EXPLORING EARLY WARNING SIGNALS ACROSS DISCIPLINES

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Abstract

Introduction: Throughout history, civilizations have relied on early warning signals, as is seen exemplified by the famous Mayan prediction of the apocalypse. Despite their importance across domains, early warning signals are often confined within disciplinary boundaries. This study aims to explore how early warning signals overlap across disciplines and how collaboration could enhance their comprehension. Additionally, the article examines possible actions and associated obstacles.
Methods: A qualitative study consisting of 14 semi-structured interviews were conducted online via Microsoft Teams with 14 participants from diverse backgrounds, recruited through email. Inductive thematic analysis was employed.
Results: Interviewees identified various early warning signals specific to their fields, reflecting the complexity and difficulty in interpretation. Despite signal diversity, similarities emerged such as the need for timely action and the recognition of delicate system balance that may lead to abrupt shifts. Collaboration across disciplines was crucial for understanding and responding to signals. The results highlighted a diverse range of actions. While proactive approaches were evident, other disciplines leaned more to communication and policy translation. However, obstacles such as financial challenges, delayed disease detection and a lack of urgency hinder proactive responses.
Discussion: This study showed the complexity of early warning signals, echoing previous research on challenges defining them. The findings echoed the variability and context-dependency of these signals. Interviewees emphasized the importance of cross-disciplinary collaboration aligning with other studies. Future research could expand the sample size, diversity and potentially develop an integrated framework for identifying and responding to early warning signals.

Introduction

The Mayans famously predicted that the world would end on December 21st, 2012, although their predictions fortunately did not result in an apocalypse. Nonetheless, it does illustrate the use of early warning signals throughout history (1).
In the modern world, numerous complex systems exist, ranging from climate patterns to health conditions. For example, specific signals precede the onset of draughts in climate systems(2). Similarly, in medicine certain signals may indicate the potential development of diseases like cancer. Each of which have early signals what would have indicated an upcoming tipping point, sometimes only recognized in hindsight (3). The signals may vary across disciplines, meteorological and soil indicators for meteorological variability (4-8) or virus spreading and vaccination coverage for public health (9-15). If the signals remain hidden or unrecognized, the (financial) impact can be enormous (4-15). The COVID-19 pandemic serves as a prime example (9). Evidence suggests that earlier non pharmaceutical interventions could have halved the cumulative deaths in the United Kingdom (12-14).

Furthermore, research has explored various theories on tipping points such as 'critical slowing down (16-18) or the bifurcation and center manifold theory (19),(20). The progression of complex diseases over time may adhere to the principles of the bifurcation theory (21),(22). This theory suggests that individuals, in the absence of symptoms, remain in a state of apparent normalcy. The pre-disease state, where cancer is developing, may take up to twenty years. However, within this 'normal' state the individual can be with relatively no symptoms although there could be subtle signs such as incubation or inflammation. The disease state is characterized by difficulty in recognizing the individuals as sick, and treatment may not fully restore them to a normal healthy state. Conversely, the pre-disease phase can be of significance as it can be potentially reversible. This phase signifies a critical juncture where timely intervention can restore individuals to a state of health. Thus, to prevent diseases like cancer it can be of significance to look at the early warning signals of the pre-disease state. If one can detect the early warning signals of the pre-disease state one can prevent the disease from progressing all together (19) ,(22).

There is a significant amount of literature on early signals within individual domains as well as on general transition patterns and tipping points (3),(16-23) In each of these fields early detection, thus early warning signals, play an important role. Moreover, they all do extensive research in early warning signals analyzing the characteristics and share them with fellow researchers in mainly their own field. Despite the collective focus on early warning signals the different backgrounds do not lead them to the same conferences or scientific journals. This lack of transdisciplinary interaction could prevent the ability to see connections between seemingly unrelated signals. As a result, this could lead to a delayed action to the signals until it is too late (24). Here we aim to take the first steps exploring the conceptual commonalities of early signals across various domains, not to discern general patterns, but to broaden the perspective on early signals within the respective fields. The question is: how can perceptions, prediction models and consequential actions of an early signal in one domain help those in another? For instance, is there room for rational decisions in public health (such as, early shut-down of society in case of an approaching pandemic) based on the characteristics of the indicators that are used in tsunami warning systems? Therefore, this article focuses on the question: How do early warning signals overlap across different fields, and how does collaboration between disciplines affect how these signals are understood and acted upon? Additionally, what actions are taken in response to these signals, and what obstacles hinder proactive intervention.

