A confluence of global crises: An unprecedented learning moment for climate change from the COVID-19 pandemic

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Abstract

Global crises exhibit common patterns and interlinkages, from which critical lessons can be learned. In particular, the ongoing COVID-19 pandemic offers an unprecedented moment for unearthing insights helpful for climate change response. This research aims to systematically identify, assess, and prioritize such relevant lessons. To this end, we adopted a Horizon Scanning (HS) approach to collect 553 related lessons from multiple sources, including reviewing 108 peer-reviewed journal articles and two surveys. A total of 372 respondents contributed and ranked relevant lessons, of which 31 experts across countries, sectors, and disciplines had ranked the same lessons ranked in the second survey. Adopting the HS approach was not only helpful to collect relevant lessons, but also effective in promoting the general public's engagement in scientific research, which is essential to amplify its voice regarding two major crises that are directly affecting the lives and livelihoods of people. Results of this research indicate that both participant groups (experts and non-experts) perceived climate change to be more threatening than COVID-19. However, they expressed different areas of concern regarding the two crises. Among all thematic areas, "Research and innovation" and "Policy and governance" are of supreme importance for COVID-19 and climate change. This research provides invaluable information for actors who are at the frontline of fighting both crises.

1. Introduction

With millions of confirmed cases and deaths, the ongoing COVID-19 pandemic is an unprecedented global crisis in the recent history of humanity (Fan et al., 2020). The pandemic has triggered extraordinary social measures (Cole and Dodds, 2021; Hepburn et al., 2020) and heavily affected the global economy (Kumar and Ayedee, 2021) and imposed serious implications for CO_2 emissions and the Paris Agreement on climate change (Shan et al., 2021). The implications of COVID-19 on climate change action are enormous, including putting on hold many climate actions (Loureiro and Alló, 2021). For instance, this includes postponing the 26^{th} conference of parties (COP26) in Glasgow (United Kingdom), an important milestone for committing more ambitious Nationally Determined Contributions (NDCs), for one year due to the challenges of holding an inclusive and ambitious gathering of climate change actors. The outbreak of this pandemic seems to be related to several global problems, for instance, climate change, urbanization, and global travel (Barouki et al., 2021). Despite the fundamental differences between the COVID-19 pandemic and climate change (Manzanedo and Manning, 2020), there are interlinkages (e.g. both are global crises), shared patterns (e.g. serious implications on multiple sectors), and commonalities (e.g. multiple root causes and complex interactions) that are typical for the Anthropocene era (Fuentes et al., 2020; Heyd, 2021; Lancet, 2021). Both, COVID-19 and climate change have interferences with development, research, global cooperation, and resilience (Hepburn et al., 2020; Manzanedo and Manning, 2020). To combat the COVID-19 pandemic, global societies have witnessed massive changes in all life aspects, and governments committed to radical measures to control the spread of COVID-19 and reduce losses of lives (Baldwin and Lenton, 2020). On the other hand, the world has

been experiencing climate change effects for decades (IPCC, 2021), yet few such drastic measures have been taken, reflecting the urgency of the climate emergency (Coates et al., 2020). This has raised numerous critical questions on comparable global efforts in fighting climate change (Salas et al., 2020), a threatening crisis that moved down the top global agenda because of the pressing urgency to deal with COVID-19 (Lancet, 2021).

Delayed action on both climate change and COVID-19 is threatening. Therefore, policymakers and the global community concerned about such global crises must be able to make informed decisions, based on sound scientific findings (Baldwin and Lenton, 2020; Jin, 2020; Manzanedo and Manning, 2020). The current pandemic outbreak offers an exceptional window into a global crisis and provides invaluable insights and profound lessons into how this crisis may be addressed and which policy approaches are considered favorable(8). Reflecting from the COVID-19 pandemic, these lessons can be of political, social, economic, and policy nature, among others. Examples of such lessons that can be found in the literature stress the importance of global solidarity and international cooperation (Cole and Dodds, 2021; Klenert et al., 2020), emphasize how costly a delayed intervention can be (Fan et al., 2020; Fuentes et al., 2020; Heyd, 2021; Jin, 2020), underline the importance of crisis prevention (Cole and Dodds, 2021; Manzanedo and Manning, 2020), highlight how inequality can be exacerbated without timely action (Klenert et al., 2020; Salas et al., 2020), and draw attention to the centrality of research and innovation in facing new challenges (Ching and Kajino, 2020; Jin, 2020). The term lesson used in the current research, thus, refers to the insights that can be drawn from the COVID-19 pandemic and potentially applied to climate change policy making and implementation. Given the wide-spectrum of potential lessons, we are aiming mainly to provide policy-makers at different levels with up-to-date and evidence-based knowledge that can help in making the right decisions regarding climate change, reflecting from the ongoing COVID-19 pandemic.

