LEARNING FROM A CRISIS

Lessons learned and knowledge agenda to improve pandemic preparedness

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Contents

Summary

This report outlines pandemic preparedness in the Netherlands throughout the COVID-19 pandemic with respect to gathering crucial information and converting this into advice for policymakers. We evaluated numerous aspects of pandemic preparedness by conducting in-depth sessions with experts across different domains. The aim of these sessions were to reflect on the way in which advice from different disciplines was given during the pandemic, and identify the research questions that to be answered so that scientific advice can be provided in a more effective way in the future. We found that advisers from the biomedical domain were relatively well-prepared to synthesize information and provide advice during the pandemic, but there is room for improvement. For instance, the most important route for the spread of the virus (and thus, how to best prevent transmission) continued to be unclear for a long time. It was not evident how the enormous number of new studies should be dealt with. In the social domain, there was already a lot of fundamental knowledge about society and other important associated topics such as behaviour. However, this could not always be specifically applied to the situation of a pandemic. For instance, it was not known how detrimental an extended lockdown could be to mental health. In addition, a clear protocol to deal with a pandemic from a social sciences perspective was lacking, as was a place where all insights could be pooled. These same drawbacks apply to the economic domain. Thus, support measures were rapidly established but later, these had to be rendered more specific. However, the biggest scope for improvement exists in the provision ofdomain-overarching recommendations. There was, and still is, no domain-overarching organisation that provides advice to policymakers, and the infrastructure for communication and knowledge sharing between domains can be improved. As such, various fundamental questions remain unanswered at the interfaces of the domains.
In this report, a knowledge agenda is drawn up of research questions that still need to be answered on bothdomain-overarching questions and questions for each of the individual domains. This knowledge agenda outlines which knowledge gaps currently exist that should be prioritised in pandemic preparedness research. The most important domain-overarching research question is whether advising policymakers in an integrated (interdisciplinary) manner is possible. There is also a need for a better

knowledge infrastructure between domains, such as ensuring observational studies on infectious diseases collect both biomedical and social sciences data. Finally, there are fundamental questions at the interface of the various domains. These concern, for example, the interaction between behaviour and public health measures and the spread of the virus, or how to ensure reliable procurement and distribution of crucial goods. A large number of questions have also been identified within the individual domains. An important research question for the social and economic domains is the drawing up a protocol for a pandemic, which lists the crucial knowledge gaps that need to be addressed at the beginning of a pandemic. In addition, there is a paucity of empirical evidence on different behavioural interventions. For the biomedical domain, one of the future challenges is to improve the organisation and synthesis of the many independent studies in the event of a pandemic. Another example is how scientists can more rapidly determine the most important virus transmission route (and the associated public health measures required to reduce transmission).

The above questions were compiled on the basis of two cases, which were discussed with numerous experts (see Appendix). We examined an early moment (23 March 2020, the first lockdown) and a later moment (22 April 2021, reopening of society) during the COVID-19 crisis. For each of these cases, the fundamental knowledge, guidelines and infrastructure, and organisation present were investigated. In so doing, we considered three scientific domains: biomedical, social and economic. In addition, we examined the domain-overarching pandemic preparedness. For this study, extensive literature research was carried out and a large number of interviews were held with prominent experts. Participants from all domains participated in two work sessions during which the two cases were evaluated through multiple rounds of simulation.

The conclusion of this report is that knowledge from different domains must be combined to answer the remaining fundamental questions. Infrastructure and organisation are also required to bring together the knowledge from the domains and convert it into integrated advice. We will need to initiate joint research for the domain-overarching questions. Simulations held during the second meeting revealed what the provision of joint, interdisciplinary advice could look like and its potential added value. The most important lessons from this are as follows[1]:

- Lesson 1: Integrated advice does not occur automatically: it requires action and investment from scientists and policymakers
- Lesson 2: A joint framework for weighting advice from different scientific disciplines is feasible and can provide general guidance, also when the disciplines also continue to issue advice independently
- Lesson 3: There are still unanswered questions concerning the different facets of integrated advice and how those come together in a broadly supported, integrated decision-making framework

[1] See the paper 'Contours of integrated pandemic advice' (PDPC): https://convergence.nl/learning-from-a-crisis/

We call upon scientists, advisory bodies and policymakers to take action now so that they will be better prepared in the event of a new pandemic.

Introduction

The COVID-19 pandemic represented a crisis of unprecedented proportions. The considerable uncertainty caused by a novel disease meant that rapid decision-making and far-reaching measures were often based on incomplete and/or uncertain information. The question is not so much *if* but rather *when* the next pandemic will present itself. Given the enormous impact on our society that the COVID-19 pandemic has had, it is necessary to learn from this recent crisis in order to provide better scientific advice in the future.

The COVID-19 pandemic has clearly demonstrated that the effective control of a pandemic requires not just biomedical knowledge but alsosocial and economic knowledge. The impact of measures on social cohesion, marginalised groups, sectors and trust in the government proved to be far more significant than initially thought. That was, in part, due to the long duration of the pandemic. However, it is clear that more social and economic knowledge is needed to complement biomedical information in order to improve pandemic preparedness.

Furthermore, effective pandemic preparedness cannot consist solely of separate independent biomedical, social and economic elements. Adequate preparations must be realised from a domain-overarching perspective. This is not just a national matter; the deployment of international networks and knowledge is also important. Poor preparation in one of the areas constitutes poor preparation across the board.
In this report, we examine the state of pandemic preparedness during the COVID-19 crisis. We investigate which questions must be answered to be better prepared for a new pandemic. However, being better prepared in the future is not just a matter of conducting research within different subject areas, but also demands interdisciplinary understanding. This requires an open attitude and critical reflection from all of the disciplines concerned. The sessions we have held with participants from all domains give reason to believe this is possible.

Methodology

To investigate the pandemic preparedness and draw up the pandemic knowledge agenda, we examined two specific moments during the pandemic. These are 23 March 2020, the moment of the first lockdown, and 22 April 2021, the first step in the 'reopening of society'. For these moments, we took three steps:

1. Desk research
2. Interviews with experts
3. Joint work sessions

Drawing up a pandemic knowledge agenda is a very extensive task. Therefore our goal was not to be complete, but rather to draw important lessons from the COVID-19 pandemic.

Demarcation

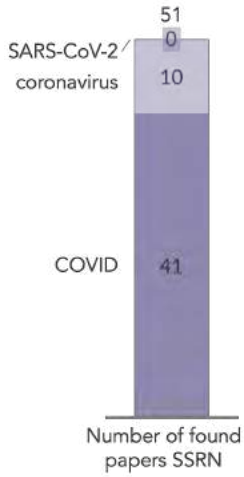
Besides the question as to which knowledge was already present at the beginning of the pandemic, possible subsequent questions are: which knowledge was used by policymakers and why was possibly existing knowledge not used? The latter is, however, an entirely different question and lies outside of the scope of this study. Furthermore, science and politics are continually changing and after the moments considered (that is; from 21 April 2021 onwards) more aspects regarding pandemic preparedness were added, such as the establishment of the Societal Impact Team (SIT). Nevertheless, important lessons can still be learned from the first year of the pandemic, and these lessons are described in this report.

Literature research

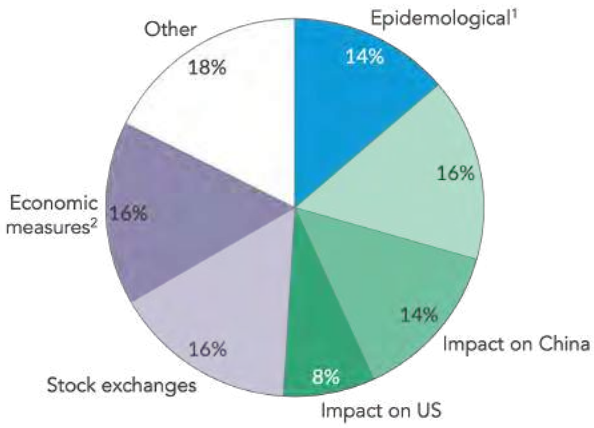
As a starting point for the first work session, thorough literature research was used to establish which knowledge was available on 23 March 2020. The following sources were used:

- Available scientific literature specifically for SARS-COV-2 on 23/3/2020
  Papers and preprints published on PubMed, medRXiv or bioRXiv, EconPapers, PsycInfo, arXiv between 1/1/2020 and 23/3/2020 were examined. These were identified and categorised on the basis of the search terms "SARS-CoV-2", "COVID", "novel coronavirus", "SARS-like", "nCoV" (see Figure 1).*Figure 1: Outcomes database search PubMed, medRXiv and bioRXiv*

Number of papers per search term
[SSRN category Economics, before 23/3/2020]



Classification of categories



1) Among other things, explanation of epidemiological models
2) For example, support packages

1

- Public advice documents and sources
  All relevant advice documents and other public sources published around 23 March 2020 were examined. This concerns advice from the OMT, RIVM, LCI, SCP, RVS, CPB, WHO and ECDC, IMF, OECD, Rabobank, ING, ABN AMRO, DNB, ECB (for a list of abbreviations, see chapter 13) as equally the professional journal ESB and the archive for media reports of the Dutch broadcaster NOS and the Dutch TV news programme EenVandaag. Only knowledge available on or before 23 March was taken into account. In addition, the Twitter timelines of several prominent scientists and the studies (including preprints) mentioned there were examined for the period 1/1/2020 to 23/3/2020.

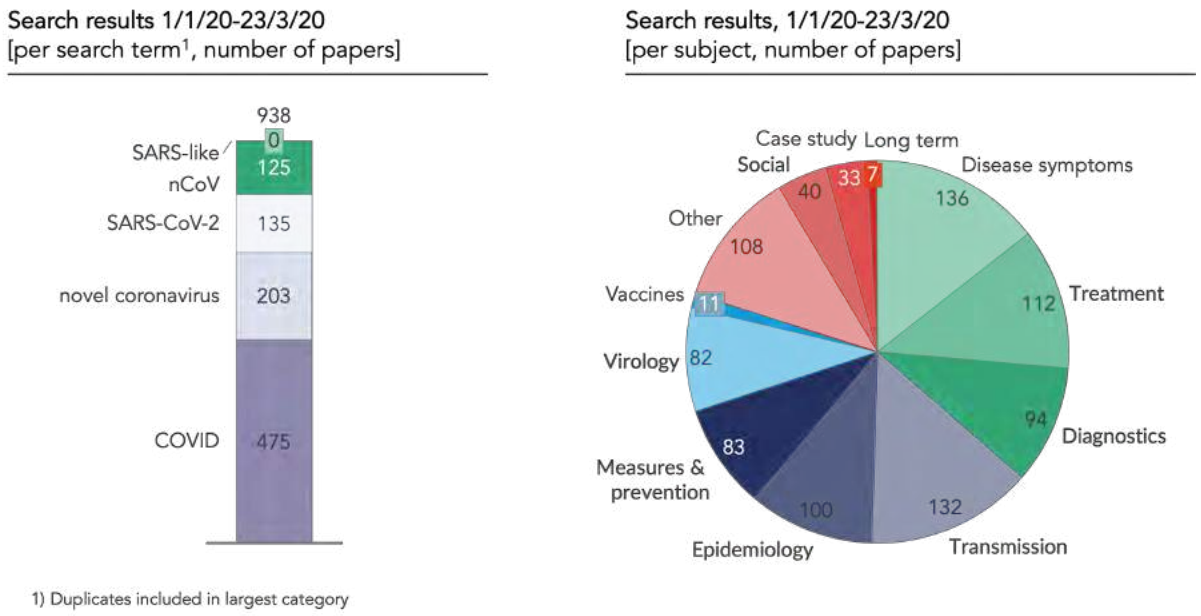


Figure 1: Outcomes database search PubMed, medRXiv and bioRXiv

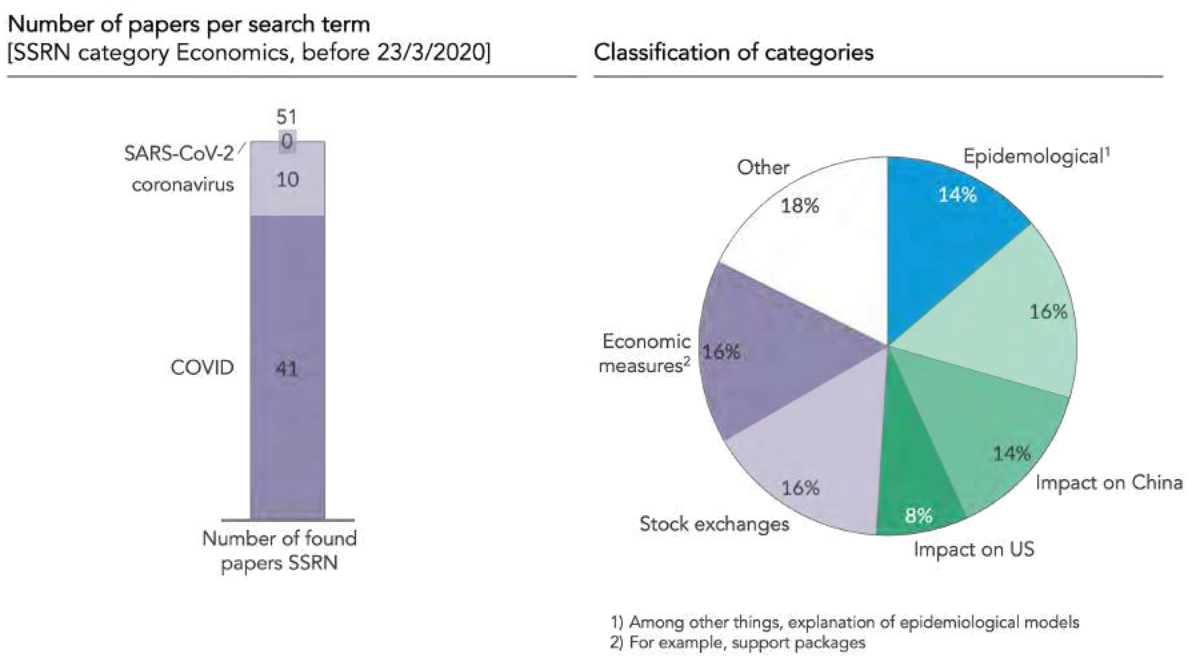


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Figure 2: Outcomes database search SSRN in the category Economics2

In the same way, the moment of 22 April 2021 was investigated. Around this time, more than 100,000 papers about COVID-19 had already been published.