Materials and Methods

Research design

This study is an interpretative qualitative interview study. Through the use of an inductive thematic analysis, the aim is to examine the perspectives on early warning signals across different disciplines

Participant recruitment

The study population consists of people specialized in different fields (table 1). Participants were recruited through email, or through the research project Better Wave than Worry, which aims to build a domain- agnostic knowledge base for detecting, aligning and using early warning signals (24). This method of recruitment yielded 16 participants and 14 participants were willing to participate in this study.

Interviewee Number	Professional Background
Interviewee 1	Genetics
Interviewee 2	Veterinary Medicine specialized in cardiology
Interviewee 3	Veterinary Medicine specialized in mosquito borne infectious diseases
Interviewee 4	Simulation models about epidemiology of infectious diseases
Interviewee 5	Bioethics of emerging technologies
Interviewee 6	Psychology of clinical genetics
Interviewee 7	Simulation model about the epidemiology of infectious diseases
Interviewee 8	Ethics of clinical genetics
Interviewee 9	Genetics and language development
Interviewee 10	Neuronal networks and optical communication
Interviewee 11	Parasitism (plant)
Interviewee 12	Extreme weather events
Interviewee 13	Societal challenges
Interviewee 14	Cardiogenetics

Table 1 Participants professional background

Data collection

A total of 14 semi-structured interviews were conducted, all of which were held online via MS Teams between March 18th and April 22, 2024. The interviews were facilitated by two independent researchers, with each researcher conducting a portion of the interviews. Except for three interviews conducted in English, all others were conducted in Dutch. Each interview lasted approximately 45 to 60 minutes. Prior to the interviews, participants signed consent forms to grant permission for audio recording and transcription. The interview guide comprised of three main themes, signals, interdisciplinary and actions, was developed before data collection (table 2). Before data collection, the interview structure and discussion topics underwent pilot testing with our supervisor from the genetics department UMC Utrecht to ensure coherence and relevance.

Topic	Example questions
Signal	What is an early warning signal?
	What is your understanding of early warning signals within your field or domain are they used in daily practice?
	What is the timeframe in which your signal can be detected?
	Can you provide examples of early warning signals that have been identified or used in your area of expertise? (traffic light, ticking bomb, goose bumps moment, Duracell battery
Interdisciplinary	Have you collaborated with researchers from other disciplines or fields in the past? If so, could you provide examples?
	What are some common characteristics or patterns you have observed among early warning signals across diverse domains?
	How do you perceive the importance of interdisciplinary collaboration in the identification and utilization of early warning signals?
Actions	What are possible actions in response to the identified early warning signals and who is responsible for them
	What obstacles or factors contribute to a lack of proactive responses to early warning signals in your field or domain?
	What is the impact of actions based on your signal?

Table 2 Topics and example questions used during the interviews

Data analysis

A total of 11 interviews were transcribed in Dutch, with an additional 3 conducted in English using Microsoft Teams. Due to technical issues with Microsoft Teams transcription, one English interview was transcribed using Microsoft Word. Additionally, a dictaphone was used to record audio as a form of data backup, ensuring audio recordings were available in case Microsoft Teams failed. All transcripts were read and coded by two researchers independently (AB) and (EV). The identified topics provided the groundwork for developing categories and codes during deductive coding, resulting in 8 categories and 78 codes (appendix 1). Combining inductive and deductive coding thus iterative coding enabled a comprehensive analysis of the data.

Results

We interviewed 14 experts in genetics, veterinary medicine, bioethics, optical communication, simulation models, optical communication, plant parasitism, extreme weather events and societal challenges on the characteristics and consequences of early signals in their respective research fields. For most of the experts the Better Wave project was their first acquaintance with 'early signal' as a transdisciplinary concept. Most had difficulties discerning specific characteristics of the early signals within their respective disciplines, but the analysis revealed several interesting leads.