Although several previous studies have contributed to collecting and analyzing such lessons (Andrieu et al., 2021; Baldwin and Lenton, 2020; Botzen et al., 2021; El Zowalaty et al., 2020; Herrero and Thornton, 2020; Hochachka, 2020; Howarth et al., 2020; Kakderi et al., 2021; Manzanedo and Manning, 2020; Negev et al., 2021; Perkins et al., 2021; Prideaux et al., 2020; Ruiu et al., 2020; Salas, 2020; Sarkis et al., 2020; Sheehan and Fox, 2020), no systematic review of these lessons has been conducted. In addition, the number of collected lessons in these studies was limited and, in many cases, confined to limited thematic areas. Employing the Horizon Scanning (HS) approach enables a more comprehensive overview by expanding the information sources across regions, disciplines, and professions, which can be quite helpful to inform and support decision-making (Hines et al., 2019). Enlarging the information sources through the HS has the potential to allow investigating opportunities, threats signs, and outlooks of phenomena. Concerning the aim of the current research, it allows identifying important lessons that might be missed if a single source of information (e.g., literature) is used. As of the date of writing this paper, this is the first research with this scale to collect a magnitude of lessons from COVID-19 that addresses a wide spectrum of thematic areas from published literature, the public, and experts. Therefore, the ultimate goal is to gather, analyze, rank, and reflect on the most critical lessons that, if addressed, would advance climate change action. This research provides recent, useful information for successfully navigating the challenges of climate change reflecting from the ongoing COVID-19 pandemic.

2. Materials and methods

In this research, we adopted a HS approach with a thorough literature review of 108 peer-reviewed journal articles, as well as surveys for the public and experts. A total of 372 participants have contributed to these surveys. In the following sub-sections, details on the HS approach adopted herein, including the reviewed literature, distributed surveys, and the subsequent statistical analysis are provided.

2.1 Horizon scanning approach

The HS approach is a useful methodology to detect early signals that imply likely future changes (Hines et al., 2018) . It can be used to identify opportunities and threats (Kemp et al., 2020) and to describe early signs of phenomena that might require changes in policies and strategies (Sutherland et al., 2021).

Therefore, it offers a useful tool to anticipate emerging issues, opportunities, and threats (Hines et al., 2018). The earlier applications of this method include uses in businesses and commercial purposes (Doos et al., 2016; Stevens et al., 1998). Recently, this approach has been used in a wide range of disciplines and for multiple applications, including environmental issues (Bengston, 2013; Kark et al., 2016; Pihl et al., 2021). Due to its ability to predict future changes, it can be used to change mindsets, create alternative options, and guide policy-making (Hines et al., 2019). In the current research, we subdivided the HS process into four stages, namely, (i) lesson collection, (ii) filtration, (iii) categorizing, merging, and validation, and (iv) evaluation (Fig. 1).

