering and psychology. I am not going to review all of those approaches, instead I am taking a sustainability approach to resilience.

2. Regime Shifts as Complex Features of Self-Organising Systems

I am going to talk about tipping points in the earth's system. There are observation models, paleo-ecological data as well as experiments that show these things happen, but they are difficult to include in earth system models, such as in those used by the Intergovernmental Panel on Climate Change (IPCC) or others to estimate the impact of humanity on the world. As was stated this morning, these models basically assume that the human economy grows and then looks at the impact on the natural world, but there is no feedback on the natural world changing what people do. We have tried for decades to understand this by collecting the missing pieces but it is difficult to connect nonlinear dynamics to more linear things in any reliable way.

FIGURE 16



Regime shifts occur when a system shifts from being organised around one set of mutually reinforcing feedbacks to another. These shifts usually occur due to a combination of a weakening in the feedbacks that maintain a regime, and a shock that changes a system, pushing its change to the degree that a different set of feedback processes operate.[81]

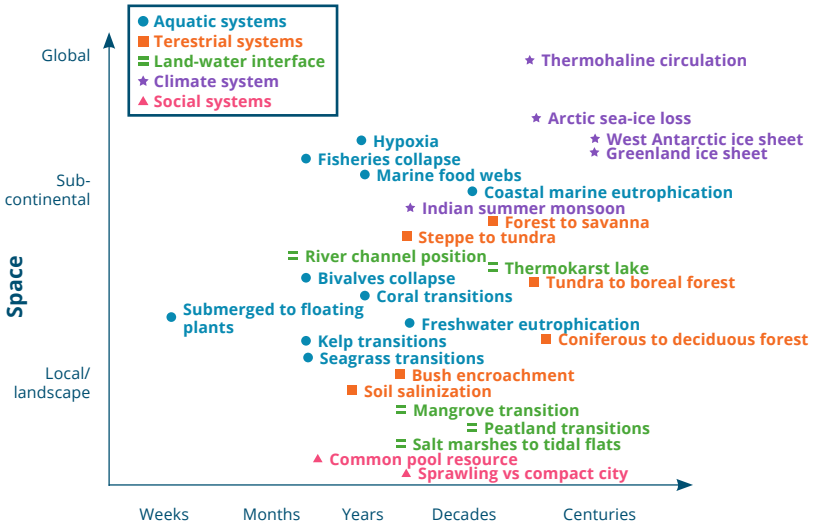
A well-understood, well-studied, and sadly very frequently encountered tipping point is the transition from coral reefs to algae-dominant reefs. You can think about these regime shifts mathematically. The idea is that a system can exist in multiple configurations where different sets of feedbacks dominate (Figure 16). These shifts can occur for two reasons. One is there is some shock that pushes you from one set of feedbacks to another. More usually, there is gradual change in the strengths of the feedback, which means that you can no longer cope with previous shocks. As an example, for the coral

81 *Figure 16*. The occurrence of regime shifts. Adapted from "The Regime Shifts Database: a framework for analyzing regime shifts in social ecological systems," by R. Biggs, G. D. Peterson & J. C. Rocha, 2018, *Ecology and Society, 23*(3):9. Licensed by CC BY-NC 4.0.

reefs, fishing decreases the populations of herbivorous fish. When there is a hurricane, coral reefs do not recover, even though they were able to recover after previous hurricanes because algae are able to outcompete the grazing of the herbivorous fish. Due to the lack of data, these regime shifts are very difficult to predict mathematically.

My colleagues and I have taken a comparative approach to regime shifts by developing a database of what types of tipping points occur. We started with the best-known, most important regime shifts, but have increasingly tried to include more social-ecological regime shifts, from agro-ecosystems and other human-dominated ecosystems. Figure 17 compares some of the regime shifts by the scales at which they operate and their drivers. What you can see from this figure are earth system tipping points, such as the thermohaline circulation that was mentioned earlier, and also these local-scale tipping points, such as eutrophication, and thermokarst collapse in the Arctic. When we look across all of these, what you see is what drives these regime shifts. It is a wide variety of processes that occur at different scales. Some drivers for example are operating at a global scale, such as climate change. These drivers are common, but so are local drivers such as river channel change and coral transition.

FIGURE 17



The spatial and temporal scales at which different types of regime shift operate. Regime shift names are coloured according to ecosystem type: blue are marine regime shifts; green are terrestrial and orange are subcontinental regime shifts.[82]

The scales at which drivers operate reveals who can alter the risk of a regime shift. In the case where there are regime shifts driven by global changes, you can increase the resilience of a desired regime by managing the things on local level, but you only have limited capacity to do that. For example, by changing my grazing practices, I could regulate the probability of a shift between savannah and forest, but at some point, if rainfall increases, this savannah is going to convert to a forest. By assessing the scales at which drivers operate, you can grasp what your options are. There are many regime shifts known to have occurred but whose mechanisms are poorly understood or contested. For example, the loss of Arctic sea ice is something that some people think might be a tipping point, but other people believe it is not. Part of this disagreement comes from not understanding the mechanisms of the shift.

82 *Figure 17*. Spatial and temporal scales of regime shifts. Adapted from "The Regime Shifts Database: a framework for analyzing regime shifts in social ecological systems," by R. Biggs, G. D. Peterson & J. C. Rocha, 2018, *Ecology and Society, 23*(3):9. Licensed by CC BY-NC 4.0.