Signals definition and interpretation

Most interviewees identified a variety of warning signals specific to their respective fields (table 3), indicating that these signals are both complex and difficult to interpret. While they could illustrate the signals very precisely, respondents had difficulties defining precisely what constitutes and early warning signal. One of them defined it as follows

" So, among a lot of the signals, [...] the one which really matters and the ones that gives you a warning is the one which matters more into a network of signals". – Interviewee 10

Or simply:

"[...] It's very, very complex I think ". – Interviewee 10

Professional background	Signal	Comparison
Genetics	Mutation in DNA, variant in a gene	Traffic light (information for action), time bomb (establish before disease is developed), goosebumps (feeling about impact of signal)
Veterinary medicine specialised in cardiology	Mutation in DNA, variant in a gene, biomarker for fibrosis (blood/serum)	Bin of colored marbles; color indicates disease, carrier or healthy variants and are chosen with policy
Veterinary medicine specialised in mosquito borne infectious diseases	Antibodies in animals, blood samples, clinical signs, virus particles	Multiple pins in a haystack
Simulationmodel about epidemiology of infectious diseases	Info from media, RIVM, KNMI, GGD, farm, prevalence of disease	The Sims (computer game)
Bioethics of emerging technologies	Friction points, conflicting values	Goosebumps / gut feeling
Psychology of clinical genetics	Friction points, conflicting values, need or doubts about new technology from society / science	X
Simulationmodel about epidemiology of infectious diseases	Fluctuations: transmission of infection, statistical indicators (variance / autocorrelation)	Fully loaded boat that can move back and forth, but may capsize at some point
Ethics of clinical genetics	Signals of fear / interest from society, signals from scientists about the development of new techniques for which there is no moral framework / legislation yet	Hope / gut feeling
Genetics and language development	Abnormal language development	Red flag, traffic light.
Neuronal networks and optical communication	Difficult to define :The signal that has more weight into a network	Too complex to make a comparison
Parasitism (plant)	Abnormal plant characteristics, abnormal growth.	Duracel battery
Extreme weather events	Weather forecast, el niño/ la niña,	Alarm,
Societal challenges	History and society	Ticking of a bomb
Cardiogenetics	Patient, variant in a gene,	Bell-ringer (patient) , duracel battery (patient), goosebump moment (variant in gene)

Table 3 Overview of signals and comparisons identified by our interviewees

Furthermore, interviewees were asked to draw comparisons between their early warning signals and familiar concepts, such as a traffic light, ticking bomb, goosebumps moment or any other analogy they found suitable (table 3). Interestingly their responses varied widely, with only four people offering the same comparison, two used 'traffic light' and two used 'gut feeling'. Despite the variety of comparisons several similarities can be found among the responses. For instance, the analogies such as 'red flag', 'traffic light', 'ticking bomb' and 'alarm' can indicate a sense of urgency and imminent danger, emphasizing the importance of timely action in response to signals indicating potential risks or threats. Additionally, comparisons like 'Duracell battery' or 'fully loaded boat that can move back and forth, but may capsize at some point' both potentially can indicate the delicate balance of systems and may eventually reach a point where they fail or deplete. They can illustrate the systems that can operate smoothly but may undergo abrupt shifts or reach critical thresholds.

"An example I have is a boat or a ship. [...] When heavily loaded, its stable. When pushed to the side, a heavily loaded boat takes longer to return to its initial state [...] ". – Interviewee 7

As a result of the complexity, interpreting the impact of early signals inherently comprises a certain level of uncertainty. Interviewees had a variety of responses on dealing with uncertainties regarding signals. Some mentioned the importance of seeking confirmation for unknown factors, or perceived it more as prediction or advice. Interestingly, some participants exhibited a higher tolerance for uncertainties, by either selectively ignoring uncertain issues or having multiple alternative strategies.

" So simply ignoring uncertain things, the risk of that is that things can escape your attention that might be relevant". – Interviewee 12

<u>Working across disciplines</u>

There was unanimous agreement among interviewees regarding the importance of collaboration between various disciplines in order to benefit from each other's insight and experiences. This does not only include interaction between scientists or professionals, but also comprises interactions with society as a whole emphasizing the need for collaboration beyond traditional disciplinary boundaries.

"A comprehensive understanding of the entire problem requires expertise across multiple specialties, backgrounds and scientific domains". - interviewee 11

" [...] Perhaps you have even less interdisciplinary collaboration within the academy, but then you're more likely to continue further. I also mean transdisciplinary, or that you shouldn't just continue working only with scientists, but that you should also look at which societal organizations you can involve, for example, so that you don't remain so abstract, I think". - interviewee 5

One interviewee pointed out that working interdisciplinary is a valuable opportunity to learn from each other. Suggesting that individuals can benefit from each other's insight and experiences.

" I think that aligns with the imaging work that the extreme weather specialist was involved in. We could potentially complement that with the MRI scans were planning to conduct. For instance, AI-based image analysis is something that I believe has been further developed in that context. Here with animals, there has not been much progress yet, but it's something that is increasingly being done in human research. So there seems to be an opportunity there indeed". – Interviewee 2

Despite the consensus, many acknowledged the challenges of effectively communicating and understanding across different disciplines.