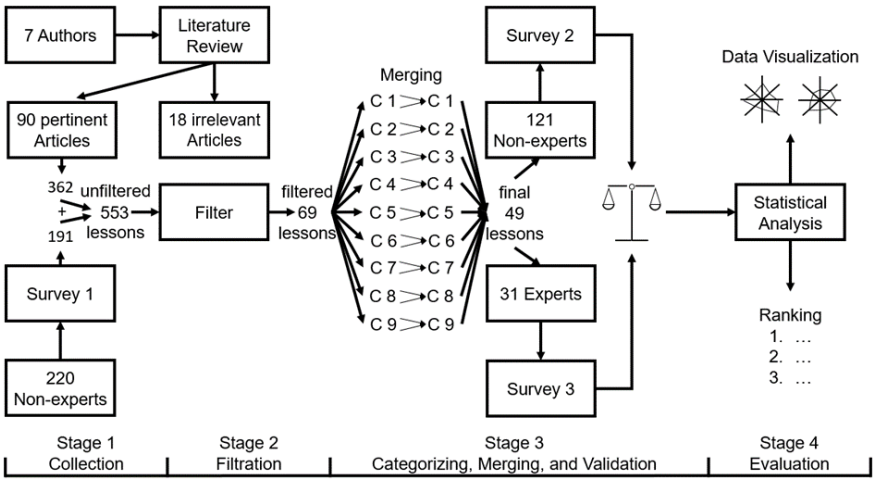

Fig. 1. Visualization of the Horizon Scanning (HS) methodology adopted in the current study. The process involves four stages, namely, lessons collection; filtration; categorization, merging and validation; and evaluation.

2.1.1 Stage 1 - Lessons collection

In the current research, we scanned two main sources of information regarding transferable lessons from COVID-19 to climate change. These sources are published peer-reviewed articles and individuals from 49 different countries, including experts and non-experts. For the non-experts, we asked the first survey participants to confirm their willingness to participate in the second survey. For the participant selection in the expert survey, besides a number of authors of the 90 deemed pertinent articles out of the considered literature (108 peer-reviewed articles), experts from academia who contributed to research concerning COVID-19 and climate change were selected.

To collect and rank lessons from individuals, we created two online surveys (See the Supplementary Information file; Section SI.1). The first survey was designed to collect COVID-19 lessons from all participants. In order to increase the pool of participants and to get insights from different countries, we reached out to participants by creating our website, as well as social media, and LinkedIn pages expanding on the project goals and spreading the word. Moreover, all our surveys were available in four languages, i.e., English, German, Spanish, and Arabic. For the online surveys, the soSci-Survey online platform (https://www.soscisurvey.de/) was used. Online surveys allowed for a diversification of sources and inclusion of lived experiences of people directly affected by different policy measures undertaken by various countries and regions. For all surveys, the participants were informed about the purpose of the research and the use of data and asked about their voluntary participation. The first survey was published in May 2021. The participants were asked, using a 5-point Likert-scale, how they would rate their level of expertise regarding the issues of COVID-19 and climate change, and how concerned they are about them.

* "How would you rate your level of expertise on COVID-19? How would you rate your level of expertise

on climate change?" * "How concerned are you about COVID-19? How concerned are you about climate change?" Then the participants were asked two open questions: * "What are your lessons learned from the COVID-19 pandemic in general?" * "What are your lessons learned from the COVID-19 pandemic related to climate change?"

Finally, the socio-demographic data of the participants were requested in order to characterize the sample. The entire survey was anonymous, and the participants have been assigned special identification numbers to replace their biometric information. The participants in the first survey were 220, leading to a total number of 69 unique relevant lessons, containing a range of similar lessons that were merged. These lessons were assigned to nine thematic areas (see section 2.1.3). The lessons collected were then turned into the second public survey, the survey was published in July 2021 with the help of the Sosci-survey platform. First, the participants had to rank the thematic areas according to their importance for climate change or COVID-19:

1. "In relation to the current COVID-19 pandemic, how important do you think the following areas are for finding a solution?" 2. "Concerning the global issue of Climate Change, how important do you think the following areas are for finding suitable solutions?"

These questions were asked through a 5 level Likert-scale from 1 "not important" to 5 "very important".

To better assess the sample, all study participants were asked to indicate their level of expertise regarding how familiar they are with climate change and COVID-19, using a five-point Likert scale, where 1 represents "not an expert" and 5 "expert". The lessons that ranked highest on these criteria were considered in the further process.

In the second survey, the most relevant lessons learned were listed, using our developed filtering procedure. Subsequently, participants were asked to judge the relevance of the lessons learned on a seven-point-Likert-Scale, with 1 "strongly disagree" to 7 "strongly agree". The Likert-Scale was increased from 5 to 7 with the aim to point out a gradient and more nuanced differences in responses. The same survey was distributed to the experts' group at the same time. In the second part of this survey, participants ranked lessons according to their importance. For this, a seven-point Likert scale form was used. Through this, the most important lessons for the general public could be identified. Finally, socio-demographic data was requested, and information about the use of data and voluntary participation were provided.