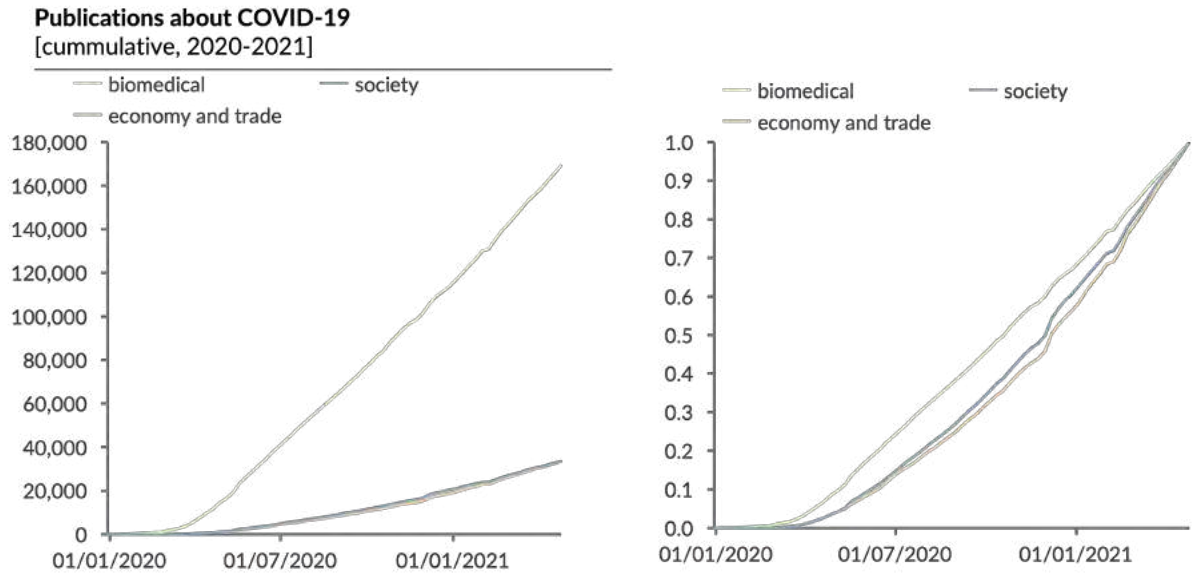

Figure 3: Number of papers published within different disciplines up to and including 22/4/20213
Source: dimensions.ai

Interviews with experts

Furthermore, interviews (total: 35) were conducted with experts and researchers from the biomedical, social and economic domains. The interviews were held with 13 biomedical experts, 13 social experts, 4 economic experts and 5 experts regarding the interaction between the three domains. The knowledge gathered was tested and further augmented during the interviews.

Interdisciplinary work sessions on 7 July 2022 and 15 February 2023

On 7 July 2022, a work session was held, which was attended by a total of 18 scientists from the biomedical and social domains. The knowledge agenda was set up in two steps based on the aforementioned research.

1) Evaluating the available and deployed knowledge on 23 March 2020. In doing so, the following questions were answered:
   - Which knowledge was available?
   - How was this knowledge accessed and made available for the provision of advice?
   - Which knowledge was available, but not used?
   - In retrospect, which knowledge would have been required in order to provide better advice?
2) Formulation of knowledge questions and lessons learned for an integrated pandemic knowledge agenda

The session was supervised by research consultancy Gupta Strategists.

On 15 February 2023, a follow-up session was held to further supplement the outcomes with insights from other disciplines. Besides the biomedical and social domain, the economic domain was also taken into account. The group present for the first session was expanded with economists and public administration experts. In addition, a second moment during the corona pandemic was examined: 22 April 2021, the reopening of society.

Two cases: First lockdown, 23 March 2020 and reopening of the society, 22 April 2021

In this chapter, we briefly describe the two cases used to determine the pandemic preparedness and the drawing up of the knowledge agenda. We describe the contours of the state of knowledge on 23 March 2020 and, subsequently, the way in which knowledge developed up to and including 22 April 2021.

Domains

As previously stated, the existing knowledge was divided across three domains: biomedical, social and economic. Even though economics is, in principle, a social science we opted to consider this a separate domain due to the special role the economy plays within the provision of advice. The economic domain examines the economy in the narrow sense (macroeconomy, with for example GDP as the standard) as well as welfare in a broader sense. In this report, we explicitly consider both aspects.

Timeline

Much uncertainty existed during the first month of the pandemic. Measures followed each other in quick succession. In Figure 4, a short timeline is provided, beginning from the moment that the first measures were implemented.Figure 4: Timeline COVID-19 measures up until 23 March 2020 4

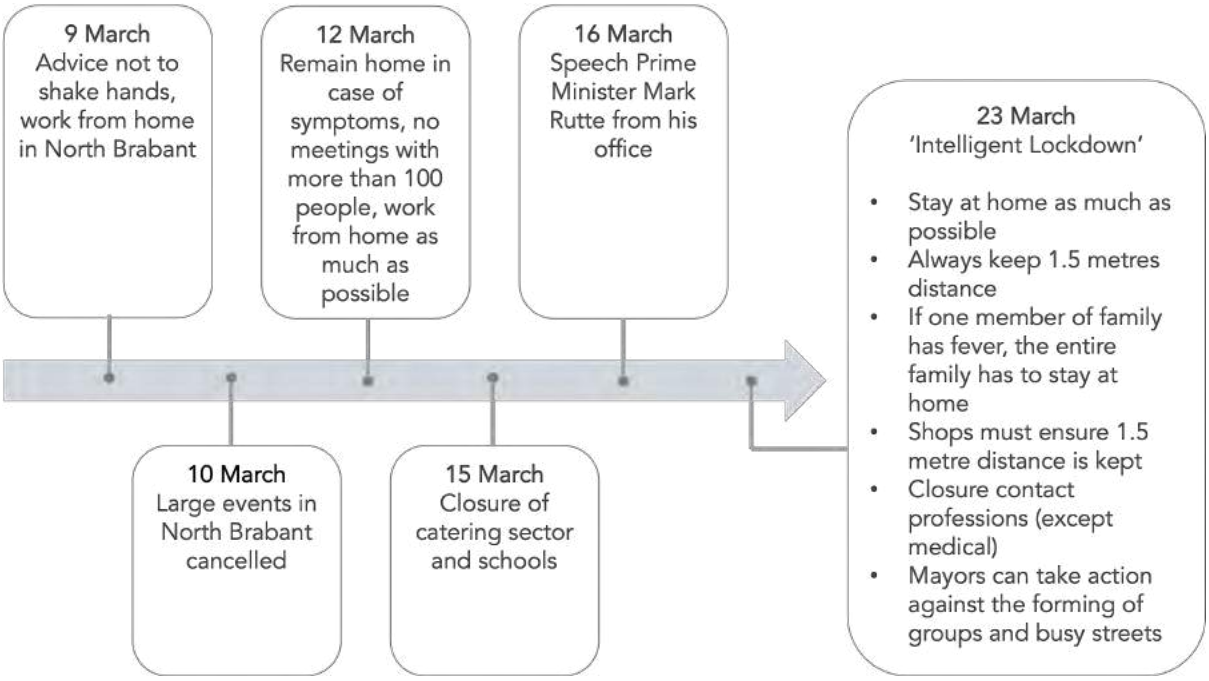

Figure 4: Timeline COVID-19 measures up until 23 March 2020 4

After the speech of Prime Minister Mark Rutte from his office at the Houses of Parliament, the 'Intelligent Lockdown' was implemented on 23 March 2020. Everybody had to stay at home as much as possible, the 1.5-metre distance measure was introduced, and the entire household had to go into quarantine in the case of fever. The catering industry and schools had already been closed on 15 March 2020. Other shops could, in principle, remain open (as long as the 1.5 metres distance was possible), but many decided to close on their own accord.

1. Disease and infectiousness
   a. Pathogen
   b. Pathogenesis
   c. Incubation
   d. Disease symptoms
   e. Immunity
   f. Reservoir
   g. Infection route
   h. Infection period
   i. Infectiousness
2. Diagnostics
3. Risk groups
4. Epidemiology
5. Prevention
6. Measures
7. Profylaxis & treatment
8. History

Figure 5: LCI classification of the parameters to be investigated5

Current state of knowledge: biomedical

Overview on 23 March 2020:

Fundamental knowledge: There was already a lot of fundamental knowledge in preparation for a pandemic. Of course, the beginning of the pandemic required the acquisition of new knowledge about an as yet unknown virus.
Guidelines and infrastructure: Based on (international) guidelines and protocols, it was clear in advance which knowledge is vital at the beginning of an outbreak. As a result of this, studies could begin very rapidly. However, scope for improvement remains.

Organisation: it has been clearly documented how the structure for providing advice for the OMT was set up. In the OMT, the RIVM invites researchers in a personal capacity to take part. As a result of this, the composition of the OMT varied quite a bit, especially at the beginning of the pandemic.
The biomedical pandemic plans were effective from the first indications of the outbreak of a potentially novel virus onwards. It had already been determined in advance how the national OMT structure would have to be realised. It was also immediately clear which questions were crucial to answer concerning this novel virus. For this, lists exist with standard indicators, for example those of the National Coordination Centre for Communicable Disease Control (LCI).

In Figures 6 and 7, an overview is provided of the extent to which standard indicators were already known on 23 March 2020. This is based on the literature research and interviews with the participants.

Figure 6: State of knowledge on 23 March based on the parameters under heading 1. Disease and infectiousness in the LCI guidelines6Figure 7: State of knowledge on 23 March based on the other parameters in the LCI guidelines7

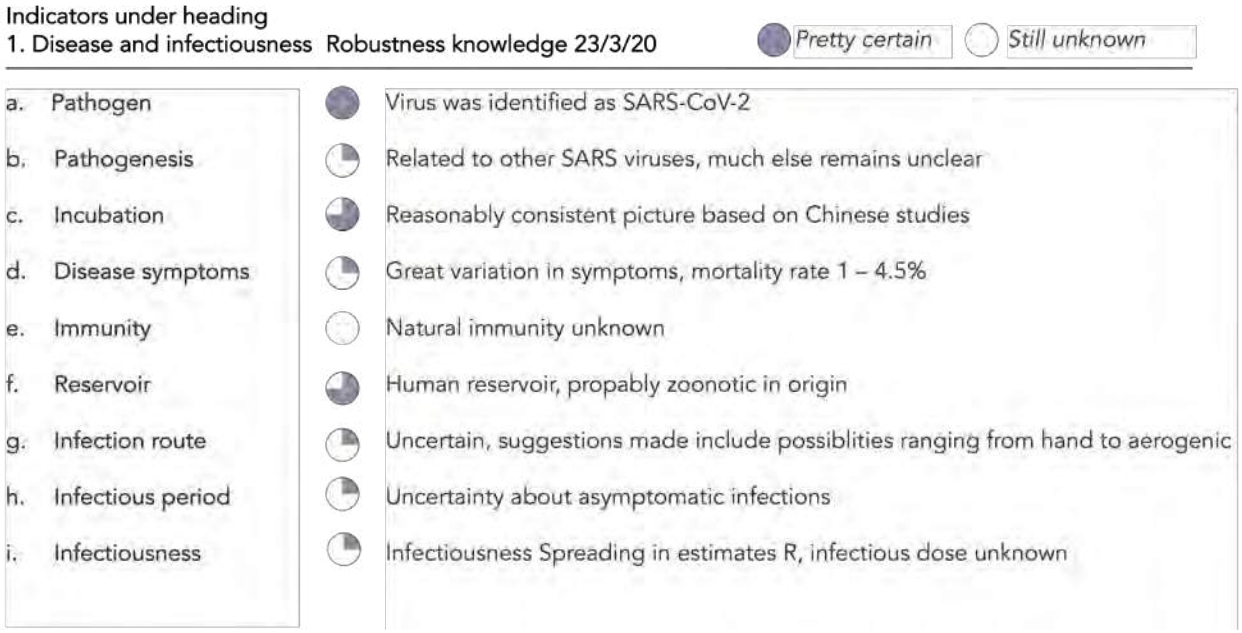

Figure 6: State of knowledge on 23 March based on the parameters under heading 1. Disease and infectiousness in the LCI guidelines6

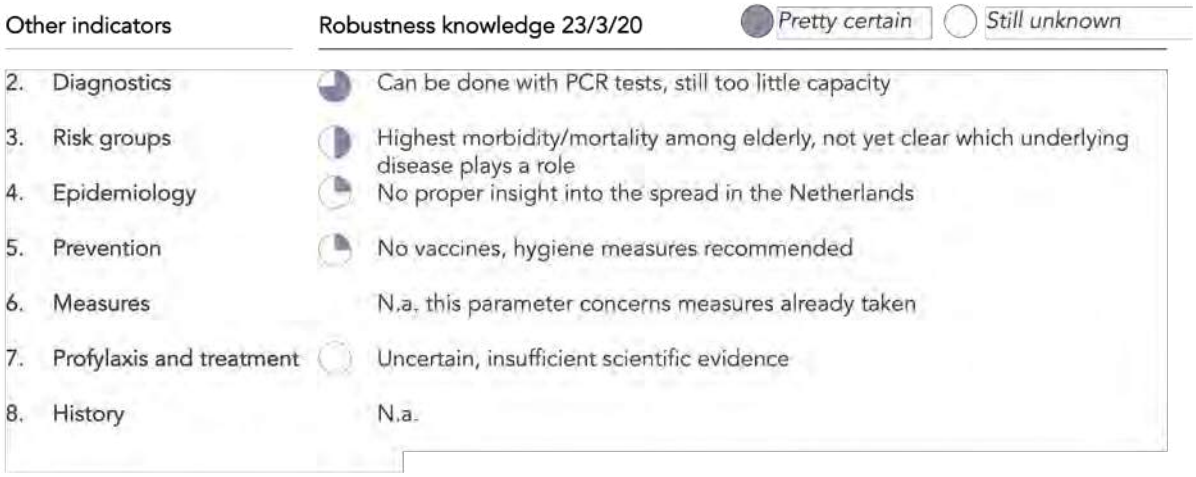

Figure 7: State of knowledge on 23 March based on the other parameters in the LCI guidelines7

Several issues were already clear

Several issues were already largely clear on 23 March 2020. The pathogen (1 a. in Figure 6) was identified and given the name SARS-CoV-2. The majority of the spread

unmistakably took place from person to person (human reservoir 1 f.) and because of rapidly shared sequence analyses, polymerase chain reaction (PCR) tests that worked well were already available for diagnostics (2.) Based predominantly on Chinese studies, a reasonably accurate idea of the incubation time (1 c.) of the virus also existed.