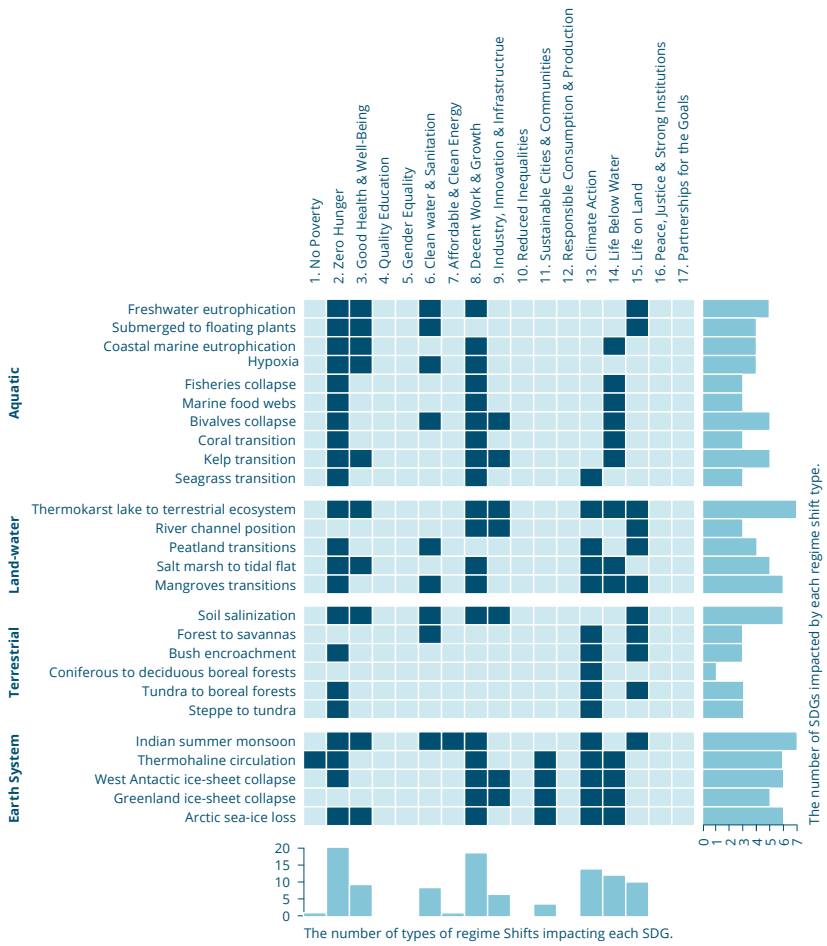
A big part of the risk of tipping points, or regime shifts, is that we know that we are unlikely to be able to predict or control their dynamics.

Finally, regime shifts do not occur in isolation from one another. My colleagues and I used our database to look at potential connections between these regime shifts. Most research on it is disciplinarily focused, rather than looking across them. Comparing regime shifts we found that almost all of them had at least one connection to another regime shift. About 40 % of all possible pairs of connections were actually feasible. Or in other words, there are many pathways by which regime shifts can impact one another, which raises the risk of cascading regime shifts and it needs to be better assessed.

We have also been looking at how regime shifts impact human well-being and therefore we have looked at how they can interfere with the ability of people's ability to achieve the Sustainable Development Goals (SDGs). The SDGs are globally agreed-upon goals for human development. By looking at our database and research on how changes in nature affect people's achievement of different SDGs, we are able to identify how different regime shifts can impact the SDGs (Figure 18). By mapping out where regime shifts can occur, we can also estimate where people are vulnerable to specific types of regime shifts and where they are not. For example, people in Germany are not vulnerable to melting permafrost and the formation or drainage of thermokarst lakes, but people in the Arctic are. Through this mapping process you can identify how many people are exposed to a specific regime shift. By doing that, we can see these regime shifts could have substantial impact on achieving seven of the SDGs. All of the world's regions are vulnerable to substantial disruption. However, most plans for human development take the stability of nature for granted, rather than thinking of how to navigate a dynamic nature, which is the platform on which all of human activity takes place.

Our work does not predict when events occur, or give probabilities of events. But it does characterise the dynamics of nature. And nature is, to paraphrase a famous climate scientist Wally Broecker, 'an angry beast, and we are poking it with sticks.' What he meant by that is as human activities simplify and transform nature we can expect nature to react in surprising ways. And therefore, we should expect surprising things to occur, and we should prepare to be surprised rather than trying to predict the future and eliminate surprise.

FIGURE 18



Preliminary comparison of how different types of regime shifts could impact countries' abilities to achieve the sustainable development goals.[83]

83 Maciejewski, K., R. Biggs, G.D. Peterson, and J. Rocha. Ecological regime shifts could undermine achievement of the Sustainable Development Goals. Manuscript unpublished.

3. Social-ecological Dynamics – Collapse, Resilience or Transformation?

Resilience can be thought of as the capacity of people to successfully cope with surprise. I am now going to talk about social-ecological resilience, and I will focus on work we have done to assess that form of resilience in the Arctic.

People in the Arctic are experiencing a variety of surprises. Climate change is occurring nearly at twice the global rate in the Arctic, which makes the Arctic a sort of forerunner of more extreme change in other places. There are also substantial changes in Arctic governance, quite a growth in population in many areas and loss of population in others. Moreover, there is a large increase in extractive activities, both oil and gas as well as mineral extraction.