To allow for collecting interdisciplinary lessons from COVID-19 relevant to climate change, we reviewed 108 published articles with themes of COVID-19 and climate change. These articles have been collected and screened for relevance, based on whether insights from COVID-19 were applicable to climate change. Refer to the Supplementary Information file for a list of the 108 reviewed literature (SI.2). Out of 108 peer-reviewed articles, 90 were deemed pertinent and contained lessons from COVID-19 relevant to climate change. From the relevant literature, a total of 362 lessons were collected.

2.1.2 Stage 2 - Filtration

For lesson filtration, we adopted the common criteria described by Hines et al. (2019) after being customized to fit the specific purpose of the current research. We developed a quantitative matrix to evaluate all the collected lessons based on these criteria (Table 1), with a 0 score (red) meaning criteria not applicable, 1 (yellow) less applicable, and 2 (green) highly applicable.

Table 1. The filtration methodology, including criteria used for this procedure.

	Criteria	Meaning of the criteria
1	Evidence	How are the assumptions in this lesson backed up? How valid is this lesson?
2	Potential impact	How big is the impact, if the lesson is actually learned/ implemented?
3	Plausibility	How likely is it that the learnings are recognized, and some sort of action is implemented
4	Scale	What scale is the lesson focusing on?
5	Stakeholders	Who is affected by the implications of the lesson? Who has to act according to it?

6	Policy priority	Why should this be an issue in further consideration? What is the political importance?
7	Level of innovation/ novelty	How innovative/ ground-breaking would this lesson be?
8	Timeframe	When would the implementation take place? Sense of urgency?
9	Applicable actions	Is there any sort of action that is implicated by the lesson?

2.1.3 Stage 3 - Categorizing, merging, and validation

We grouped the filtered lessons into nine main categories, namely, (i) communication, (ii) economy, (iii) environmental health, (iv) international partnership and cooperation, (v) monitoring and data sharing, (vi) perception and behavior, (vii) policy and governance, (viii) research and innovation, and (ix) socio-economic inequalities. Operational definitions of these themes are listed in table (2).

Table 2. Operational definitions of the nine themes used as a base to cluster and group the lessons identified in the current research.

No.	Term	Explanation
1	Communication	Communication is about creating, designing, creating channels, and trans
2	Economy	Economy systems govern resource allocation and human activities regard
3	Environmental health	There are many interlinkages between people and their environments. Th
4	International partnership and cooperation	For global crises that are transboundary in nature such as climate chang
5	Monitoring and data sharing	It refers to efforts for continuously observing the development of climate
6	Perception and behavior	People display similarities and differences regarding how they observe, pe
7	Policy and governance	The set of roles and measures created by policy-makers to plan, control,
8	Research and innovation	For new global crises, the role of research and innovation is crucial. Effor
9	Socio-economic inequalities	Crises might impose unequal impacts on different society groups. Unders

After categorizing, the remaining lessons with interchangeable content were merged to avoid repetition. The resulting final lessons were turned into a second survey, in which 121 non-expert participants were asked to score the relevance of the lessons to their best knowledge in regard to climate change. To validate the filtration as well as the results of survey 2, we designed a third survey and invited 31 experts to score the same lessons as in the second survey.

2.1.4 Stage 4 - Evaluation

According to their scoring in survey 2 and survey 3, the final lessons were statistically evaluated. The scoring of the various categories and the countries of origin of the participants were further visualized. Additionally, the top-scoring lessons were ranked.

2.2 Description of survey participants

Overall, 372 participants from all over the world took part in the surveys. Of these, 220 completed the first survey, 121 filled in the second, and 31 participated in the separate survey for experts. The participants come from 49 different countries (Fig. 2a, b), but in all groups, the participants were most frequently from Germany (37.6%). On average, the participants were 38 years old, with a noticeable difference in average age between the non-expert and expert groups; 48 and 32 years old, respectively. The gender distribution among the experts was not balanced. Significantly more men (71%) than women (25.8%) took part in the survey. Among the non-experts, the gender distribution was somewhat more balanced: female= 56%, male= 43% and diverse =1%. This results in a total distribution of 53.6% female, 45.3% male, and 1.1% diverse participants. The experts' group consists of 31 professionals from 15 countries (Fig. 2c). These experts are drawn from multiple disciplines, including climate change, health, virology, economics, and behavioral and environmental economics. For a full list of expert disciplines, the reader can refer to the Supplementary file (Section SI.3). The aim of involving these experts was to identify the priorities of experts for interventions

in each field, as well as offer the possibility to compare their stance to the general public's opinion.