Figure 6: State of knowledge on 23 March based on the parameters under heading 1. Disease and infectiousness in the LCI guidelines6

Uncertainty about the disease symptoms

Much remained unknown about the precise disease symptoms (1 d.). Although many studies had been published about this or were in preprint (136 on PubMed, medRXiv and bioRXiv), these did not provide an unequivocal picture. Based on the first studies (Huang, et al., 2020) (Yang, et al., 2020) the symptom fever seemed to be part of almost all cases, but this conclusion was gradually adjusted (Guan, et al., 2020) (Chen, et al., 2020).

Uncertainty about the infectiousness, transmission route and infection period

From the literature (Kutter et al., 2018) it had already become apparent that a respiratory virus such as SARS-CoV-2 mainly spreads via three routes: direct (via hands and surfaces), aerogenic (in large droplets) and aerosol (in small droplets), see Figure 9. Which of these was the most important was not yet known on 23 March 2020. There were different and sometimes conflicting indications. For instance, based on the initial studies and experience with the previous SARS virus, it was assumed that it involved an aerogenic infection, that is to say: via sneezing and coughing. That is because these initial studies suggested that nearly all patients had (severe) symptoms (Huang, et al., 2020). It was therefore likely that few asymptomatic or presymptomatic infections would occur. On the other hand, a few studies had already been published by 23 March 2020, which seemed to dismiss this last assumption (Bi, et al., 2020), (Mizumoto & Chowell, 2020). However, these studies had not been peer-reviewed yet. The measures taken around 23 March 2020 were largely recommended on the basis of the assumption of predominantly aerogenic infection.

Figure 9: General knowledge about infection route taken by respiratory viruses9

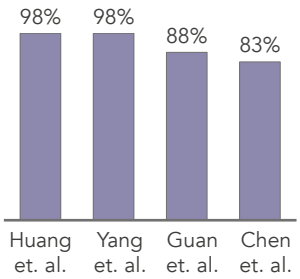

Figure 8: Percentage of COVID-19 patients with fever based on the initial studies from China8

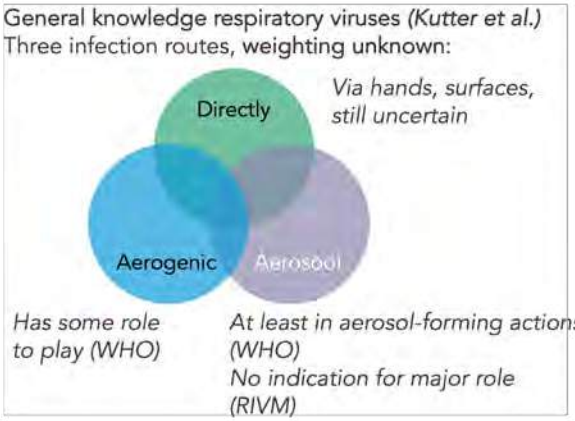

Figure 9: General knowledge about infection route taken by respiratory viruses9

Unclear picture of epidemiology

There was not an accurate picture of the spread of the virus in the Netherlands (epidemiology, 4. in Figure 7). Due to the lack of test material, it proved not at all possible to test everybody. By means of, amongst other things, a study in the Dutch province of Brabant among healthcare personnel (conducted by the RIVM, in collaboration with hospitals) and genomic sequencing analysis performed by Erasmus MC, it had already become apparent that the virus had spread widely throughout the Netherlands.

Figure 7: State of knowledge on 23 March based on the other parameters in the LCI guidelines7

Models predicted a very high ICU occupancy

Besides describing the standard indicators, a beginning was made almost straightaway with predicting the spread of the virus based on mathematical models. However, these models included a large uncertainty margin. Based on virtually all models (RIVM) it was discovered that the intensive care unit (ICU) capacity in the Netherlands was far from adequate to accommodate all COVID-19 patients requiring intensive care, which is why eventually the decision was taken to implement a lockdown.

Long-term situation and vaccinations still unknown

On 23 March 2020, there was a reasonable (scientific) consensus that the virus would not disappear within a short period of time. From various quarters, a wave of infections was predicted that could last for years (Ferguson et al., 2020, Lipsitch et al., 2020). This knowledge was not always clearly put forward in the advice provided and in the press conferences. Consequently, this knowledge was not always known to the general public. The same applied to a large proportion of the social scientists who were interviewed. The biggest factor of uncertainty regarding long-term predictions was the development and effectiveness of a possible vaccine. In retrospect, this came about very swiftly, but that was impossible to predict in advance.

Development on 22 April 2021

In various areas within the biomedical domain, a major knowledge development took place between 23 March 2020 and 22 April 2021. In Figures 10 and 11, the indicators from the LCI guidelines have again been listed for this second moment. Below, a number of these indicators have been explained in more detail:

Figure 10: State of knowledge on 22 April 2021, based on the parameters under heading 1. Disease and infectiousness in the LCI guidelines10

Figure 11: State of knowledge on 22 April 2021 based on the other parameters in the LCI guidelines

11

Pathogenesis became clearer

In the meantime, far more had become known about the manner in which the virus enters the body and what subsequently happens in the body. For example, micro-coagulation and acute respiratory distress syndrome (ARDS) had now come into focus.

More known about the infection rate and infectiousness

It had now become clear that the virus could also spread via long-range aerosols (Greenhalgh *et al.*, 2021), but to what extent this contributed to the infection continued to be unclear. Super-spreaders were found to play a major part in the spread of the virus. In the case of novel variants there was a greater degree of uncertainty about the infectiousness.

Extensive test capacity, source and contact tracing often had to be scaled down

From the spring of 2020 onwards, the number of test locations was considerably expanded, resulting in the daily publication of reasonably accurate figures per municipality. By investigating clusters in the source and contact tracing, the municipal health services gained a fairly accurate idea of where the infections took place. However, this source and contact tracing had to be scaled down in the case of a large number of infections, and outdated ICT systems hindered the analyses.

Vaccines were developed and appeared effective

On 6 January 2021, the first vaccination was given in the Netherlands. Vaccines appeared to provide good protection against hospital admission. For instance, the first studies from Scotland and Israel, also indicated that vaccines assisted in limiting transmission (Hall et al., 2021) (Regev-Yochay et al., 2021). However, there were concerns about the novel variants of the virus against which the vaccines might be less effective.

Much still unknown about Long COVID

In the case of other infectious diseases, such as MERS, SARS, Lyme disease and Q fever, it was known that a proportion of patients continue to experience symptoms in the long-term. Around April 2021, there were a growing number of indications concerning long-term symptoms for COVID-19 (Yelin et al., 2021). Unlike the acute symptoms, these symptoms also often appeared to occur among young people (Dennis et al., 2020). At that time, very little was known yet about the causes and treatment.

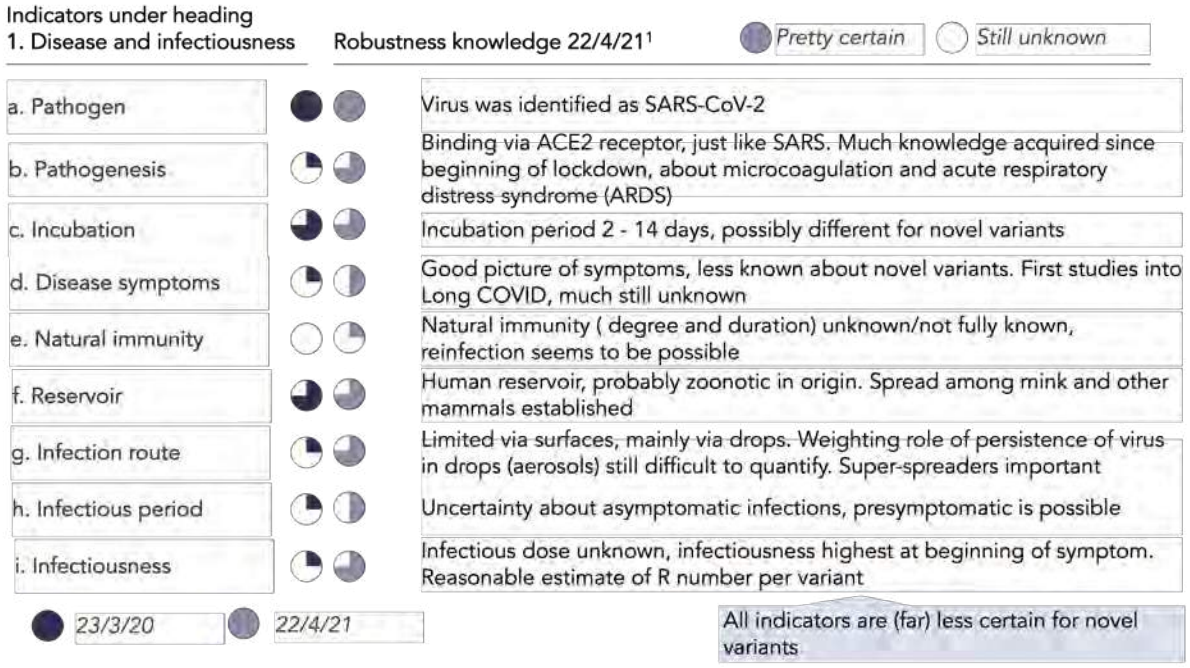

Figure 10: State of knowledge on 22 April 2021, based on the parameters under heading 1. Disease and infectiousness in the LCI guidelines10

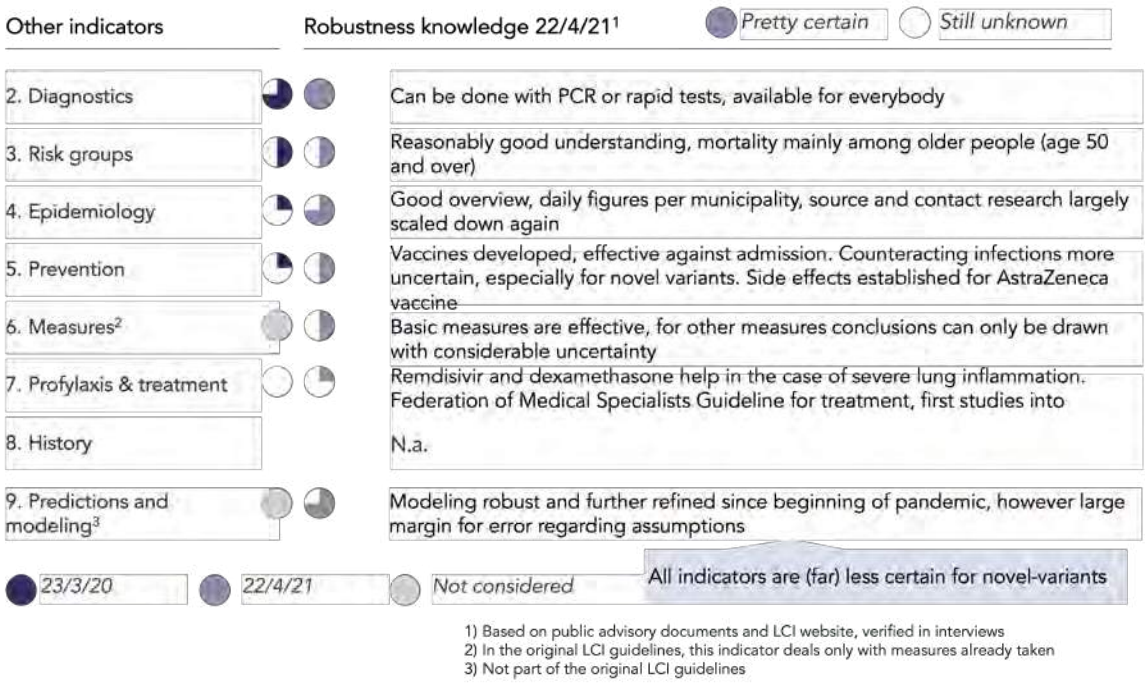

Figure 11: State of knowledge on 22 April 2021 based on the other parameters in the LCI guidelines

11

Current state of knowledge: social

Overview on 23 March 2020:

Fundamental knowledge: the social sciences had already provided much knowledge about the possible impact of the measures and the pandemic, whereas behavioural and communication sciences provided much knowledge about crisis communication and ways to influence behaviour. For various reasons, this knowledge was not always immediately addressed.
Guidelines and infrastructure: Within the social domain, there was no 'pandemic protocol', as a result of which it was not clear in the beginning, which information was crucial. Nonetheless, guidelines didexist for crisis communication, for example.
Organisation: There was no domain-wide organisation in place where advice from different subdomains could have been pooled.