What can be said about Arctic social-ecological resilience? We used a theoretical framework developed to think about social-ecological resilience, and operationalised it to compare different places in the Arctic for the Arctic Council's Arctic Resilience Report. This framework focused on four things:

- people's capacity to navigate change and uncertainty,
- nurturing diversity for renewal and reorganisation,
- combining different types of knowledge for learning,
- and creating opportunities for self-organisation.

This framework was developed in the late 1990s, but we were the first to operationalise and test it. We collected 25 case studies where people had conducted research on social-ecological dynamics in the Arctic, and then; based on the research, we divided these cases into three different resilience outcomes (focussed on people's livelihoods): loss of resilience, resilience, and transformation. Loss of resilience represents cases where people lost their livelihoods, while transformation represents situations in which people shifted to another livelihood. For resilience, Yamal Nenets people in the Arctic are reindeer pastoralists who live in an area with a lot of oil and gas development. Their population is growing and their reindeer herding activities at least for now are able to coexist with oil and gas development. For loss of resilience, a different group of reindeer herders in the Russian Far East were prevented from being pastoralists by Soviet and Russian governments, and were unable to cope with flooding. An example of transformation is Cape Dorset, in Canada. It is a small community in the Canadian Arctic where most of the people are artists. They shifted from being hunters to now being internationally known for their Inuit art.

For each of these cases we assessed a variety of traits related to the four categories mentioned above, and compared the cases using qualitative case analysis. We found that this sort of resilience framework worked to predict resilience, and in the Arctic at least, the key things that contributed to it was people's ability to self-organise. That is something that colonialism often restricted, through national policies such as forcible relocations and forced residential schools. For building resilience in the Arctic, one of the best things that Arctic nations could do is remove restrictions on local people and provide people with resources to organise themselves. We are currently conducting a similar analysis for small-scale fisheries around the world, discovering similar results. This suggests that people's capacity to self-organise plays a key role in social-ecological resilience. In particular, we found that the loss of self-organisation was strongly associated with loss of resilience.

4. Transitions for a Sustainable Future

Finally, I would like to address transformation. Many resilient aspects of our society are undesirable and need to be changed. For those things, people need to both decrease their resilience and increase the resilience of desirable alternatives. In sustainable science we are trying to create positive tipping points. I co-lead a project called Seeds of a Good Anthropocene.[84] The idea there is, if we want to have a sustainable world, it has to move away from many of the dominant structures we have today, and it is likely going to be a world that is composed of new things that are quite marginal today. We have focused on research on social-ecological transformations and energy transitions to develop a way of thinking about change. What often happens with change is you get a small group of initiatives that get connected together, and then as they grow up, they either collapse, become incorporated in the status quo, or become a new consortium of things.

Today, there is this real lack of imaginaries of desirable futures to live in. Therefore, in our project we aim to identify these 'seeds' of positive futures and then use them to create new scenarios that imagine desirable futures.

84 The Seeds of a Good Anthropocene project is a collaboration led by McGill University in Canada, the Stockholm Resilience Centre at Stockholm University in Sweden, and the Centre for Complex Systems in Transition (CST) at Stellenbosch University in South Africa. Retrieved 20 November, 2020 from https://goodanthropocenes.net/

By a 'seed' we mean something that actually exists in the world, that could grow to become a major contributor to sustainability in the future. We are purposely trying to be very pluralistic about this process to capture different types of seeds from different places. Some examples are the Foundation for Ecological Security, which combines ecological restoration and land rights in India, restoration of an urban river in downtown Seoul, the Global Seed Bank, which already proved its worth during the Syrian War, and tribal parks in Canada, where indigenous people created parks without the approval of the national government. We are doing analyses of all these kinds of seeds, and how they connect to different Sustainable Development Goals, and transformative capacity. Then we are using these to grow emergent futures. When thinking about the future, there is a real problem that what people consider plausible is completely inconsistent with what actually happens in the world. Therefore, in our project we are not interested in trying to produce likely futures. We are interested in increasing this range and variety of what people consider as plausible futures, and while doing this trying to identify missing tensions, synergies and possibilities for transitions to a sustainable future. This is a really different approach to risk than many of the other talks in the symposium.

Finally, to summarise my talk. I have presented a few approaches to resilience based on my research. Different strategies are useful for building resilience in different ways. Resilience depends on a system's properties such as diversity and connectivity, but it also depends on social processes such as management and governance. Resilience in these processes has been shown to be enhanced by including different voices, being pluralistic, by incorporating complex systems thinking in policies and management, and thinking about the role of slow variables as well as shocks.

Resilience is a way of thinking for navigating difficult-to-understand situations, it is often about trying to move from a linear understanding of the world to a more complex-based approach in management and governance.

Student Rapporteurs

Rapporteurs on Session 4 'Assessing Existential Risks'

Julia Koller
University of Konstanz

I have the great pleasure to start reporting on the topic of existential risks. Existential risks pose a huge challenge because they could lead to nothing less than human extinction itself. However, these kinds of risks are full of 'known unknowns' and 'unknown unknowns'. Today, we were presented with two examples of how scientific institutions have dealt with and are dealing with uncertainties. Regarding Professor Marotzke's presentation, it is clear that the IPCC has committed itself to the highest possible standards of scientific work. This is necessary to maintain the good reputation of the IPCC as a reliable source of information. Yet, one thing has been neglected in the past – a good communication of uncertainties. If we can learn one thing from this example, it should be that it is nearly as important to communicate uncertainties in a precise way as it is important to offer results that we can be confident in. Today, it is of utmost importance to maintain the public's trust in science. It is perhaps the largest contribution science can offer in dealing with climate change and other existential risks that we and future generations have to take on.