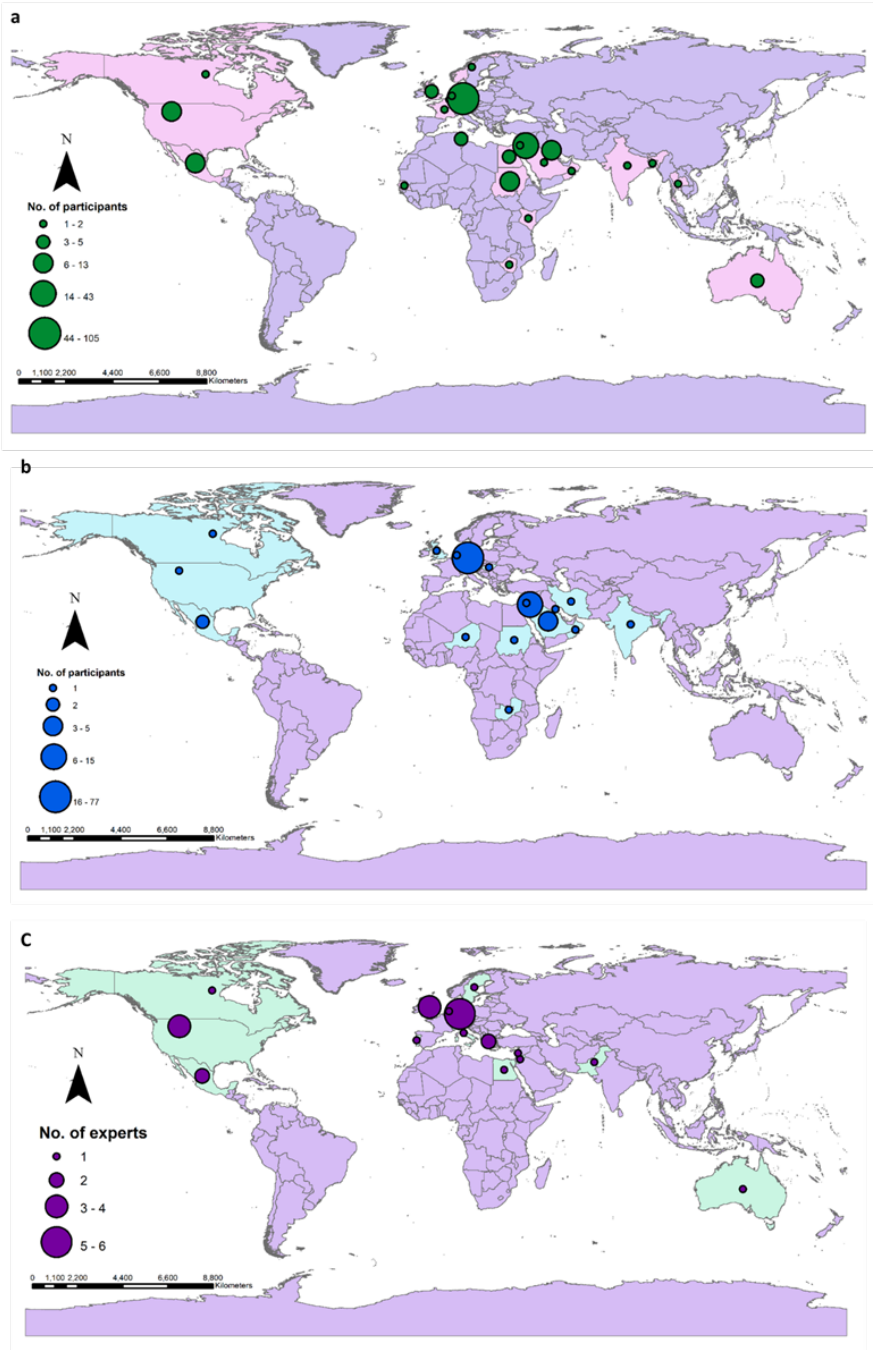

Fig. 2. Geographical distribution of participants who took part in the first (a) and second (b) surveys of the current study. The group of experts who participated in the separate experts' survey came from 15 countries (c).