On 23 March 2020, no advice about the COVID-19 crisis had been issued yet from the social perspective. However, this was issued several weeks later, for instance by the Council of Public Health & Society (RVS) and the Netherlands Institute for Social Research (SCP) (RVS, 2020), (SCP, 2020). The interviews and literature research made it clear that although a great amount of knowledge already existed, it was not immediately used. The interviewees frequently quoted the reason that the question was simply not posed. In addition, there were few if any social scientists whose

expertise included pandemic control.

Existing fundamental knowledge

It was possible to gain insights from existing studies into, amongst other things, previous pandemics and existing knowledge about the functioning of society that were also relevant on 23 March. A great deal of knowledge was already available via research in the social, behavioural and communication sciences. We describe a number of these insights below. These are entirely based on knowledge that was already available and published in peer-reviewed journals (well) before 23 March.

- Proper compliance with measures in the beginning
  Behavioural models such as the Extended Parallel Process Model (EPPM, Witte et al, 1992; 1998) can make predictions about behaviour. At the beginning of the pandemic, it could therefore have been predicted with reasonable certainty that there would be satisfactory compliance with the measures due to the considerable anxiety that people felt and because the measures implemented were tangible. But it could also be predicted that the longer the pandemic lasted, the less compliant people would become.

- Marginalised groups are always hit the hardest
  Research into various disasters had revealed that marginalised groups are always hit disproportionately hard. This was already predicted, for example, for a new influenza epidemic (Uscher-Pines et al., 2007). In addition, there is much knowledge about which groups are difficult to reach when it comes to communication. These groups are, for instance, young people, homeless people and asylum seekers.

- In the long term, the pandemic will have a major societal impact
  Once again, studies into previous disasters had made it clear that this pandemic would have a large societal impact. Thus, studies indicate an average prevalence of 5-10% post-traumatic stress disorder (PTSD) after a major disaster, based on a systematic review (Galea et al., 2008). It was also known that circumstances at a young age have a great impact (Angelini et al., 2019), as a result of which the damage, for example problems resulting from learning difficulties, entails far more than simply catching up on missed classes.

- The communication strategy needs to be adjusted
  Much is known about crisis communication. An important aspect of this is that the communication strategy needs to be adjusted in the event of a prolonged crisis. Expectations need to be managed and the communication needs to be

tailored to the target group. It is also important to communicate honestly about uncertainties (WHO, WHO outbreak communication guidelines, 2005). The WHO has published reports on crisis communication that contain concrete guidelines about this. Manuals already exist for dealing with misinformation and disinformation, including concrete actions to counteract both (Cook & Lewandowsky, 2012).

- Society begins to weight different values
  Especially at the beginning of the pandemic, the primary goal was the prevention of admissions to the ICU. However, other values began to play a role eventually and this has been researched a lot within the field of ethics, for example (e.g. (Rump, Timen, Hulscher, & Verweij, 2018)).

The thermometer

Whereas rapid tests were set up in the biomedical domain, a considerable increase in measurements was not immediately apparent in the social domain. For many years planning agencies, scientific cohorts and other organisations have conducted measurements that provide an accurate understanding of society. Examples are measurements in the area of loneliness, trust in the government, mental well-being (see Figure 12 for a selection of these "thermometers"). As this concerns parameters that often change slowly then carrying out more frequent measurements is not always worthwhile.

Figure 12: Several parameters (non-limiting) for the state of society that are regularly measured (also before the COVID-19 pandemic)12

A few-parameters state of society (non-limiting)	Last known value on 23/3/20	Source	Frequency
Loneliness	9%-11% severely lonely 26%-47% lonely *2019*	CBS, GGD, RIVM	per 1-4 years
Mental well-being	12% Psychologically unhealthy *Q1 2020*	CBS	per quarter
Literacy	12% functionally literate *2012*	PIAAC	per 10 years
Trust in the government	51% give a rating 'satisfactory' *Q4 2019*	SCP	per quarter
Willingness to be vaccinated	90,2% full participation in government vaccination programme *Q1 2020*	RIVM	per year

Figure 12: Several parameters (non-limiting) for the state of society that are regularly measured (also before the COVID-19 pandemic)12 – For the list of abbreviations, see chapter 13

Soon after the first infections, an infrastructure was established to gain scientific knowledge from behavioural research. This included compliance with measures and

trust in the government. A small cohort study had already been conducted into this as early as February (de Vries et al., 2020). In April 2021, the RIVM Behavioural Unit performed the first measurements.

Development on 22 April 2021

On 23 March 2020, there was very little specific social sciences knowledge about COVID-19. Nevertheless, during the first year of the pandemic, a large number of studies were carried out in this area. The figure below shows a number of these initiatives.

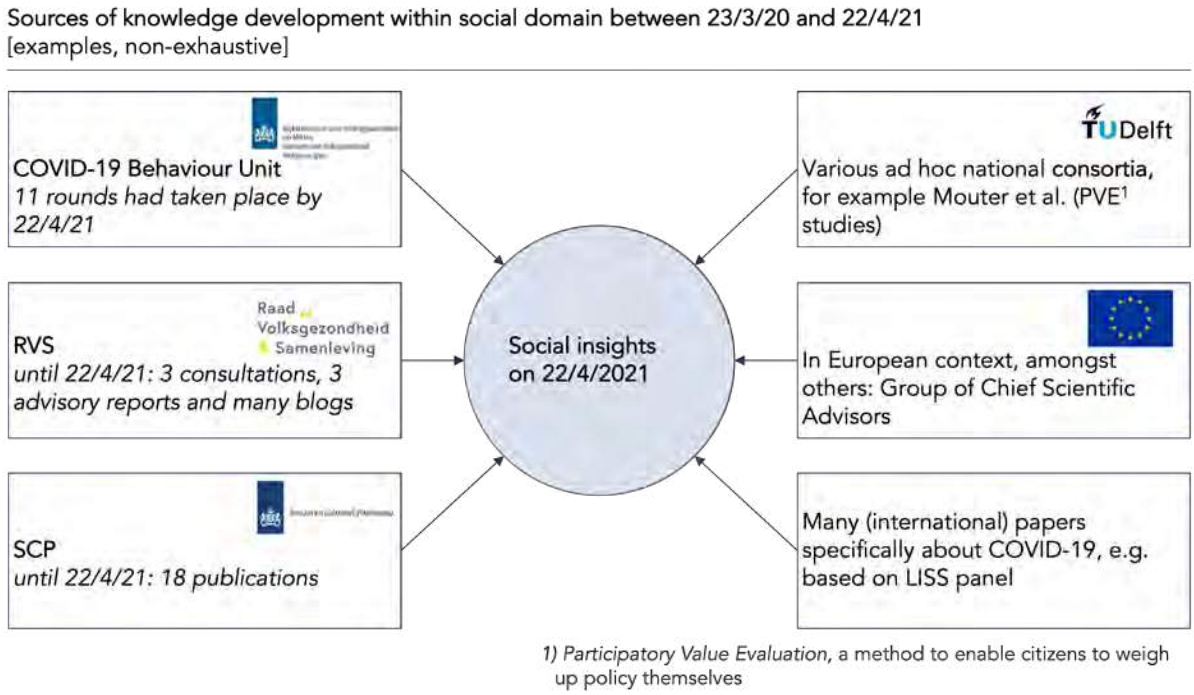

Figure 13: Overview (non-exhaustive) of several sources for new sociological insights13

These studies, among others, revealed new insights in various areas. A number of illustrative insights are listed in Figure 14.

Figure 14: Illustrative insights on 22/4/2021 within the social domain14

Knowledge on 22/4/2021 about subjects	Illustrative insights on 22/4/2021: [selection, non-exhaustive]
Effect of virus and measures on society	Mental health is low, especially among young people and vulnerable groups
	Negative effects on learning achievements have increased considerably, effect strongest among vulnerable groups
Accompanying measures	Support vulnerable groups, remedy negative effects on learning achievements
People's behaviour	Little support for curfew and maximum number of visitors
Communication about virus and vaccines	Important to communicate transparently about vaccinations and choice for measures
Governance and policy	Trust in government has decreased, citizens need to be included in policy

Figure 14: Illustrative insights on 22/4/2021 within the social domain14

Effect of virus and measures on society

Many of the social consequences that could have been predicted on 23 March 2020 based on historical knowledge, were substantiated with figures a year later. For example, negative effects on learning achievements were clearly measurable. Although anxiety and depression had not increased for the general population (Van de Velden et al., 2021), young people's mental well-being was at a low point (CBS, 2021).

Accompanying measures

With accompanying policy, the most severe consequences of the COVID-19 measures for marginalised groups can be reduced. Based on sociological knowledge, it was possible to reason which policy was necessary for this (SCP, 2021). Targeted support measures for schools in disadvantaged neighbourhoods, for example, alleviated some of the negative effects on learning achievements. Initiatives against loneliness supported elderly people. Much of this accompanying policy was devised during the pandemic based on existing (and also newly acquired) knowledge about society.

People's behaviour

Based on research from, amongst others, the RIVM Behavioural Unit, the degree of support for and compliance with measures was clear for most of the population. Ad hoc consortia also carried out other behavioural studies, for instance, into people's preferences regarding the relaxation of measures (Mouter et al., 2021).

Communication about the virus, measures and vaccines

For many years, communication scientists have been investigating how to communicate about vaccination effectively. Based on such research, it was known on 22 April 2021, for example, that transparent communication about (possible) side effects of vaccines was necessary (see Claasen et al., 2020). Communication also proved to be one of the most cost-effective measures against the spread of a virus (Haug et al., 2021).

Governance and policy

After trust in the government rose sharply at the beginning of the COVID-19 pandemic, this had once again strongly decreased in April. Within the social sciences, extensive knowledge exists about how to set up governance and policy to keep citizens on board. Methods such as Participatory Value Evaluation (PVE) can include citizens in policy considerations.

Current state of knowledge: economic

Fundamental knowledge: Fundamental knowledge about what the effect is on, for instance, the GDP if you close part of the economy. In addition, knowledge about ways of weighing decisions, such as a social costs and benefits analysis (SCBA). The specific economic consequences of a (pandemic) lockdown *were* not yet known. Models had not yet been drawn up for supply security.
Guidelines on infrastructure: Infrastructure existed to acquire insight into all groups and create initial prognoses. Afterwards, these could be made more specific. Data was not real-time, except for the monitoring of pin payments (this information is not in the public domain, however). There were no clear guidelines about which knowledge is needed for making a broad deliberation.
Organisation: There was no domain-wide organisation where advice from different subdomains could be pooled.

On 23 March 2023, the three largest Dutch banks had already published several reports about the (possible) impact of the virus. On 3 March, the Netherlands Bureau for Economic Policy Analysis (CPB) published an initial calculation in the Central Economic Plan, which was then still based on the scenario that the virus would remain limited to China. On 26 March, an extensive scenario analysis was published (CPB, 2020). Internationally, the Organisation for Economic Co-operation and Development (OECD) and International Monetary Fund (IMF) had, among others, also published several papers, including recommendations for policy responses (IMF, 2020).

We distinguish three areas for which relevant insights from the economy existed. These are summarised in the figure below.

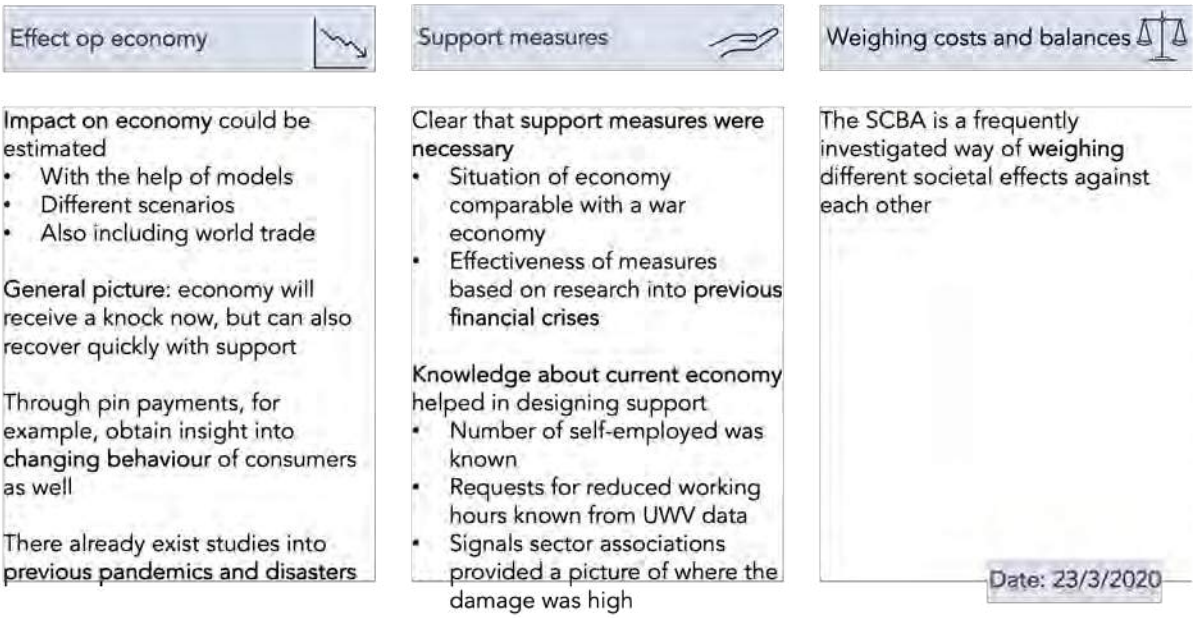

Figure 15: Overview of the most important economic insights on 23 March 202015

Effect on the economy

Models could estimate the impact of the virus on specific measures on the economy. At the CPB, for example, there were models that could also include the impact of world trade. Around 23 March 2020, several forecasts were published by the banks and the CPB, each of which calculated the impact of different scenarios. Based on studies into previous disasters and pandemics, including the Spanish influenza, the consequences could, up to a certain extent, be accurately estimated (Burns et al., 2006) (Botzen, 2019). Research had also been done into the long-term consequences of disasters (but not specifically into the COVID-19 pandemic), e.g. (DuPont & Noy, 2016; and Panwar, 2019).