Josianne Kollmann
University of Konstanz

I would like to reflect on the talk given by Professor Wieler on the threats of pandemics. He made it rather clear that it is not a question of whether a pandemic will occur, but only when, and that it is most likely caused by an airborne-transmitted disease, like influenza. Therefore, this is another existential risk consisting of many known unknowns. We do know that the danger exists, but we do not know when it will occur and how exactly. As well as in the previous talk on the climate change, the gist of this talk was, how should we deal with uncertainty? Professor Wieler made his recommendation very clear. He suggested smart surveillance as the bread and butter of risk assessment and pandemic preparedness. This surveillance should consist of

a continuous systematic collection and interpretation of health-related data needed for the planning, the implementation, and evaluation of public health practice. Even though the risk of a pandemic contains a lot of uncertainty, we do have the data on previous outbreaks as well as the technical possibilities, such as, for example, artificial intelligence, to prepare for the risk. Based on this surveillance, early outbreak detection, fast intervention, and forecast of outbreak severity is possible. He emphasised how important it is that, to make this surveillance possible, the public health sector needs to cooperate with health authorities and the public. Therefore, one important approach of dealing with uncertainty and existential risks is not running away, as Pan's mother did when she saw her malformed son, it is being prepared when reliable prediction is impossible.

Anna Roessing
University of Bath

In several presentations, experts from different disciplinary backgrounds depicted not only possible future risks and threats but also introduced new approaches to thinking about these events, make them knowable, and ideally manageable.

Three frameworks and questions appeared to me as particularly relevant or thought-provoking in engaging with possible high-impact events in the future: One is the concept of existential risk and its moral and epistemological conundrums in thinking about and responding to low probability but high-impact risks. Second, and related to the first, a renewed interest in the time horizons informing or justifying political action, challenges the prevailing engagement with the future and demands its re-prioritisation. Whilst each presentation engaged differently with the short, medium, and long-term future - ranging from climate models with projections for the coming decades or centuries to pandemic risks analysis that emphasises the short to medium term future - the significance of its events demands for action in the present.

Third, the tension between the uncertainty of these events occurring (or about the different ways they could realise) and the urgency of their prevention, challenges the established methodologies and declared principles of the sciences to be evidence-led. Global health and biosecurity, for instance, emerge as the playing field for scientific approaches to navigate political decision-making yet whilst facing high degrees of uncertainty. It appears a slippery slope to avert false alarms while remaining sensitive and alert to any

weak signals of possible events occurring. What is known or can be reasonably anticipated about the future and the translation of this knowledge into political action, consequently, requires more attention and care.

Central to this endeavour appears a new way of engaging with uncertainties as an inherent aspect to the scientific practice. Prominently - although not exclusively - the climate sciences yet demonstrate the dangers the politicisation of uncertainty may yield. It reveals the intricate yet complicated relationship between 'the sciences' and 'the politics', in which the acknowledgement of limits (imperfect, ambiguous or absent data) in any science-led assessments of the future, and science's credibility to inform political agendas is constantly negotiated. Interdisciplinary work between the natural and the social sciences might prove helpful to understand and navigate the social dynamics surrounding the generation of knowledge, (un)certainty and its interpretation.

Lastly, but importantly, this session also highlighted the opportunity an uncertain, yet non-deterministic future yields for prospects of agency in the present to alter trajectories and outcomes of the future. That means if we do not perceive catastrophic risks as a singular event, but as contingent on our decisions, we maintain time and political space to act. Rather than passively awaiting the next pandemic, political room for manoeuvre remains to develop disease and outbreak surveillance infrastructures, to strengthen global public health systems, and to provide the institutional links between the sciences, politics, and the public in the present.

Rapporteurs on Session 5 'Coping with Risks'

Sophia Knopf
Technical University of Munich

We have heard a lot about the perception and the assessment of risk within the last days, and in this last panel, we turned to possible coping strategies. We were introduced to the two concepts of risk literacy and resilience. As this panel just took place, we have not summarised each presentation, but we are trying to cross-cut and identify what we took away, what might be an inspiration for further thinking and we also have a conclusion.

What really stood out to us was that this panel offered a new perspective on risk; it contextualised it within broader structures. This would be, for example, the social-historical context by acknowledging the role that the experience of others also placed on our own perception, by looking at systems, regimes and regime shifts and, going even further, the biosphere and the Anthropocene. It is inspiring to take into account the day-to-day experiences that we share, but also the broader imaginaries that we have for our future and how we can create it. We also identified familiar topics, i.e. uncertainty and complexity and the discrepancy between the objective risk that we have tried to get a grip on in the last days, and the perceived risks.

Stijn Carpentier
KU Leuven

Those listed above were our main takeaways, but of course, we are students. We are in the comfortable position that, at times, we can use concrete results as a springboard for further speculation. So instead I am going to talk about the things we expected or things that were hinted at but not really elaborated on in this conference. We could have had a conference for weeks. So, while we realise that we will not break new ground, we will not say anything new because we do not have the background. We want to highlight some things that others can perhaps take home and elaborate further upon within their own fields. I am going to talk about actors and audience because I think these are two big things that have been touched upon but not further elaborated. First, the actors. We are scientists adopting this narrative of risk. We are approaching it from our fields. There is a huge difference between what we think about risk, but there are other actors as well, i.e. society, but there are maybe also malicious actors. Perhaps we should start to think about the dual use of risk analysis. Are there maybe commercial concerns that might use our risk resilience or our risk literacy to captivate it and use it for their own profits, or are there malicious governments, like China, Russia, as we talked about yesterday, that might use this risk literacy narrative, in their own narratives?