2.5 Statistical analysis

The main statistical method used in this empirical study was descriptive statistics. The data obtained from the various questionnaires were processed, summarized, and presented appropriately in order to draw meaningful conclusions from the data. With the help of descriptive statistics, it was possible to characterize the sample and to describe and compare the different groups of experts and non-experts. For this purpose, various comparisons of means were carried out, e.g., between experts and non-experts, with the help of the T-test for independent samples. A normal distribution of data was tested and assumed. Additionally, the standard deviation was also considered and included in the comparison. The Data analysis was conducted with the statistical software IBM SPSS (Statistical Package for Social Sciences) and Microsoft Excel program.

3. Results and discussion

3.1 Identified lessons and their categories

Analysis of the identified lessons revealed the most pressing issues regarding climate change and COVID-19. Visualizing the main keywords contained in these lessons (Fig. 3) displays that subjects such as climate trajectories, global politics, decision-making, timely action, and public attention show the highest frequencies. This indicates the relative importance of these issues. This graphical representation of keywords allows our target group to quickly identify the most common themes underlined in the collected lessons. Our final list of 49 lessons belongs to nine broad thematic areas, as described above. Lessons belonging to categories such as "perception and behaviour", "policy and governance", "research and education", and "scoio-economic inequality" show a relatively higher number of lessons than the other themes (Fig. 4).

Fig. 3. A word cloud illustrating the Incidence of key terms contained in the collected lessons, demonstrating their frequency, and thus, their relative importance concerning climate change and COVID-19 crises.

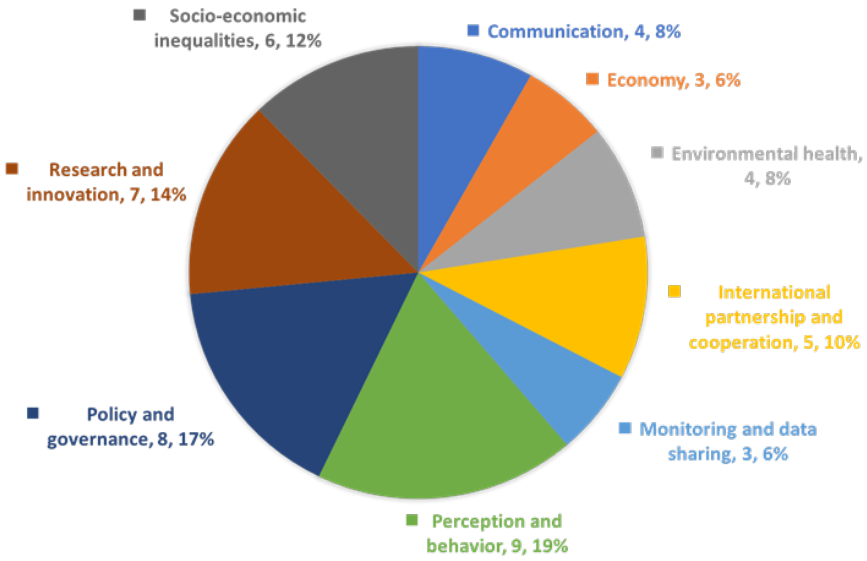

Fig 4. Distribution of the 49 unique lessons collected in this research to nine thematic areas. The number of lessons and percentage of lessons in each category are indicated.

3.2 Levels of concern and expertise of respondents to COVID-19 and Climate change

The results of our analysis show that the non-expert group considered themselves to have an equal level of expertise in both topics, with a mean (M) value of 3.6 for both topics and standard deviation (SD) of 0.87 and 0.92 for climate change and COVID-19, respectively (Table 3). The experts, on the other hand, indicated remarkably more often to be experts with regards to climate change (M= 4.1, SD= 0.944) than with COVID-19 (M= 2.9, SD= 0.957).

Table 3. Level of expertise and concern for expert and non-expert respondents to the first survey of the current research.