Figure 16: GDP forecast published circa 23 March 202016

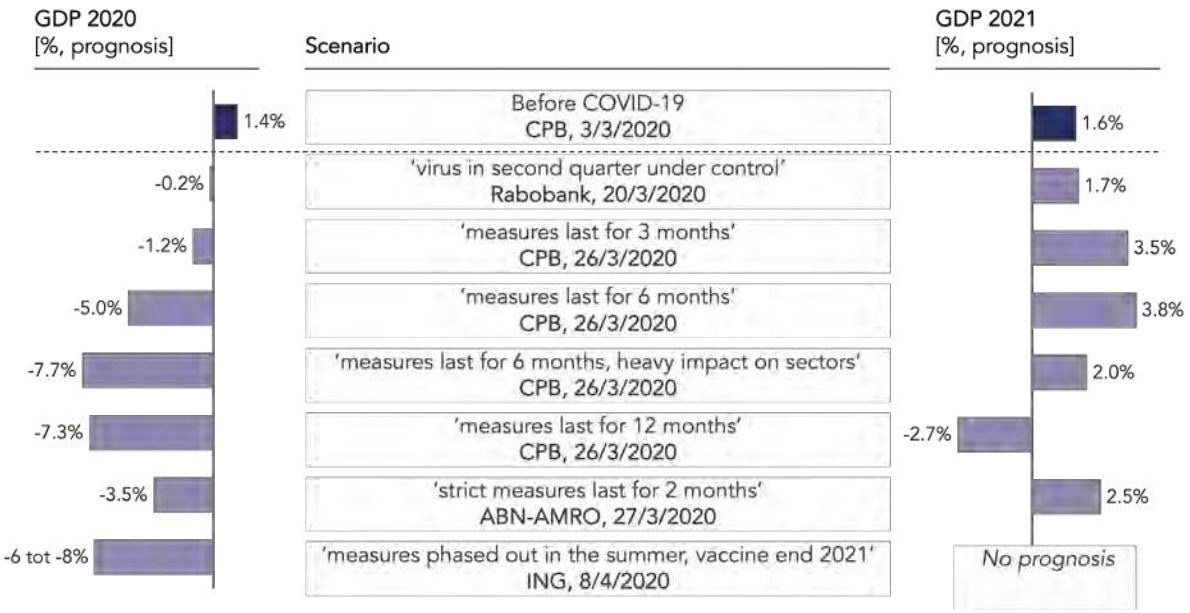

Figure 16: GDP forecast published circa 23 March 202016

Support measures

Based on various (financial) crises, research was done into the effectiveness of support measures (among others by the CPB, 2011). On 23 March, it had become clear that these were necessary to mitigate bankruptcies and to ensure continuing trust in the economy. The aim of the Temporary Emergency measure Bridging for Retention of Work (NOW) packages was to allow as much money as possible to reach working people. The government finances were in such good order that large-scale support packages were possible.

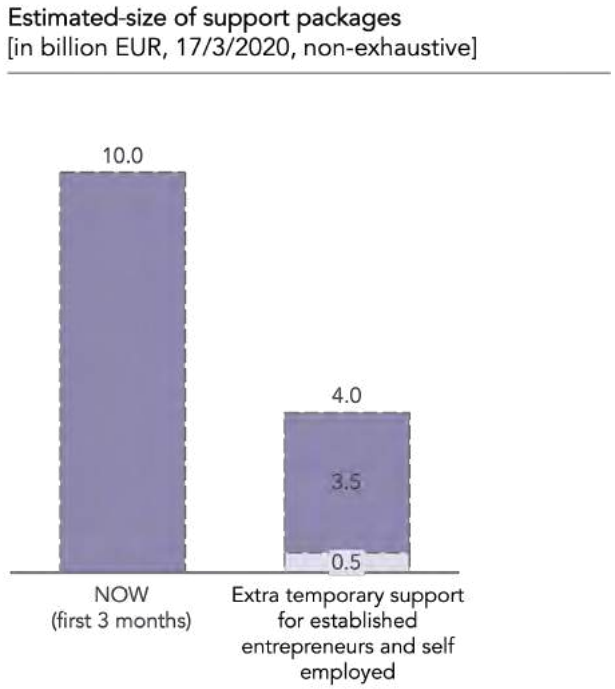

Figure 17: Estimated size of first support measures by the Ministry of Finance (Letter to the Dutch Parliament, 17/3/2020)17

Initially, the support packages were set up broadly so that these could be realised as rapidly as possible. Later (after 23 March 2020), these were refined with specific support for the self-employed, for instance. The accurate registration of entrepreneurs and employers in the Netherlands (for example, by the Employee Insurance Agency (UWV) and Statistics Netherlands (CBS)) helped with setting up the support in a targeted manner. However, due to limited insight into cash flows in the SME sector, for instance, part of the support had to be settled in retrospect by accountants.

Balancing the costs and the benefits

The knowledge in the previous two points concerns the economy in its narrow sense. However, among economists there is also extensive knowledge about the economy in its broader sense (welfare andwell-being).

An important subject that forms part of this is balancing the various societal costs and benefits. The SCBA is a frequently investigated tool that can be used for this. On 23 March 2020, such an SCBA could have also been made with the still limited knowledge available at that time. This would then have provided insight into the deliberations made and their possible costs. Input from previous studies could have been used to estimate the societal costs. For example, an extra year of education appears to yield about 9% extra annual income for the rest of a person's life (Psacharopoulos, 2018). Incidentally, civil servants at the Ministry of Economic Affairs and Climate Policy did carry out an SCBA in March 2020, which was not public knowledge at that time, but was disclosed later via a Freedom of Information request). The conclusion of this SCBA was that COVID-19 measures would possibly cost (far) more years of life than that they would yield.

An SCBA often elicits a discussion. The figure below shows a number of discussion points. From April 2020 onwards, several publications also appeared that discussed the use and limitations of SCBAs in the context of COVID-19 (Jacobs, 2020) (Fransman, 2020) (Koopmans, 2020).

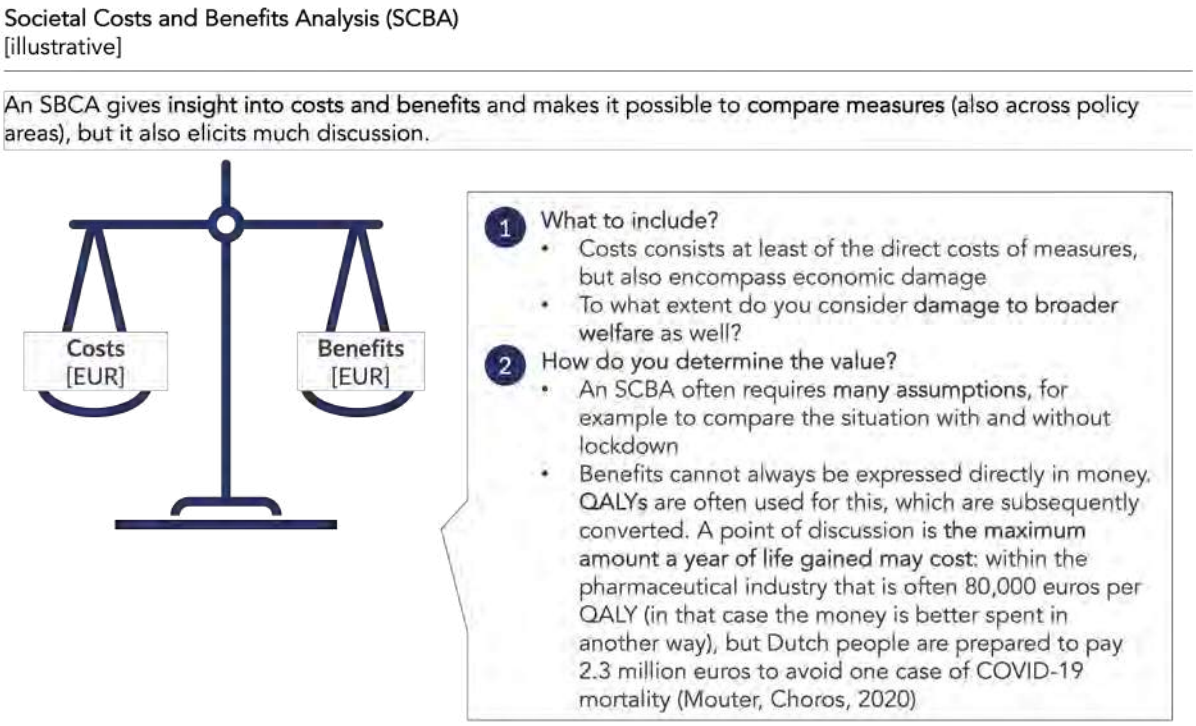

Figure 18: Explanation of societal costs and benefits analysis18

Development on 22 April 2021

If we examine the situation more than a year later, it is clear that the economy was even more resilient than had been thought beforehand. After a short but severe dip in 2020, the GDP had largely recovered again in 2021. Unemployment also remained low. The economy proved to be highly adaptive; consumers began spending more money online.

The support measures were increasingly refined over time and seem to have had an effect. The number of bankruptcies was even historically low (CBS, 2021). As this can also have negative consequences (e.g. less scope for innovation) there was a discussion amongst economists as to whether or not the support measures should be phased out. These could be transitioned into a recovery policy aimed at repairing damage and retraining people (e.g. CPB, SEO).
In the meantime, SCBAs had been calculated in April 2021 (Kolen, 2020) (Frijters, 2020)[2]. Although these were still subject to a great deal of uncertainty, they revealed that a hard lockdown, such as during the first wave, is not the right option.
Another development within the economy was the use of models that can include the economic effects in transmission models. For example, these could be used to calculate behavioural effects (e.g. Eichenbaum, 2020). Based on the network theory, successful efforts were also made to model the impact of super-spreaders so that these could be better predicted (see, for instance, Thurner et al., 2020).

[2] Paper was later withdrawn

In addition, models were also used to calculate alternative lockdown strategies, such as differentiated lockdowns in which different measures apply to different age groups dependent on their vulnerability (Baarsma et al. 2020). Many model simulations showed that these strategies could be more effective and efficient than a 'normal' lockdown (Acemoglu et al. 2020) (Neufeld et al., 2020).

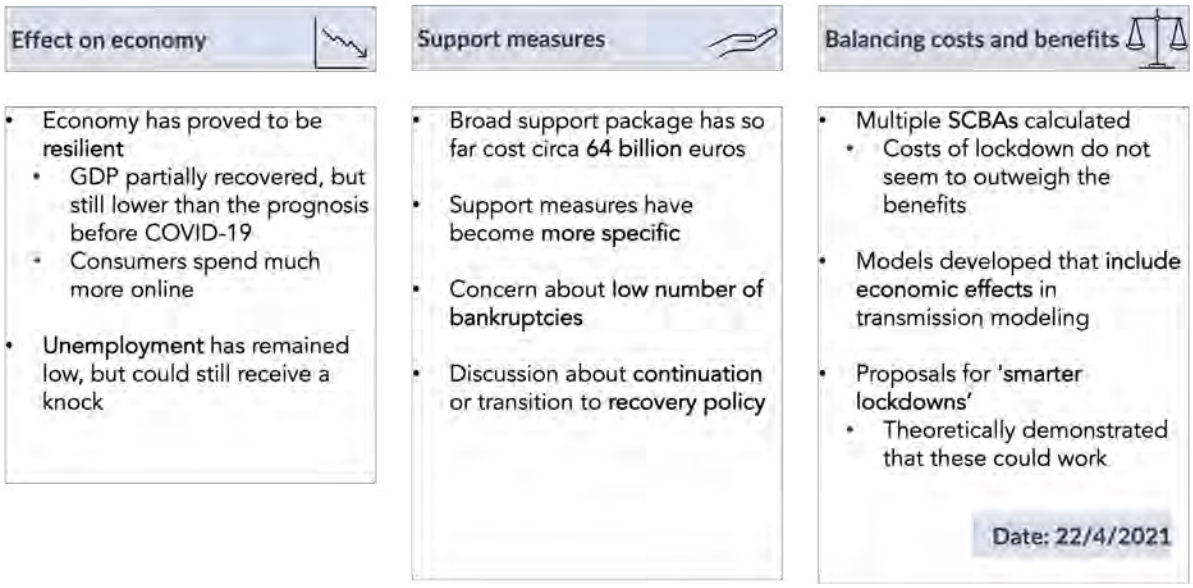

Figure 19: Overview of the development of knowledge and insights on 22 April 2021 within the economic domain

Results: Pandemic preparedness and knowledge agenda

Pandemic preparedness

In this study, we examined the state of scientific knowledge and the pandemic preparedness in the Netherlands according to the the advice given at two moments during the pandemic. These are the moment of the first lockdown on 23 March 2020, and society's reopening on 22 April 2021.

In Table 1, we list the most important conclusions about the state of pandemic preparedness on 23 March 2020. In the table, we distinguish three categories that emerge from the following questions:

1. What is needed in terms of *fundamental knowledge* about issues that are necessary to understand in advance?
2. What is needed in terms of *guidelines and infrastructure* to gather crucial knowledge?
3. What is needed in terms of *organisation* to pool the knowledge and use it to advise?

Classification domains

This report makes use of the broad classification in three domains: 'biomedical' (including epidemiology, virology, infectious disease control), 'social' (including social, behavioural and communication sciences) and 'economic'. We opted to classify the economy as a separate domain despite economics being a social science, it assumed a separate position during the COVID-19 pandemic. When advice was provided to the Dutch government, the economic impact (in the narrow sense with, for instance, GDP as the standard) of public health measures was generally considered independently of the social and epidemiological impact. In addition, economics differs from other social sciences because economists on the whole, deploy far more models and quantifiable predictions. It is therefore useful to independently examine where future improvements are feasible. However, it is important to note that economics concerns more than just the macroeconomy, but also issues such as more comprehensive standards for welfare, health and life satisfaction. In this report, we also consider these aspects within the economic domain.