" The coordination from the multidisciplinarity. […] I think it adds a lot of value, but multidisciplinarity is not something people are naturally good at. And often people think they are". – *Interviewee 8*

These insights underscore the importance of collaboration across disciplines in tackling complex problems. While collaboration presents opportunities for mutual learning and sharing insights it can also provide challenges in effective communication and understanding across disciplines. These results highlight the need for having an environment that supports and encourages interdisciplinary collaboration, while also addressing the barriers. Addressing the barriers could enable us to better interpret and respond to early warning signals across diverse field.

Actions and obstacles

The interviewees provided an extensive range of actions in response to the early warning signal identified within their respective fields (table 4). The actions ranged from specific medical interventions, running models on computers to broader societal measures aimed at alleviating the consequences of various threats, such as droughts or disease outbreaks.

Professional background	Actions	Obstacles
Genetics	Double check if variant is pathogenic, refer to treating physician, possibly clinical trials (new treatment)	Often only when disease has developed and not preventive ('late notice'), show financial/cost effectiveness
Veterinary medicine specialised in cardiology	Share outcomes with breed associations and offer DNA testing to breeders for the disease variant found Offer breeding program to pair dogs that produce healthy offspring	Patients often only come late when disease has already developed ('late notice'), human researchers do not immediately think of animal/dog models, owners care more about their own interests than animal health, shifting responsibilities, financially
Veterinary medicine specialised in mosquito borne infectious diseases	Take precautions against mosquitoes/disease, vaccinate, cull high-risk groups, put puzzle pieces and signals side by side, seek confirmation, try to predict, weigh signals, report certain diseases, deploy diagnostic	Lack of knowledge / awareness of possible viruses / infections / diseases during diagnosis -> late notice, symptoms too mild to raise the alarm immediately, cross-reaction of antibodies for different viruses, travel and vaccination interferes with diagnostics , lack of finances / manpower / urgency (only urgent when outbreak occurs)
Simulationmodel about epidemiology of infectious diseases	Test interventions with models, weigh signals / factors, cull risk factors, inform and advise to advisory committees, health council, government, farms, monitor, publish	Hard to predict where and when something will break out or spread, many assumptions instead of certainty, privacy of data farms e.g.
Bioethics of emerging technologies	Communicate conflicting values, advisory report to research group/government	No clear action/little impact action.
Psychology of clinical genetics	Communicate/inform, establish values, translate and advise on policy	Incomplete signals (not everyone represented) & bias (people already interested in science), beliefs (culture/religion), lack of trust in science
Simulationmodel about epidemiology of infectious diseases	Monitor, precautionary measures, weigh signals, share outcomes, develop multi-use model	Late notice: only during epidemic, lack of knowledge/awareness, collect enough clear data, lack of urgency (only during epidemic)
Ethics of clinical genetics	Desired outcome, ethical, society represented, awareness	Distrust in science, uncertainty about technology, incomplete signals (not everyone represented)
Genetics and language development	Prevention, additional guidance precautionary measures	Financial, time, lack of knowledge/awareness, unfeasible, alarm raised too late
Neuronal networks and optical communication	Run models on a computer to be able to train the chip create some sort of a memory	Different signals to weigh, lack of knowledge, lack of urgency , financial , political
Parasitism (plant)	make detection tool, play with cultivation frequency, plant immune response, growth, integrated pest management	Lack of knowledge, too late to raise the alarm, financial, political, time
Extreme weather events	Social actions against e.g. consequences of drought eg against famine	No clear action on a large scale. Technical limitation, financial, political, security, limited time, not enough capacity.
Societal challenges	Give advice, no action necessary.	Financial, political, no clear action known
Cardiogenetics	Treatment, screening	Security needed , patient , time , financial, lack of knowledge

Table 4: Actions in response to early warning signals and associated obstacles

Many interviewees outlined steps tailored to their disciplines, demonstrating a proactive approach. In the field of genetics actions included verifying the pathogenicity of variants, screening and prevention. Similarly, in veterinary medicine, interventions ranged from vaccinating animals to culling high-risk groups (table 4). However, in field like bioethics and societal challenges actions revolved more around communication and policy translation (table 4). Tough while most emphasized the importance of proactive interventions, some interviewees highlighted the absence of any immediate action necessary.