On a second point, the audience, and I am really glad that anthropology was mentioned. I myself am a historian and a student of Islamic studies, and anthropology is so important in this kind of topic because, one, what is the political relevance of risk? That is something we touched on, the ambiguity between policy making, risk analysis, and then the bigger audiences. But also, what is acceptability of risk, and why should we think that Western

acceptability of risk is the same as, for example, in Southeast Asia? An example from anthropology is Clifford Geertz's research into gambling with animal fights in Bali. They would take enormous risks that for us Westerners are totally incomprehensible. Why they would wage their home for a cockfight, for example.

On a third point, we are analysing risk in terms of linear time. That was also mentioned in some of the talks, but there are still and there always have been communities which analyse time in a cyclical context; for example, in Indonesia, the country with the largest Muslim community. So if you take a risk analysis out of the West and present it to, for example, Ismaili Islam, then it just will not stick. It will not happen.

What do we do if we want to create narratives for this global challenge that hold for the whole world? That is my main takeaway. We really have to embrace all narratives if we want to make a difference as scientists. We cannot stay in the ivory tower. We have to find a connection to our audiences and other actors.

Anna Ajlani
Technical University of Munich

During the past few days, we have learned that blurring the line between science and the public can have quite beneficial effects in times of fighting misperception and reinstating trust in science. As a health scientist, I found it especially interesting how narratives are formed when we are communicating health risks to the public. Keeping the double role we have as scientists and as citizens in mind, this conference has once again emphasised the core purpose of science, which is to serve the public without interest in personal gain and in order to ensure the best and safest possible living conditions for all.

How to Improve Risk Literacy?

Ralph Hertwig
Max Planck Institute for Human Development

Abstract: *This concluding talk briefly addresses four issues in the way people reckon with risk: First, how can we inform people about important risks? Second, how miscalibrated is people's perception of risks? Third, could (some) systematic biases in people's risk perception and behaviours represent adaptive responses to immeasurable uncertainties? Finally, I discuss how two learning modes about risks (descriptions vs. experience) can help us understand a variety of seemingly bewildering risk behaviours and suggest novel ways of communicating risks.*

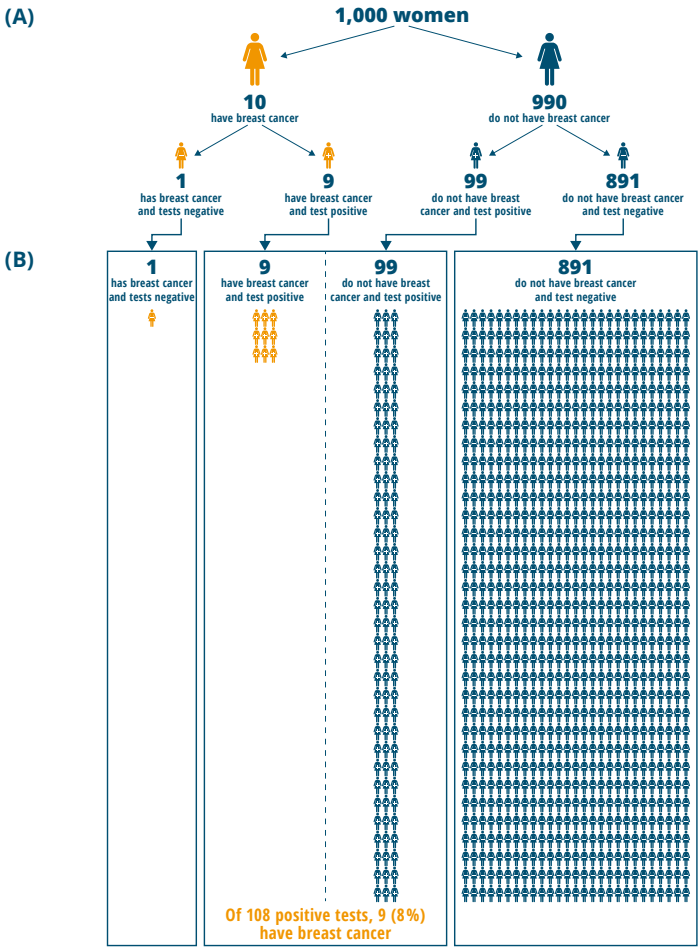
I approach the topic of risk literacy from four different perspectives. The first one is what I call the *Enlightenment approach*. That is the aspiration and belief that people's risk literacy can be boosted.[85] We have heard a number of talks in this conference emphasising how bad people seem to be in their perception of risks. Rather than accepting this verdict, the Enlightenment approach seeks to improve the way people reckon with risks by representing and communicating them as accessibly and transparently as possible.

1. The Enlightenment Approach: Transparent Representations of Risk and Uncertainty

The creed of this approach is that good representations of risk can empower people to gain insights into the existence, likelihood, and magnitude of risks. Let me illustrate one such good representation. A risk everybody faces is that of a serious disease such as cancer. David Spiegelhalter, professor of the Public Understanding of Risk at the University of Cambridge, has thought, possibly

85 Gigerenzer, G., Gaissmaier, W., Kurz-Milcke, E., Schwartz, L.M., & Woloshin, S. (2007). Helping doctors and patients make sense of health statistics. *Psychological Science in the Public Interest, 8*(2), 53–96; Hertwig, R., & Grüne-Yanoff, T. (2017). Nudging and boosting: Steering or empowering good decisions. *Perspectives on Psychological Science, 12*(6), 973–986.