This classification is, of course, a simplification since a wide variety of disciplines exist within the domains. The pandemic preparedness between disciplines within a domain can differ as well. The conclusions presented are therefore only valid for the domain as a whole and not necessarily for the individual disciplines.

National and international

Table 1 describes the pandemic preparedness for the Dutch situation on 23 March 2020. At that moment, the virus outbreak had already developed into a worldwide pandemic. The state of pandemic preparedness at the international and European levels did not differ that much from the Dutch level. The international and European aspects are important in this regard because for adequate local pandemic preparedness, we also need to deploy knowledge that is internationally available at, for instance, the World Health Organization (WHO) and European Centre for Disease Prevention and Control. At the same time, the local situation may also require deviations from international guidelines and recommendations. Cultural and political differences can mean that international knowledge is not always directly transferable. In spite of this, international collaboration can yield many benefits.

Although international collaboration for pandemic preparedness is well established in the biomedical domain, there is scope for improvement here too.

Table 1: Most important conclusions about improving pandemic preparedness based on the case 23 March 20201

State of pandemic preparedness in science:

	Biomedical	Social	Economic	Domain-overarching
Fundamental knowledge	• There is already a lot of fundamental knowledge about pandemics and viruses • Some crucial questions for pandemic preparedness remain	• A lot of general knowledge on social sciences exists already • There was a lack of specific knowledge about COVID-19 • Knowledge could not always be applied in practice	• Fundamental knowledge exists on: the consequences of closing part of the economy support measures and weighting measures • However, specific consequence of lockdown was not yet known	• There was little domain-overarching research
Guidelines & infrastructure	• There were unequivocal (international) guidelines that help to rapidly collect the right knowledge • There is scope for improvement in knowledge infrastructure	• No clear guidelines for knowledge acquisition (which did exist for communication, for example) • As a result it was not clear which information was crucial	• Infrastructure present to gain insight into all groups and make projections • Must subsequently be made more specific • No clear guidelines for knowledge acquisition	• No domain-overarching guidelines exist • Interdisciplinary cohort studies[3] are required as infrastructure
Organisation	• Advice is organised in a clear manner • However, there is scope for improvement • For instance: Organisation of independent studies can be improved	• No domain-wide organisation where advice and different subdomains could be brought together	• No domain-wide organisation where advice and different subdomains could be brought together	• No organisation where advice from different domains could be brought together

Legend (indicative score):

Fully present on 23 March 2020  Entirely absent on 23 March 2020

[3] A cohort study is an observational study in which a group of people with one or more common characteristics are followed over a longer period of time and measurements are performed repeatedly, to examine determinants of specific outcomes of interest. A domain-overarching cohort can collect biomedical, social or economic measurements, allowing the interaction between the disciplines to be taken into account. Several examples of domain-overarching observational research exist.

Knowledge agenda

Besides the state of pandemic preparedness, concrete matters were identified in this research that can contribute to improving the pandemic preparedness (see below) and that jointly form the pandemic knowledge agenda. The complete knowledge agenda is provided below, and is elaborated in Chapters 6 to 9. The knowledge agenda is the outcome of the two work sessions. With this, it was not our aim to be complete, but to draw important lessons from the COVID-19 pandemic.

Specific research questions for each separate domain have been identified. Within the biomedical domain, it is important to investigate in advance how we deal with a large quantity of new research of variable quality. Furthermore, there is a lack of fundamental knowledge about, for instance, the use of syndromic surveillance, and there is scope for improvement with respect to development of guidelines and organisation.

Biomedical	Research questions	Category
	How do you deal with the large number of new studies for which the quality and origin are variable?	Fundamental knowledge
	(How) can we deploy syndromic surveillance as an early detection method?	Fundamental knowledge
	How can we more rapidly answer open questions about the infection route of a virus and the associated protective equipment at the beginning of a pandemic?	Fundamental knowledge
	Until when is source and contact tracing useful as a means of limiting the transmission?	Guidelines & infrastructure
	Which steps are needed to even more rapidly map the infectious disease pyramid, aggregated per population group?	Guidelines & infrastructure
	Which organisation method is needed to pool independent studies quickly during a pandemic?	Organisation

Within the social domain, the development of a pandemic handbook (or protocol) is at the top of the agenda so that crucial knowledge can rapidly be acquired at the beginning of a pandemic. Furthermore, behavioural research infrastructure require need to be improved, as well as investigating how to ensure that certain population subgroups are better represented in behavioural research. Lastly, how to provide pooled scientific knowledge and advice to policymakers.

Social	Research questions	Category
	Which issues need to be included in a pandemic protocol for the social domain?	Guidelines & infrastructure
	How do we translate social knowledge into concrete actions for society, on points where that has not yet sufficiently happened?	Fundamental knowledge
	Which (further) intervention possibilities are there against misinformation and disinformation?	Fundamental knowledge
	Which knowledge about solidarity and impact is important at the beginning of a major crisis, also from an ethical perspective?	Fundamental knowledge
	What would a 'societal impact pyramid' look like, as opposed to the infectious disease pyramid?	Fundamental knowledge
	Can we provide more empirical evidence for behavioural interventions during a pandemic?	Fundamental knowledge
	What are the behavioural determinants for complying with measures during a pandemic, for example?	Fundamental knowledge
	How do we ensure that certain subgroups are better represented in behavioural research during a future pandemic?	Guidelines & infrastructure
	Can we set up an infrastructure so that more fundamental behavioural studies can be immediately carried out during a future pandemic?	Guidelines & infrastructure
	How do we ensure a clear role for communication and behavioural sciences in the advice-providing structure?	Organisation
	How do we ensure a central place where social knowledge from academia can be pooled to provide advice?	Organisation
	How do we ensure that institutional knowledge ends up in policy? What requirements does this place on the design of the advice?	Organisation

Within the economic domain, there is also a need for a pandemic protocol so that crucial knowledge can be rapidly acquired at the beginning of a pandemic. In addition, more empirical research must be done into Dutch society because many insights are currently only based on studies carried out in other countries. Furthermore, the advice provided could be improved by creating a central place for pooling knowledge.

Economic	Research questions	Category
	How can we use world trade models to obtain insight into the scarcity of goods and security of supply?	Fundamental knowledge
	How do we gain more empirical knowledge about Dutch society and economy?	Fundamental knowledge
	Which impact has the pandemic had on the size of the informal economy?	Fundamental knowledge
	Which issues need to be included in the pandemic protocol for the economic domain? Specifically: which knowledge is needed to be able to make a comprehensive assessment about measures (with, for instance, a Social Costs and Benefits Analaysis (SCBA, an economic approach to weighing up different choices)?	Guidelines & infrastructure
	How do we ensure a central location where scientific, social and economic knowledge can be pooled to provide advice?	Organisation

We end with the domain-overarching questions, which were categorised into fundamental research questions that requires combined knowledge from the different domains. Additionally, guidelines & infrastructure and organisation are needed to bring together knowledge from all domains and to translate this into advice.

Domain-overarching	Research questions	Category
	How do we make long-term scenarios rapidly available at the beginning of the pandemic so that the impact is clear for all domains?	Fundamental knowledge
	How can fundamental biomedical questions about, for example, infection routes be answered, with due consideration to social factors and behaviour?	Fundamental knowledge
	How can the contact matrix be recalibrated and refined, and how do contacts change during a pandemic?	Fundamental knowledge
	How can human behaviour be included in infectious disease transmission models?	Fundamental knowledge
	Until when is source and contact tracing necessary from both a biomedical and social perspective?	Fundamental knowledge

What is the proper duration of (compulsory) isolation based on both biomedical and social factors?	Fundamental knowledge
What is a suitable assessment framework to realise a domain-overarching choice for measures?	Fundamental knowledge
In an assessment framework and/or the advice, how do you deal with knowledge that is difficult or impossible to quantify?	Fundamental knowledge
Taking the current consequences into account, how can you optimally deploy accompanying policy? Is it possible to draw up a range of accompanying measures?	Fundamental knowledge
For which crucial goods must the supply (procurement and distribution) be guaranteed during a pandemic?	Guidelines & infrastructure
Is it possible to establish a broad cohort that is a reflection of society (in terms of geography, SES, age, etc.) so that a knowledge infrastructure can be rapidly established in the event of a future outbreak? This would explicitly concern a study in which biomedical as well as social knowledge could be acquired.	Guidelines & infrastructure
How do you organise knowledge infrastructure to efficiently feed the provision of advice (domain-overarching)?	Guidelines & infrastructure
How do you ensure a better exchange of data between different domains and organisations?	Guidelines & infrastructure
How do we maintain protocols for, and knowledge about, pandemic preparedness at an appropriate level during periods between pandemics?	Organisation
How can we set up an advisory body that can bring together scientific knowledge from all domains?	Organisation
Can we, alongside domain-specific advice, establish a multidisciplinary team that considers the long-term perspective?	Organisation

Focus: Biomedical knowledge agenda

In this chapter, we elaborate the research questions in the biomedical domain.

Fundamental knowledge

We have identified several points within the biomedical domain for which fundamental knowledge is still required to be better prepared for a future pandemic.

Biomedical	Research questions	Category
	How do you deal with the large number of new studies of which the quality and origin is variable?	Fundamental knowledge

During this pandemic, scientific research was carried out worldwide at a very rapid pace (see figure 20). This meant that each day brought many new articles, some of which were still in preprint and therefore not yet reviewed. Furthermore, at the beginning of the pandemic, the majority of the knowledge originated from China and was therefore not necessarily representative of the Dutch situation. The expectation is that a similar pattern will be seen during new pandemics as well.

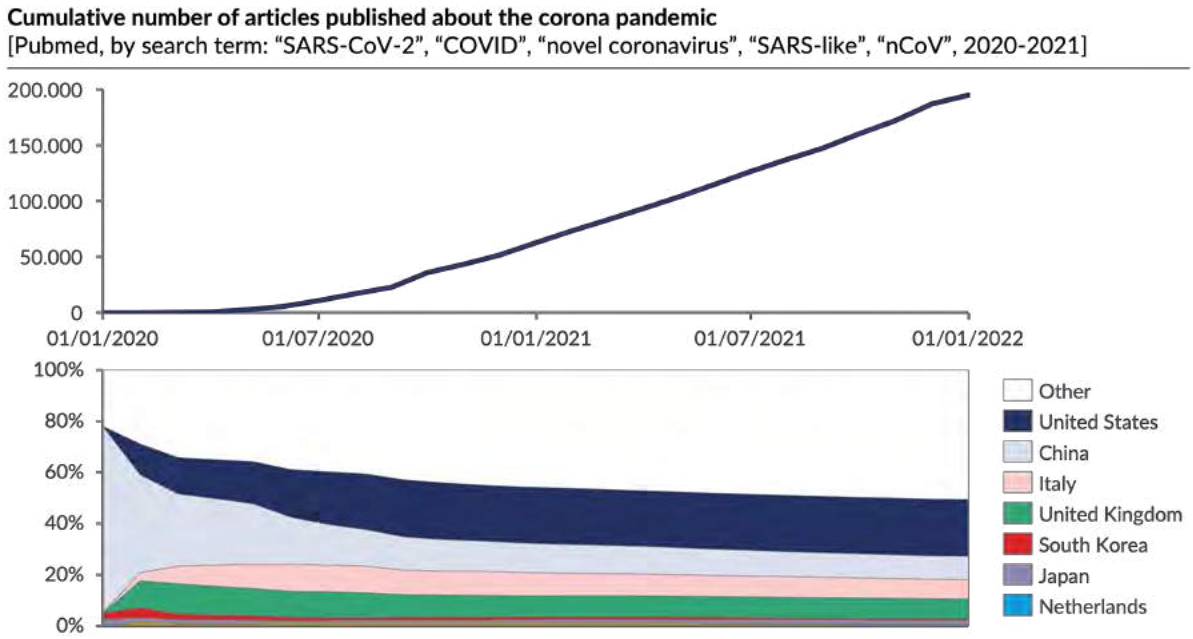

Figure 20: Trend in number of published articles about SARS-COV-2 and the distribution across the countries where the articles were published, source: PubMed, analysis Gupta Strategists19

It is important that we start thinking now about how to deal with knowledge where the robustness has not yet been demonstrated and that may need translation to the Dutch situation. This will require fundamental research on the basis of which guidelines can subsequently be drawn up.

Biomedical	Research questions	Category
	How can we more rapidly answer questions about the infection route of a virus and the associated protective measures at the beginning of a pandemic?	Fundamental knowledge

One of the major questions during the pandemic, and certainly on 23 March 2020, concerned establishing the most important transmission route of the virus. As this factor is crucial for the control of a virus in the future, we need to be able to answer questions about this as rapidly as possible.

Biomedical	Research questions	Category
	(How) can we deploy syndromic surveillance as an early detection method?	Fundamental knowledge

At the beginning of the COVID-19 pandemic, limited test capacity meant that surveillance data were incomplete. In particular, signals from nursing homes indicated a large number of infections there, but this was not fully reflected in test data. We recommend investigating whether syndromic surveillance can contribute to more rapidly describing the epidemiology of a possible future virus. This may help overcome early shortages in test material, and allow for appropriate allocation of tests without compromising insights into the spread of the pathogen in the wider community. In March 2020, this would have allowed, for instance, individuals with COVID-19-like symptoms and an epidemiological link to Austria instead of the north of Italy, to still be included in surveillance data. The application of syndromic surveillance requires further investigation in the Netherlands, including the, infrastructure needed to carry out regular measurements.

Guidelines & infrastructure

Besides fundamental knowledge, which must be available beforehand, it is also important to improve guidelines and infrastructure so that at the beginning of a new pandemic, information can be rapidly collected. This applies to several points.

Biomedical	Research questions	Category
	Which steps are needed to even more rapidly determine the infectious disease pyramid, aggregated per population group?	Guidelines & infrastructure

In the case of a novel virus outbreak, it is important to describe the infectious disease pyramid as rapidly as possible. This is shown in Figure 21. On 23 March, the COVID-19 disease pyramid was unclear.