		Climate change
		Mean (M)
Level of	Expert	4.1
	Non-experts	3.6
Level of concern	Expert	4.8
	Non-experts	4.3
Note: experts (n= 31); non-experts (n= 220)	Note: experts (n= 31); non-experts (n= 220)	Note: experts (n= 31); non-

Overall, all participants indicated high levels of concern (> 3.9). In comparison, all participants, both experts (M= 4.8, SD= 0.425) and non-experts (M= 4.3, SD= 0.986) were significantly more concerned about climate change than the current COVID-19 pandemic (M= 4.27, $p < 0.001$, SD= 1.42). This was evaluated by mean value comparison using the paired samples t-test. For this purpose, all valid responses on the level of concern of the non-experts from survey 1 and the experts were considered together (n=251), and the mean values between the two response options "Climate Change" (M= 4.3, SD= 1.108) and "COVID-19" (M= 3.9, SD= 0.064) were compared.

3.3 COVID-19: Thematic areas of concern

[CHART]Among all thematic areas of concern over COVID-19, "communication" is ranked top by the non-

expert group (M= 4.53, SD= 0.918). Perception of the crisis and the associated behaviors and measures was ranked top by the expert group (M= 4.74, SD= 0.445). Both participant groups have valued the importance of "research and innovation". While this response is justifiable for the expert group, it might be that the recent discovery of COVID-19 vaccines and their importance in combating this crisis has increased public awareness of the crucial role of science in global crises. Most surprisingly, "economy" and "environmental health" were ranked as the lowest areas of concern by both groups. A graphical representation of the different nine topics as ranked by both respondent groups is shown in figure (5).

Fig. 5. Ranking the nine thematic areas of concern based on their importance for COVID-19 (left) and climate change (right), The total number of the second survey responses (experts and non-experts) is 152, who ranked and validated 49 lessons.

3. Climate change: Thematic areas of concern

"Policy and governance" ranked top among all areas of concern (M= 4.74, SD= 0.514) according to the group of experts (Fig. 5). "International partnership and cooperation" and "research and innovation" (M= 4.62 and 4.74, SD= 0.923 and 0.514, respectively) represent important themes for both experts and non-experts. Both respondent groups ranked "research and innovation" as the second most important thematic area for climate change. Among all areas of climate change concern, "monitoring and data sharing" is the lowest-ranked by the non-expert participants (M= 3.77, SD= 1.275) and "environmental health" by experts (M= 4.35, SD= 0.755). Themes such as "economy" and "perception and behavior" ranked less important as well. Contrary to COVID-19, where both respondent groups have considered "economy" to be a very important aspect, both groups considered "economy" the least area of concern among all topics when it comes to climate change (Fig. 5).

3.5 Reflections on thematic areas of concern

Considering that all thematic areas were judged on a scale from 1 to 5, it is pertinent to underline that all scores are relatively high (M> 3.77) and, consequently, all thematic areas can be considered relevant to both crises, i.e., COVID-19 and climate change. The average score for all nine topics in total for both climate change and COVID-19 is relatively higher for experts than for the non-experts group. The highest differential for both COVID-19 and climate change is on "monitoring and data sharing". For both crises, experts ranked "monitoring and data sharing" higher than the non-experts did, with it even being the lowest-scored topic for climate change for the non-experts.

While experts deemed that working on the area of "perception and behavior" of individuals is crucial for combating COVID-19, non-experts ranked this aspect comparatively lower. However, experts also ranked the importance of "perception and behavior" lower concerning climate change action. Valuing the role of "communication" among non-experts reflects the importance of information sharing and transparency regarding global crises for the public (Fuentes et al., 2020; Samani et al., 2021; Zabaniotou, 2020). It also emphasizes that sharing reliable and correct information is not only crucial to foster better public emergency preparedness and resilience (Sheehan and Fox, 2020) but also to minimize polarization and mistrust between stakeholders (Lyytimäki et al., 2020). "Perception and behavior" of the public has been ranked top by the expert group, and it massively depends on the amount, quality, and interpretation of information (Charoenwong et al., 2020). This connection between the top-ranked areas of concern of the two respondent groups implies synergetic effects between the two areas of concern, i.e., "communication" and "perception and behavior", if tackled appropriately.