FIGURE 19



Visualizations of the predictive accuracy of a cancer screening test. (A) Tree diagram showing the consequences for 1,000 women attending mammography screening from a population with 1 % prevalence of the disease, when the screening test correctly classifies 90 % of women with cancer and 90 % of women without cancer. Although nearly all the women with cancer are detected, they are greatly outnumbered by false-positive tests arising from those without cancer. (B) Icon array of the same information, which shows explicitly that out of 108 positive tests, only nine (8 %) would be expected to reveal breast cancer.[86]

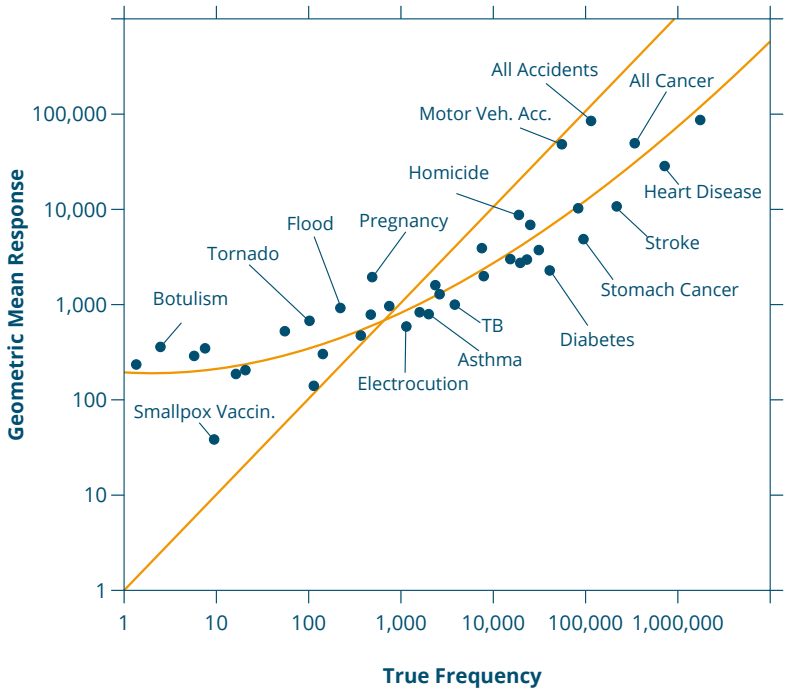
86 *Figure 19*. Visualizations of the predictive accuracy of a cancer screening test. Adapted from "Visualizing uncertainty about the future," by D. Spiegelhalter, M. Pearson & I. Short, 2011, *Science, 333*(6048), p. 1396. Copyright 2011 by the American Association for the Advancement of Science.

more than anyone else, about graphical representations that can foster insight into such risks. Imagine, for instance, an asymptomatic woman who goes to the doctor for a routine mammogram. The mammogram suggests an abnormal result. How worried should she be? It turns out that the probability that she actually has breast cancer given the positive test result (the positive predictive value) is relatively small: 8 %. A transparent depiction of the underlying information that gives rise to this number is shown in Figure 19. The graph starts with 1,000 women who have had a mammogram. Among this group, there is a large group of 990 women who do not have breast cancer. Yet some of them will still test positive because the diagnostic test is not perfect. There is a much smaller group of women who do have breast cancer, and most of them will test positive. It is then the ratio of the false-positive results relative to all positive results that is crucial. Specifically, out of 108 people who test positive, only nine of them, or 8 %, actually have breast cancer. The key to this relatively small probability is that most of the positive results are false positives. The tree in Figure 19 is a visual representation that walks people through the relevant quantities in order to clarify how one arrives at this crucial number, 8 %.

2. Systematic Over- and Underestimation of Risks

The intent of the Enlightenment approach is to foster an accurate understanding of risks by giving people specific cognitive tools and representations of information. What appears to underlie this endeavour is the ideal of a well-calibrated citizen, a person who has a reasonably accurate mental model of the risks in their world. Is that a realistic goal? And is it even desirable? Let me introduce you to a classic graph from Lichtenstein, Slovic, Fischhoff, Layman and Combs (1978). These authors started a line of research in the late 1970s exploring people's calibration of risks. People were asked to estimate the mortality rate (in the United States) associated with a wide range of risks, including motor vehicle accidents, botulism, and lung cancer. Figure 20 plots these estimates against the risks' true frequencies. The results strongly suggest that people's perceptions of risks are not well calibrated: They often overestimate rare risks (e.g. botulism) and underestimate common ones (e.g. stroke).

FIGURE 20



The relationship between estimated and actual number of deaths per year for 41 causes of death. Each point is the mean estimate (geometric mean) of 39 students. The observation that, for rare causes of deaths, the mean estimated number is higher and that, for frequent causes, this number is lower has been called the *primary bias*. The curved line is the best fitting quadratic regression line.[87]

This graph has become iconic, supporting a widely drawn conclusion that people appear to fear the wrong things.[88] Yet this pattern of estimation is not unique to estimates of risks. The pattern of overestimation of rare events and underestimation of common events occurs across a wide range of domains.