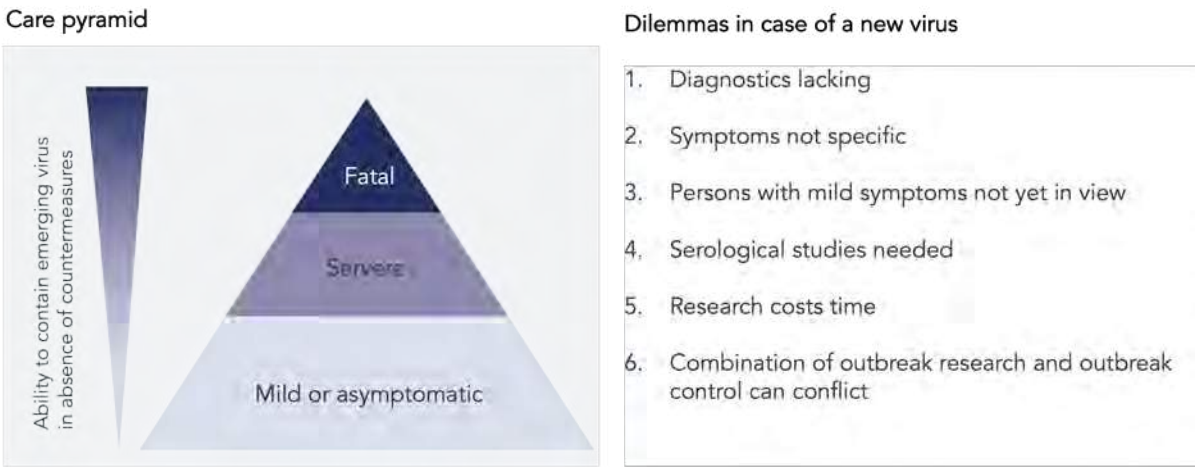

Figure 21: Infectious disease pyramid and standard dilemmas that are investigated for each new outbreak20

Figure 21: Infectious disease pyramid and standard dilemmas that are investigated for each new outbreak20

At the top of the pyramid, which represents the mortality rate, the estimates reported varied considerably, for instance. Figure 22 shows some of the estimates that were available at that moment.

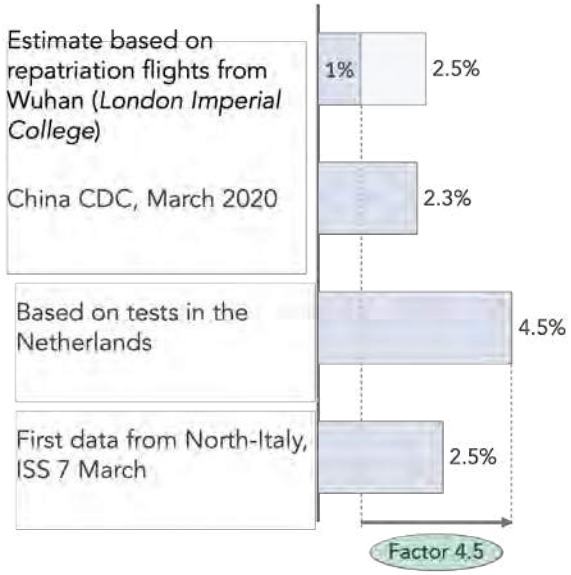

Figure 22: Knowledge about the mortality rate from different sources on 23 March 2020

It was also unclear what proportion of infected individuals experienced mild symptoms or were even asymptomatic. The first studies from China (Huang, Yang) created the impression that almost every patient had fever, but this was later refuted (e.g. Guan, Chen), as can also be read from Figure 8. For a long time, fever nevertheless remained a prerequisite symptom in the case definition for COVID-19.
Figure 8: Percentage of COVID-19 patients with fever based on the initial studies from China8

Thus, in future, it is vitally important to even more rapidly describe the infectious disease pyramid per group in society (both according to age and socioeconomic status (SES), such as via a cohort study.21

Biomedical	Research questions	Category
	Until when is source and contact tracing useful as a means of limiting the transmission?	Guidelines & infrastructure

In the case of an outbreak of a notifiable pathogen, public health law in the Netherlands stipulates that the municipal health service must carry out source and contact tracing. This can contribute to describing the spread and taking necessary steps to limit the transmission of the pathogen. During the initial months of the COVID-19 pandemic, however, the usefulness of source and contact tracingsource and contact tracing swiftly decreased because there were far too many infections and only a limited number of employees available to conduct this research. Furthermore, it was already known by then that the transmission of the virus was possible up until 48 hours before the first symptoms occurred; this meant that the effect of source and contact tracing was often too late to mitigate the further spread of the virus. Careful research is needed to determine if source and contact tracing remains useful when not all infected individuals can be contacted, and at which point it would be better to deploy resources elsewhere.

Organisation

Biomedical	Research questions	Category
	Which organisation method is needed to pool independent studies during a pandemic?	Organisation

One last remaining question concerns the organisation of independent studies during a pandemic. At the beginning of the pandemic, we witnessed the start of a large number of studies aimed at gaining a better understanding of the virus. It was often the case that near-identical research was conducted at several locations or that such research had already been done in other countries. If these independent studies are better organised and pooled, they can be realised more efficiently, which means that vital knowledge will become available faster.

Focus: Social knowledge agenda

In this chapter, we elaborate the research questions in the social domain.

Fundamental knowledge

Social	Research questions	Category
	How do we translate social knowledge into concrete actions for society, on points where that has not yet sufficiently happened?	Fundamental knowledge
	Which (further) intervention possibilities are there against misinformation and disinformation?	Fundamental knowledge

For a portion of the social knowledge, the challenge lies in being able to deploy it specifically for a crisis such as the COVID-19 pandemic. Therefore, this knowledge must be rendered more actionable. That means making tangible what can be done and/or must be done in a specific situation. This could also include reflections on the form in which policymakers could most effectively deploy this knowledge.
Many studies already exist into misinformation and disinformation. However, further research is required to better understand the intervention possibilities, particularly in the case of disinformation on a similar scale as during the COVID-19 pandemic. These intervention possibilities (and crisis intervention in general) should, amongst other things, be aimed at mitigating social unrest resulting from incorrect information and should also promote compliance with measures that counteract the spread of the virus.

Social	Research questions	Category
	Can we provide more empirical evidence for behavioural interventions during a pandemic?	Fundamental knowledge
	What are the behavioural determinants for complying with measures during a pandemic, for example?	Fundamental knowledge

More empirical research is needed into behavioural interventions in general. During the COVID-19 pandemic, this could only be carried out to a very limited extent (RIVM Behavioural Unit, 2022), 2022). The published studies mainly provided theoretical elaborations for interventions (such as West et al., 2020). Moreover, during the pandemic, the behavioural studies were primarily descriptive in nature. Fundamental research into underlying behavioural determinants is still largely lacking.

Social	Research questions	Category
	Which knowledge about solidarity and impact is important at **the beginning** of a major crisis, also from an ethical perspective?	Fundamental knowledge

The limitations of solidarity in the Netherlands became visible during the pandemic. The question as to 'what kind of society do we wish to live in' (Harari, 2020) was regularly posed in the course of discussions, even during the initial months of the pandemic. Many of the decisions taken gave rise to huge public debates. Therefore it is important, from the outset, to elucidate the ethical considerations that decisions are based on and how the impact of these is weighed. Further research into solidarity and impact can help to support this.

Social	Research questions	Category
	What would a 'societal impact pyramid' look like, as opposed to the infectious disease pyramid?	Fundamental knowledge

During the first session, the idea arose to design a 'societal impact pyramid' as an equivalent of the infectious disease pyramid. By mapping this at the beginning of a pandemic or another crisis, it should become clear which groups will be hardest hit by the crisis. We recommend investigating and elaborating this further.

Guidelines & infrastructure

Social	Research questions	Category
	Which issues need to be included in a pandemic protocol for the social domain?	Guidelines & infrastructure

The biomedical pandemic protocols became effective at the first signs of a potentially novel virus outbreak. Based on the standard list of indicators, it was immediately clear to the biomedical field which questions needed to be answered. No equivalent of this exists yet in the social domain. By determining in advance which knowledge is crucial, this can be collected more rapidly at the beginning of a crisis. In this plan, translating academic knowledge into actions that can be applied in the very short term (day-to-day basis) is important. And there is also a need for a knowledge infrastructure to ensure that applicable knowledge from the subdomains is pooled and becomes part of the advice. Within the social sciences, nobody has currently been tasked with doing research into a new pandemic. Therefore, a clear structure must ensure that researchers can (and are allowed to) quickly switch research responsibilities when this becomes necessary. This will often concern research aimed at more rapid results than is the case for most standard scientific studies. In addition, proper arrangements need to be made for the funding of such research.

Social	Research questions	Category
	How do we ensure that certain subgroups are better included in behavioural research during a future pandemic?	Guidelines & infrastructure
	Can we set up an infrastructure so that more fundamental behavioural studies can be immediately carried out during a future pandemic?	Guidelines & infrastructure

During the pandemic, a large number of behavioural studies were swiftly carried out by, amongst others, the RIVM Behavioural Unit. It was also possible to carry out longitudinal studies by using existing panels such as the LISS panel (Longitudinal Internet studies for the Social Sciences - see: https://www.lissdata.nl/Home).
Certain aspects of the infrastructure are also in need of improvement. The first point concerns a known problem in carrying out surveys. Certain groups in society (e.g. functionally illiterate people and immigrants) are generally difficult to reach with surveys. This was also the case during the pandemic, and due to the considerable time pressure, it often posed an even bigger problem still. Therefore, ways need to be found that will render it possible to do measurements among these groups in the event of a new pandemic.
Second, investments need to be made in a better infrastructure for behavioural research in general. As previously stated, there was a lack of empirical studies into behavioural interventions and the underlying behavioural determinants. During interviews, the reason given for this was that many social scientists find it difficult to rapidly change their ongoing studies. And there are no funds available to do this either. For pandemic preparedness to be improved, a group of scientists needs to be called into existence that can immediately begin research in the event of a crisis (comparable to a voluntary fire brigade).

Organisation

Social	Research questions	Category
	How do we ensure a central place where social knowledge from academia can be pooled to provide advice?	Organisation
	How do we ensure a clear role for communication and behavioural sciences in the advice-providing structure?	Organisation
	How do we ensure that institutional knowledge ends up in policy? What requirements does this place on the design of the advice?	Organisation

Within the biomedical domain, there is a clear organisation that can pool information from different subdomains during a crisis. That is the Outbreak Management Team (OMT). Within the social domain, this does not (yet) exist, which is one of the reasons why it took a long time before social consequences were properly considered in the

recommendations. With the establishment of the Societal Impact Team (SIT), that organisation does now exist.

At the beginning of the COVID-19 crisis, communication and behavioural sciences were completely missing in the structure for the provision of advice. With the establishment of the RIVM Behavioural Unit, this was improved but even today, this unit has still not been accorded a formal role in the provision of recommendations. Since knowledge about behaviour and communication can be of considerable value during a crisis, these disciplines should be given a clear role to play in the provision of advice. This will not only improve the pandemic readiness of policymakers, but also allow academics to make good use of knowledge about the best way to communicate certain recommendations.

A last and frequently heard challenge is that much knowledge never reached policymakers, or that they were insufficiently aware of its existence. This is of particular concern to many social scientists. Public administration researchers could investigate how this might be improved in the future.

Focus: Economic knowledge agenda

In this chapter, we elaborate the research questions in the economic domain.

Fundamental knowledge

Economic	Research questions	Category
	How can we use world trade models to obtain insight into the scarcity of goods and security of supply?	Fundamental knowledge
	How do we gain more empirical knowledge about Dutch society and economy?	Fundamental knowledge
	Which impact has the pandemic had on the size of the informal economy?	Fundamental knowledge

At the beginning of the COVID-19 pandemic, models were able to provide reasonable estimates of the consequences of the lockdown on the Dutch GDP. A number of fundamental questions were identified to further improve these estimates in the case of a new pandemic.
First, it would be good to obtain insight from existing world trade models about the possible scarcity of goods. International trade flows are reasonably well described and could be used to predict where possible delivery problems might arise.

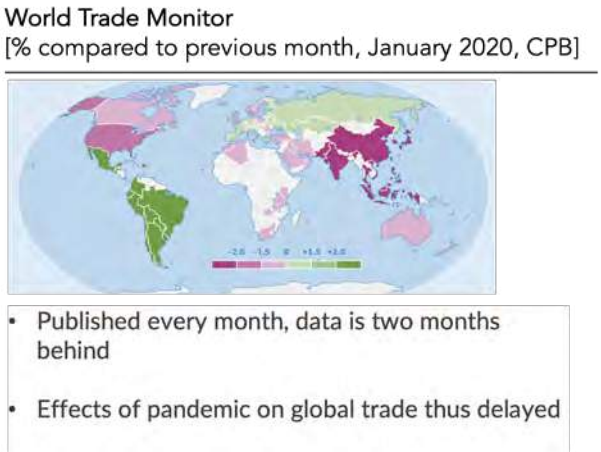

Figure 23: World Trade Monitor of the Netherlands Bureau for Economic Policy Analysis (CPB). Models about world trade could also be used to obtain insight into the scarcity of goods and supply chain problems.22

Additionally, there is a need for more empirical research into the Dutch economy. At present, many studies into economic issues are based on studies in other countries and therefore possibly not always applicable to the Netherlands on a one-to-one basis.

Finally, it would be interesting to examine to what extent the informal economy (undeclared work) has grown or shrunk during the pandemic. For example, there are indications that many hairdressers visited people at home to give haircuts when people working in contact professions could not carry out their work. Gaining a better understanding of this could help to more accurately estimate the consequences of measures in the future.