"[…] What we are actually trying to do is prevent people from getting sick or at least animals. If it is really a virus that has a lot of impact, then you would actually want to be even earlier, you would almost want to predict it". – Interviewee 3

"We don't really have […] to do anything. We don't even need to say you have to do this. We write reports and say how citizens think about something in the hope it might be considered in the policy". – Interviewee 13

Furthermore, a significant amount of the actions described by the interviewees involved collaboration and communication with other disciplines. This underscores the importance of multidisciplinary cooperation in responding to early warning signals. Interestingly, one interviewee highlighted uncertainty over technology and trust in science as a significant obstacle.

"If we […] find something that shows potential for strong collaboration with a breed association we […] try to present the results and also explore how we can quickly translate that into a DNA test. Additionally, we aim to disseminate it through various communication channels we have for such purposes". – Interviewee 2

Simultaneously, interviewees highlighted various obstacles in responding to early warning signals (table 4). Firstly, the impact of financial challenges in for instance the high costs associated with treatments or interventions can pose significant barriers.

"[…] Those gene therapies are so expensive, and for Duchenne, one was approved […] in 2023, costing 3 million euros per patient. I think the high costs are also something that, […] could pose problems". - Interviewee 8

Furthermore, several interviewees pointed out the difficulty in handling the late notice in disease management particularly late detection. Thus, the issue of diseases being identified only after they have developed, rather than through preventive measures. Additionally, some interviewees perceived a lack of urgency in addressing problems. One interviewee compared it to climate change, people know that it is serious but action is lacking.

"[...] It's still very difficult to conduct research on it, because at this point, the patient comes in with complaints and then you're actually already too late". - Interviewee 2

These results highlight the diverse range of actions and their obstacles undertaken in response to early warning signals. While proactive approaches were evident, other areas leaned more to communication and policy translation. Collaboration and communication with other disciplines were also components of many actions, emphasizing the importance of multidisciplinary cooperation. Additionally, several obstacles were identified in response to early warning signals. Such as the financial challenges, the lack of urgency and the delayed detection of diseases. These findings illustrate the importance of proactive measures and interdisciplinary collaboration in effectively responding to early warning signals, while also underscoring the need for more urgency in responding to signals.

Discussion

In this study, early warning signals across several disciplines were explored through interviews with 14 experts from diverse backgrounds. Three key themes were explored, signals, interdisciplinary collaboration and actions. The results revealed a relatively diverse range of signals specific to each discipline, showing the challenge of precisely defining early warning signals. Furthermore, the interviewees unanimously emphasized the importance of interdisciplinary work while some also underscored the value of transdisciplinary work. However, challenges across disciplines were acknowledged. Additionally, interviewees described various actions in response to signals, from specific interventions to collaborative efforts. Yet, obstacles such as financial challenges and late disease detection hindered proactive intervention. Moreover, some interviewees perceived a lack of urgency in addressing problems.

Our study identified a notable challenge in precisely defining an early warning signal, drawing upon findings from previous research in various disciplines (3),(25),(26). While each discipline presented a unique array of signals, our findings highlight a common struggle among interviewees to articulate a clear and concise definition. This aligns with the notion that early warning signals are context-dependent and may vary widely across different systems and disciplines (3). In the results some interviewees compared their signal to' a boat that may capsize' or a 'Duracell battery'. Both comparisons potentially indicate the delicate balance and the possible reaching of a tipping point. This aligns with existing literature showing that signals can have a certain tipping point, at which they undergo abrupt changes or reach critical threshold (3),(16-23). Scheffer et al. illustrated also how similar early-warning signals can appear in widely different systems, such as a flickering before epileptic seizure or the end of a glacial period (3). Additionally, some signals could indicate a sense of urgency and imminent danger. Hengsen et al. formulated it like this a signal is a flashpoint or initial event, which could signify the onset of a crisis, serves as a precursor to the implementation of strategies and interventions aimed at averting the escalation of the situation into a full-blown crisis (27). Thus, some signals encourage proactive intervention emphasizing the importance of timely action in response to signals indicating potential risks or threats. Another characteristic found in literature, which was not evident in our results, is Ansoff's acknowledgement of the imprecise nature of early warning signals. He suggests when a potential threat emerges in an organization, they must be prepared for very vague information. He describes an early warning signal as a vague early indication about a significant impactful event (28).

Although working interdisciplinary was unanimously important according to our interviewees. One interviewee pointed out it is not always easy to understand each other. As is confirmed in the literature by Klein et al. Effectively engaging in interdisciplinary collaboration requires more than just bringing together experts from different fields; it demands intentional efforts to foster cooperation and generate new insights (29).