87 *Figure 20*. Graph of estimated and actual number of deaths per year. Adapted from "Judged frequency of lethal events" by S. Lichtenstein, P. Slovic, B. Fischhoff, M. Layman, & B. Combs, 1978, *Journal of Experimental Psychology: Human Learning and Memory, 4*(6), 565. Copyright 1978 by the American Psychological Association.

88 See for instance Renn, O. (2014). *Das Risikoparadox. Warum wir uns vor dem Falschen fürchten*. Frankfurt am Main: Fischer.

For instance, Sedlmeier, Hertwig, and Gigerenzer (1998)[89] asked people to judge the frequency of letters in the first or second position in German words. People proved to be surprisingly good at the task. The estimated relative frequencies in the first versus the second position closely agreed with the rank ordering of the actual values, except for an overestimation of low values and an underestimation of high values. This pattern of over- and undershooting is not unique to estimates of risks. It appears to occur whenever there is a high degree of epistemic uncertainty (incomplete knowledge). This pattern has also been explained as a consequence of *regression toward the mean*, a statistical regularity associated with unsystematic noise in the estimates.[90] One consequence of this interpretation is that the pattern in Figure 20 is not unique; it occurs in domains other than estimates of risk, and in order to explain it, one need not assume that the way people process risk-specific information is systematically distorted.

3. Can Misperceptions be Adaptive?

Imagine you are walking in the dark and hear an object coming toward you. You are likely to perceive this sound as approaching at a higher speed than that of equivalent receding sounds. Neuhoff, who found this effect, suggested that throughout human evolutionary history looming objects have posed a threat to survival. For this reason, perceptual systems have evolved that are adaptively biased, giving people the impression that the object has arrived when it is actually still some distance away.[91] The bias provides people with a temporal margin of safety, securing them a bit more time to initiate protective actions. This is just one example showing that the human perceptual system includes adaptions that have been shaped by environmental challenges. These adaptions weigh systematic biases higher than accuracy.

The existence of these adaptations should give us pause when we consider the ideal of the well-calibrated citizen. Consider one reaction Americans

89 Sedlmeier, P., Hertwig, R., & Gigerenzer, G. (1998). Are judgments of the positional frequencies of letters systematically biased due to availability? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*(3), 754–770.

90 Hertwig, R., Pachur, T., & Kurzenhäuser, S. (2005). Judgments of risk frequencies: Tests of possible cognitive mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(4), 621–642.

91 Neuhoff, J. G. (2016). Looming sounds are perceived as faster than receding sounds. *Cognitive Research: Principles and Implications, 1*, 15.

had to the terrorist attacks on September 11, 2001. Gigerenzer showed that Americans reduced their air travel after the attack, and, for a period of one year, interstate highway travel increased.[92] This, in turn, appears to have caused an estimated 1,500 more Americans to die on the road than would otherwise have been expected – possibly in an attempt to avoid the fate of the passengers who died on September 11. One interpretation of this analysis is that it is just another example of people fearing the wrong things. Travelling by plane is extremely safe and the additional death toll could have been avoided had Americans not panicked and altered their behaviour. Yet this conclusion benefits from hindsight. In the months after September 11, nobody could say with certainty whether air travel had become subject to more risks from the ground, the airspace, or inside the plane. From this perspective, avoiding air travel, at least for some time, could be seen as an adaptive, cautionary response to a highly uncertain world in which past standard assumptions about risks and safety may no longer hold. Perhaps Americans simply behaved as our ancestors did when they reacted as if looming objects were approaching faster than they actually were.

4. The Description–Experience Gap: Two Modes of Learning About Risks

Many experts consider Mount Vesuvius to be the most dangerous volcano on earth. It is an active volcano in the vicinity of a large metropolitan area, the city of Naples. Why is it so dangerous? Volcanologists estimate the layer of magma under Vesuvius to be vast, and the statistical probability that the volcano will erupt increases each year. The consequences for the residents of Naples would likely be catastrophic.[93] How do Neapolitans respond to this looming disaster? The response is a bit odd; indeed, some residents have gone so far as to settle in close proximity to the volcano. The government has offered incentives for resettlement, but without much success. As one astute observer noted: 'In the shadow of Vesuvius, those residents have cultivated a remarkable optimism… and a form of denial as deep as the earth's

92 Gigerenzer, G. (2006). Out of the frying pan into the fire: Behavioral reactions to terrorist attacks. *Risk Analysis, 26*(2), 347–351.

93 See for instance Mastrolorenzo, G., Petrone, P., Pappalardo, L., & Sheridan, M.F. (2006). The Avellino 3780-yr-B.P. catastrophe as a worst-case scenario for a future eruption at Vesuvius. *Proceedings of the National Academy of Sciences of the United States of America, 103*(12), 4366–4370.

molten core'.[94] This diagnosis invoked two psychological concepts: overconfidence and a defence mechanism. One or both may well be at play. But here is another possible explanation that takes Neapolitans' actual experience into account: The last violent eruption of the volcano occurred in 1944. More than 27,000 days have passed in which residents experienced no violent eruption, despite experts' warnings.