Guidelines & infrastructure

Economic	Research questions	Category
	What are the questions that you must pose for a lockdown? Which knowledge is needed to be able to make a broad assessment?	Guidelines & infrastructure

Just like other social scientists, economists also need clarity about the crucial questions at the beginning of a pandemic. More specifically, it is essential to possess an overview of the kind of knowledge needed to carry out a broad assessment, for example based on an SCBA.

Organisation

Economic	Research questions	Category
	How can we ensure there is a central place where economic knowledge from academia can be pooled to provide advice?	Organisation

During the first weeks of the COVID-19 pandemic, economists had to work together on an informal basis to ponder the necessary support packages. There was no clear central location for the pooling of economic knowledge. Thanks to the establishment of the SIT, however, that location exists now.

Focus: Domain-overarching knowledge agenda

In this chapter, we elaborate the domain-overarching questions that are part of the knowledge agenda. A large number of fundamental questions have been identified that require research at the interface of various domains. Furthermore, the domain-overarching infrastructure and organisation need to be considered as well.

Fundamental knowledge

The most important domain-overarching research questions in the area of fundamental knowledge concern the design of a multidisciplinary, integrated assessment framework for measures.

Domain-overarching	Research questions	Category
	What is a suitable assessment framework to realise a domain-overarching choice for measures?	Fundamental knowledge
	In an assessment framework and/or advice, how do you deal with knowledge that is difficult or impossible to quantify?	Fundamental knowledge

One of the challenges here is how to handle knowledge that is difficult or impossible to quantify. For instance, in the case of an SCBA, it is essential to express the costs and benefits in a number (mostly euros). However, for certain (especially social) effects, it is not evident whether or how this could be possible (even though there are discussions about this within disciplines). At present, the standard approach is often limited to entering a token value for such effects. This bears the risk that a policymaker can all too easily interpret that as equal to zero.

Domain-overarching	Research questions	Category
	Taking the current consequences into account, how can you make optimal use of accompanying policy? Can you draw up a range of measures?	Fundamental knowledge

Research needs to be done into the optimal use of accompanying policy so that the impact of (necessary) measures on marginalised groups, in particular, can be reduced during a future crisis. It is important that this is considered from a domain-overarching perspective, primarily because different forms of vulnerability exist. Certain population subgroups were at greater risk of COVID-19 infection and subsequent related morbidity and mortality. In addition, some groups were harder hit by specific measures.

Ideally, at the beginning of the new pandemic, you have a range of substantiated knowledge about possible accompanying measures (examples are support for schools, keeping community centres open, etc.) that can be deployed as necessary. This range of knowledge can already be drawn up based on various scenarios, which needs to be kept up to date.

Domain-overarching	Research questions	Category
	For which crucial goods must supply be guaranteed during a pandemic?	Fundamental knowledge

The considerable shortage of facemasks and other medical devices at the beginning of the crisis made it clear that supply security is not always guaranteed in a globalised world. A start already needs to be made in mapping which goods are crucial during a pandemic. Subsequently, it must be investigated how to ensure supply of these goods can be guaranteed during a pandemic.

Domain-overarching	Research questions	Category
	How can human behaviour be included in infectious disease transmission models?	Fundamental knowledge
	How can the contact matrix be recalibrated and refined, and how do contacts change during a pandemic?	Fundamental knowledge

In addition, we have also noted two points with which to improve the modelling of the spread of the virus. Studies already exist concerning the inclusion of (aspects of) behaviour in transmission models (for example, Jones et al., 2021). In the field of economics, many models like this were also developed during the COVID-19 pandemic. Further research is still needed for the rapid implementation of such models in practice. In addition, the collaboration of behavioural scientists in realising this could be further strengthened. An important aspect to include is, for instance, the compliance with measures during the course of a pandemic.
Furthermore, we also advise recalibrating the contact matrix that is used in models. During the pandemic, a large amount of knowledge was gained about which groups in the population engage in social contactsand in which settings. This knowledge can be used to further refine the modelling. In addition, we have seen that the number and location of contacts can strongly change during the course of a pandemic. It is important to understand this so that it can be taken into account for new predictions.

Domain-overarching	Research questions	Category
	How do we make long-term scenarios rapidly available at the beginning of the pandemic so that the impact is clear for all domains?	Fundamental knowledge

Based on the above, it is important to have long-term scenarios available as rapidly as possible in the case of a future pandemic. These must clearly show the impact within all domains. In particular, the combination of biomedical scenarios with economic models and insights about behavioural change can lead to different considerations in the long term.
We also recommend that pandemic preparedness be tested in a domain-overarching manner comparable to the exercises for other disaster scenarios, such as fire drills or war games. These long-term scenarios must be examined in such tests as well.

Domain-overarching	Research questions	Category
	How can fundamental biomedical questions about, for example, infection routes be answered with due consideration to social factors and behaviour?	Fundamental knowledge

On 23 March 2020, several key questions within the biomedical domain were not yet (fully) answered. Among other things, it remained unclear what the most important infection route of the virus was. Given the considerable impact of this question (and others) in the social domain as well, it is crucial to be able to answer this question as rapidly as possible. Social factors and behaviour also have a role to play in this.

Domain-overarching	Research questions	Category
	What is the proper duration of (compulsory) isolation based on both biomedical and social factors?	Fundamental knowledge

During the COVID-19 pandemic, the duration of the isolation period was established on the basis of biomedical factors, with the most important point of information being the infectious period. However, if the isolation period is too long, then it is only to be expected compliance will decline. Therefore, to be able to optimally prevent the spread of a virus, social factors must also be considered in determining the isolation period. The first step for this is to investigate from which moment onwards such factors begin to weigh (heavily).

Domain-overarching	Research questions	Category
	Until when is source and contact tracing necessary from both a biomedical and social perspective?	Fundamental knowledge

Especially at the beginning of the pandemic, the source and contact tracing was chiefly deployed to map and curb the spread of the virus. As noted earlier, the usefulness of this approach proved to be limited when community transmission was widespread, leading to a large number of infections[4]. Nevertheless, source and contact tracing can also provide a wealth of social information, such as the locations at which infections take place. It is advisable to investigate what source and contact tracing data can teach us about the effectiveness of this instrument, and what the interaction is between behaviour, compliance with measures and the spread of the virus.

Guidelines & infrastructure

At the beginning of a pandemic, it is vital to have proper information available as rapidly as possible. The questions below need to be answered to improve this at the domain-overarching level.

Domain-overarching	Research questions	Category
	How do you set up a knowledge infrastructure to efficiently feed the provision of advice (domain-overarching)?	Guidelines & infrastructure
	How do you ensure a better exchange of data between different domains and organisations?	Guidelines & infrastructure

All of the parties involved must have access to relevant information to guarantee the provision of balanced recommendations. For example, it is important to know how a virus will develop from a biomedical perspective to estimate the social and economic consequences. An infrastructure therefore needs to be established to provide timely knowledge to all of the parties involved.
This specifically concerns the sharing of relevant data. Due to privacy concerns, data were often linkedless often than would have been desirable. For instance, raw data from the National Institute for Public Health and the Environment (RIVM) was sometimes only available in the case of collaboration with an RIVM employee. It is questionable whether this is desirable from the perspective of open science.
Further, there are suspicions that certain bodies were unnecessarily cautious in sharing data, even when the right privacy measures were in place (KNAW, 2022).

[4] This applies to the coronavirus and that can differ for a pathogen with a different incubation time.

Domain-overarching	Research questions	Category
	Is it possible to establish a broad cohort that is a reflection of society (in terms of geography, SES, age, etc.) so that a knowledge infrastructure can be rapidly established in the event of a future outbreak?	Guidelines & infrastructure

During a pandemic, it must be possible to measure the state of society so that the impact of the pandemic can be assessed. This applies to both biomedical and social aspects. For an optimal preparation, we advise considering the establishment of a broad cohort that reliably mirrors Dutch society. Pre-pandemic measurements need to be available to be able to assess the effect of a novel pathogen or possible measures. Investing in large, current cohorts, also in periods without a crisis, is therefore vitally important. This concerns both medical aspects (age, health, etc.) and social aspects (socioeconomic status, cultural background, etc.). Reaching and recruiting individuals from diverse socioeconomic groups can be labour-intensive, but is nevertheless of paramount importance. Various cohorts already exist at present. For instance, the RIVM Behavioural Unit already began a cohort in April 2020, in which a diverse range of social knowledge is being collected. However, this cohort is not representative for the population (RIVM) and no biomedical measurements were collected. Instead of commencing a completely new cohort, it would be advised to examine the extent to which we can use existing population-based cohorts for this purpose. Possible examples are the 'Generation R' cohort in Rotterdam, the HELIUS study in Amsterdam and the national LISS panel.

Organisation

Domain-overarching	Research questions	Category
	How can we set up an advisory body that can bring together scientific knowledge from all domains?	Organisation
	Can we, alongside domain-specific advice, establish a multidisciplinary team that considers the long-term perspective, for example.	Organisation

On 23 March 2020 and during the entire COVID-19 pandemic, there was an institutional structure where the biomedical advice came together, namely the Outbreak Management Team (OMT). As discussed earlier, something similar did not exist for the social or economic domains, leading to the establishment of the Societal Impact Team (SIT).
The current setup therefore consists of independent silos (SIT and OMT). It should be investigated whether the provision of integrated advice can result in better overall

recommendations. We see strong indications that this may be the case. For instance, the closure of schools; on 16 March 2020, schools were closed (and not reopened on 23 March 2020). A thorough analysis of the case revealed that from a biomedical perspective, much remained uncertain at that moment in time. However, the initial signals were that closing the schools had a relatively small effect on curbing the pandemic. In the social sciences, the knowledge was already present that a school closure has a major impact on children's long-term development.
Allowing biomedical, social and economic researchers to jointly assess such an impactful decision might possibly have led to a different advice on 23 March 2020 about the closure / reopening of schools.
A different 'flavour' of multidisciplinary advice is to retain the immediate advice within the independent domains but, at the same time, to have a multidisciplinary team consider the long term impacts. We recommend investigating this manner of providing advice as well.

Domain-overarching	Research questions	Category
	How do we maintain protocols for, and knowledge about, pandemic preparedness at an appropriate level during periods between pandemics?	Organisation

Pandemic preparedness and crisis preparation, in general, had often been investigated in the past. The importance of multidisciplinary advice had often been emphasised too. The 2016 Dutch manual for crisis management (*Nationaal Handboek Crisisbeheersing*) includes a setup with interdepartmental recommendations during (every) crisis. Nevertheless, this did not occur at the beginning of the COVID-19 pandemic. As a result, the question we face not only concerns the realisation of new or improved protocols and knowledge, but also how we can ensure that this knowledge is maintained at the proper level in periods when there is no crisis. A regular 'fire drill' for pandemic preparedness could contribute to this.

Conclusions

This report makes it clear that many research questions still need to be answered for increased pandemic preparedness in the Netherlands. This applies to the individual biomedical, social and economic domains as well as the interaction between these domains. The research questions concern not just fundamental knowledge but also a social domain protocol, structuring the provision of advice and collecting knowledge and information, and the relationship between the local situation and international knowledge and advice.
This research also reveals that researchers can respond rapidly to a crisis. During the pandemic, major steps forward were made in the development of knowledge and infrastructure within all domains. The two meetings held for this report offer confidence that the required domain-overarching (interdisciplinary) research is also feasible.
One of the most important research questions identified in this report was how an integral assessment framework can be established in order to deliver joint, multidisciplinary advice during a pandemic. During the meeting on 15 February 2023, those present made a first step in this direction by conducting two short simulations.

The most important lessons from this are[5]:

- Lesson 1: Integrated advice does not happen automatically: it requires action and investment from scientists and policymakers
- Lesson 2: A joint framework for considering advice from the perspective of different scientific disciplines is feasible and can provide general guidance, also when disciplines subsequently continue to issue advice independently
- Lesson 3: There still remain unanswered questions concerning the different facets of integral advice and how those come together in a broadly supported integral decision-making framework

In conclusion, it is advisable to (continue to) regularly test the pandemic preparedness protocol for robustness and completeness in order to maintain a high level of preparedness and, should this become necessary, take rapid and effective actions.

[5] See the paper 'Contours of integrated pandemic advice': https://convergence.nl/learning-from-a-crisis/

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List of abbreviations

- ABN AMRO: Dutch banking group
- CBS: Statistics Netherlands, Centraal Bureau voor de Statistiek
- CPB: Bureau for Economic Policy Analysis, Centraal Planbureau
- DNB: Dutch Central Bank, De Nederlandse Bank
- ECB: European Central Bank, Europese Centrale Bank
- ECDC: European Centre for Disease Prevention and Control, Europees Centrum voor ziektepreventie en -bestrijding
- GGD: Municipal Health Service, Gemeentelijke Gezondheidsdienst
- IMF: International Monetary Fund, Internationaal Monetair Fonds
- ING: Dutch banking group
- KNAW: Royal Netherlands Academy of Arts and Sciences, Koninkijke Nederlandse Akademie van Wetenschappen
- LCI: National Coordination for Communicable Diseases Control, Landelijke Coördinatie Infectieziektebestrijding
- NOW: Temporary Emergency measure Bridging for Retention of Work, Tijdelijke Noodmaatregel Overbrugging Werkgelegenheid
- OECD: Organisation for Economic Co-operation and Development, Organisatie voor Economische Samenwerking en Ontwikkeling
- OMT: Outbreak Management Team
- PIAAC: Programme for the international Assessment of Adult Competencies
- Rabobank: Dutch banking cooperation
- RIVM: National Institute for Public Health and the Environment, Rijksinstituut voor Volksgezondheid en Milieu
- RVS: The Council of Public Health & Society, Raad voor Volksgezondheid en Samenleving
- SCP: Institute for Social and Cultural Research, Het Sociaal en Cultureel Planbureau
- SEO: SEO Amsterdam Economics
- UWV: Employee Insurance Agency
- WHO: World Health Organization, Wereldgezondheidsorganisatie

Pandemic and Disaster Preparedness Center
PDPC