There was unanimous agreement among interviewees regarding the importance of collaboration between various disciplines in order to benefit from each other's insight and experiences. Thus, the collaboration beyond traditional disciplinary boundary to tackle complex issues. This perspective resonates with recent studies that say trans disciplinarity addresses the shortcomings of conventional research- for- policy methods by grounding actions in practical steps, using knowledge from various fields, and involving non-academic stakeholders as equal partners in generating knowledge collaboratively (30),(31). Moreover, collaboration within interdisciplinary teams enhances productivity, fosters a sense of individual accountability towards shared goals and it stimulates creativity (32). As evidenced by the findings of the World Health Organization, interdisciplinary teams have been instrumental in achieving improved outcomes across various critical domains, including epidemic control, infectious disease management and humanitarian aid (33).

One notable result was the emphasis on the late detection in disease management. This aligns with existing literature and the importance of preventive measures and early detection (34-36). These studies show the impact of delayed diagnosis on health outcomes and the relevance of early detection strategies in healthcare.

Strengths and limitations:

This study has strengths and limitations. The collaboration between the medical student a researcher from the genetics department, and biomedical sciences students stands out as a strength of this article. During their weekly meetings, the researchers discussed the research and this helped to refine ideas and approaches. This study used various disciplines, using diverse experts provided a broad perspective. Furthermore, the use of an interview guide and the inclusion of quotes within the result rection, and the comparison of the study findings with existing literature enhances this study's validity and credibility. However, this study did have a few limitations. The study sample size of only 14 participants was relatively small and might not represent all the different viewpoints. Moreover, the study had a few interviewees specialized in the same field. Despite efforts to ensure correct data analysis the interpretation of findings may have been influenced by the researcher subjective perspective and biases. Additionally, it was challenging to find relevant literature on the topic as it appeared to be an area with limited existing research.

Conclusion and future research

This research explored early warning signals across diverse disciplines. Revealing a variety of signals specific to each field. These signals, while complex, showcased similarities in the urgency for timely action and the delicate balance where systems may undergo abrupt shifts or reach threshold suggesting overlap across various domains. Furthermore, results suggested that high levels of cross-disciplinary collaboration could enhance the understanding and response to these signals. However, obstacles such as financial challenges, delayed disease detection, and a lack of urgency were identified as hindrances to proactive intervention.

Future research could aim to use a larger and more diverse sample size to improve the representativeness of findings and explore early warning signals in additional disciplines not covered in this study. Moreover, more studies could be done in improving cross-disciplinary collaborations. Additionally, investigating the possibility to develop an integrated framework or tools to identify, interpret and respond to early warning signals across multiple domains. This research tried to take the first steps in this aim.

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Appendix

Appendix 1: Coding guide

<u>Research Projects:</u>
Impact
Workday
Type of research Project

<u>Early Warning Signals:</u>
Example signal
Example application
Timeframe (hours days weeks)
Signal comparison (bomb, goosebumps)
Signal similarities
Consequences of the signal

<u>Methods and Technologies:</u>
Screening/sequencing / (surveillance)
IT software
Scanning
Technological advancements
New technology
Qualitative research
Confirmatory test
Tactics
(Simulation)models

<u>Impact:</u>
Life / death
Disease prevention (infection)
Psychological impact (carrier status)
Awareness
New (promising) technology
Future perspective
Prevention >
Desired outcome (ethically responsible)
Representation in society

<u>Interdisciplinary Collaboration:</u>
Application: new insights

Importance of collaboration
Lessons from/for another field
Translation to another discipline
Combining different perspectives
Control (anti-bias)

Possible Actions:
Precautions
Action based on a signal
Action timeframe
Responsibility for action
Double-checking / seeking confirmation
New treatment (trial/development)
Referral Progression of actions (shift)
Communication/information (papers)
Prediction
Monitoring / surveillance
Dealing with uncertainty
Unknown results
Seeking confirmation
Handling uncertainty
Unclear/ambiguous signal
Incompleteness
Advising

Obstacles and Challenges:
Late notice
Financial constraints
Lack of knowledge/awareness
Undesired action
Consequences
Lack of urgency
Responsibility
Unclear/incomplete signal
Bias
Need for certainty
Flawed/uncertain technology
Weighing different signals
Lack of clear action
Unfeasible action
Low impact action
Lack of trust (in science)
Privacy
Politics
Time

Culture and Regulatory Legislation:

Policy
Compensation
Beliefs
Norms/values (autonomy)
Unfamiliarity
Self-interest
Government communication
Citizen involvement
Behaviour