Mount Vesuvius and some Neapolitans' seemingly reckless behaviour are a good example of how making a distinction between two ways of learning about risk can shed new light on behavioural puzzles.[95] To put it simply, people can learn about risks in terms of description-based warnings: typically, symbolic representations using numbers, images, or other visual depictions. But in most domains of human life, symbolic representations do not exist. In these cases, there are other modes of learning. One is to learn about risks through experientially engaging with the world, for instance, by exposing oneself to a risk and experiencing the consequences or lack thereof (e.g. drinking alcohol, engaging in unprotected sex, downhill skiing). Description- and experience-based learning modes imply different psychological impacts of risks. Psychologists' research on human choice behaviour (often using choice between lotteries) has found that in decisions from description people commonly behave as if they overweight the psychological impact of rare events (relative to their objective probabilities); in decisions from experience, in contrast, people commonly behave as if they underweight the impact of rare events. The divergent weighting patterns for rare events in description and experience can lead to systematically different choices, thus giving rise to the description–experience gap.[96] Let us turn to why this gap matters for understanding risk behaviour.

94 Bruni, F. (2003, August 26). San Giuseppe Vesuviano journal; who's afraid of Vesuvius? (Pompeii is history). *The New York Times*. Retrieved 20 November, 2020 from https://www.nytimes.com/2003/08/26/world/san-giuseppe-vesuviano-journal-who-s-afraid-of-vesuvius-pompeii-is-history.html

95 Hertwig, R. (2015). Decisions from experience. In G. Keren & G. Wu (Eds.), *The Wiley Blackwell Handbook of Judgment and Decision Making* (Vol. 1, pp. 239–267). Chichester, England: Wiley Blackwell.

96 Hertwig, R., & Erev, I. (2009). The description–experience gap in risky choice. *Trends in Cognitive Sciences, 13*(12), 517–523.

5. A Fourfold Pattern of Epistemic States and Simulated Experience

In a broad simplification, all of us live in four different epistemic states with regard to risks. In some cases, people can only access their experiences because no descriptions are available; in other cases, people can only use descriptions because they lack experience. In still other cases, people can avail themselves of both kinds of knowledge, and in a fourth type of case, people are blank slates, lacking both experience and description-based knowledge. These are four distinct epistemic states.

Let us first consider the example of a person with access to both kinds of knowledge: a smoker. Nowadays, smokers learn experientially each time they light up as well as through myriad descriptions of the risks associated with smoking (e.g., health warnings on cigarette packs, newspaper reports, health statistics). The simultaneity of description and experience also holds for Neapolitans and their thinking about the risk the volcano poses. Experimental studies suggest that in this epistemic state, experience will eventually gain authority over description, even if descriptions originally anchor people's response to risks. The psychological tendency for a person to behave as if they are underweighting rare events (the risks) will begin to dominate. Such a tendency will be even more pronounced in an epistemic state that only affords experience and in which the sample of experience is limited. For illustration, consider a person who has had few sexual partners and has neither used protection nor consulted any descriptions of the risk of infection. He may deem unprotected sex to be harmless (underweighting of rare events) because he has not, to his knowledge, contracted a disease. The opposite tendency will be pronounced when the epistemic state includes only descriptions – for instance, in the case of parents considering whether to have their first child vaccinated. They may begin to research potential side effects online. In their mind, extremely rare side effects of vaccination, untamed by an actual experience of the rarity, may loom larger than they should in light of their objective probabilities (overweighting of rare events). It is hard to arrive at any systematic prediction about how people in the final epistemic state, devoid of both description and experience, respond to rare risks.

Distinguishing between these four epistemic states and the differential weighting of rare events in description and experience is likely to bring forth new insights into behavioural responses to risk. It may also suggest

new ways of communicating risk. For instance, a person's limited sample of experience with a rare risk is likely to mean they have been spared from experiencing it. They may therefore ignore risk warnings. In contrast, a lack of experience can result in descriptions of rare events (e.g., side effects of medication) looming larger than they should. In both of these epistemic states, a simulation of experience may help combat undesired behavioural tendencies by experientially demonstrating either that with enough experience even rare events sometimes occur or that rare events are indeed rare. Take, for illustration, risks in financial investments. Traditionally, financial advisors inform their clients about investment risk using symbolic descriptions such as graphs of return distributions. More recently, researchers have begun to study an alternative called *simulated experience*. Here, investors who lack experience with the stock market randomly sample and thus experience a relevant return distribution. Several studies have found simulated experience to have multiple beneficial effects for investors: It led to more accurate risk perceptions, a higher sense of being informed about the available prospects, higher confidence in the investments made, and higher investments in risky prospects when it was appropriate.[97] Learning centres in Japan that simulate the experience of being caught in the middle of a powerful earthquake in order to help members of the public understand the visceral nature of the risk are another example of how simulated experience can be harnessed to beneficial effect.

Let me briefly summarise a few main points. First, risk communicators can, should, and must aim to boost risk literacy as envisioned in the Enlightenment approach. But there will be limits; not everything about risks can be represented transparently and not everybody wants to engage with these types of educational tools. Second, a strong assumption runs through research on risk perception and communication that people should be well calibrated to the risks in the world. Perhaps, as the case of adaptive misperception of the speed of a looming sound suggests, it is worth thinking about how invariably valid this assumption is. Finally, the description–experience distinction has, I believe, enormous value for understanding behaviours that seem irrational: remember the Neapolitans. Acknowledging the role of experience in risk communication also opens up new avenues for representing risks and for harnessing the authority of simulated experience.

97 See for instance Kaufmann, C., Weber, M., & Haisley, E. (2013). The role of experience sampling and graphical displays on one's investment risk appetite. *Management Science, 59*(2), 323–340.

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