Experts and non-experts agree on the "economy" being the least sector of concern when it comes to COVID-19, yet both groups see much higher relevance for climate change than for COVID-19. It seems as if participants consider focusing on combating COVID-19 and/or climate change to be more important than their impacts on the economy. According to the study by Enria et al., 60% of participants felt that economy is seen as more important than health in decision-making, while a focus on health care has been lacking (Enria et al., 2021). This could also be another reason why participants rate the "economy" as less important.

Most participants agree that "international cooperation" is necessary to combat global crises but rated it slightly higher regarding climate change than COVID-19. Potentially, this could be due to the expectation that measures on a national level against climate change would yield less impactful results in comparison with COVID-19 and because of the option to implement a national lockdown to combat the disease.

For both climate change and COVID-19, experts ranked "policy and governance" comparatively higher. Experts considered tackling "socio-economic inequalities" and their emerging issues as more important for addressing climate change than COVID-19. With regards to "monitoring and data sharing", a large discrepancy between experts and non-experts was observed. Finally, the low rank of "environmental health" among the non-expert group emphasizes the importance of intensifying efforts that aim to raise public awareness regarding the importance of maintaining a healthy environment, which is equally important for mitigating both crises (Engström et al., 2020).

3.6 Analysis of the identified critical learned lessons

Based on an extensive analysis and filtering procedure of the 553 collected lessons (from both literature and survey), 49 unique lessons have been compiled, as mentioned earlier. These unique lessons have been ranked by both experts and non-expert respondents. Table (4) lists the top 5 lessons as ranked by each respondent group. For a matrix of unique lessons and the scores of each rating criterion, refer to the Supplementary information file (Section SI.4).

Results of the current analysis indicate different perspectives of both participant groups on COVID-19 and climate change. The highest-ranked lessons from non-experts indicate that the public considers it a necessity to create changes through improved and more effective leadership, instead of behavior change. This is indicated by the four highest-ranked lessons, which all point towards an efficient and collaborative effort from the governments' side. The non-expert group ranked the lesson "Collective behavioral changes can lead to regeneration in nature even in the short term" substantially higher than the experts do. These efforts are necessary on different levels with high transparency on both national and international levels. Public opinion was highly influenced by the role of experts as authoritative figures in strategies against the pandemic. Often, information from experts was perceived to lead to delayed or too weak political action. The desire to listen to experts consequently has become more apparent and can be considered an important lesson learned in the fight against climate change. The desire for authoritative figures and clear strategies on a global level is also present regarding climate change.

The highest-ranked lessons by the experts differ, as they mostly point towards choices that governance and society must make long-term. These enduring strategies must be applied at different levels, focusing on risk management, potential green economics, and the role of scientific data. Through applying these long-term strategies, a lack of sustainability could be challenged and more informed decisions regarding future development could be made.

The lessons indicate that collaborative efforts on a scientific basis are desired, which could well be implemented in future approaches to tackle climate change. As science communication plays a major role in this, one takeaway of the lessons could be for communicators to focus on the long-term changes needed, as the experts proposed through their ratings, but to also assess and communicate the impact or consequences of recent political decisions for the public, in line with the non-experts ranking.

Table 4. Highest-ranked lesson learned from COVID-19 relevant to climate change with their mean ranks.

Rank	Highest ranked lessons non-experts (category)	mean rank	Highest ranked lessons experts (category)	mean rank
1	It is important to choose qualified decision-makers. *(Policy and Governance)*	6.35	Investment choices need to pursue a green economic recovery and can set the track for reaching long-term sustainability goals. *(Economy)*	6.52
2	Collaborated efforts on all levels (local, regional, global) are crucial in order to tackle a global crisis. *(International Partnership and Cooperation)*	6.31	Long-term strategies for pandemic preparedness must be developed, as COVID-19 is neither the first nor only crisis that our globalized society will face. *(Research and Innovation)*	6.52
3	Political decisions should be based on scientific evidence with researchers giving science-based policy recommendations. *(Policy and Governance)*	6.22	Climate goals must be negotiated multilaterally, but also need pioneers. *(International Partnership and Cooperation)*	6.48
4	It is essential to collaborate and exchange experiences and information on an international level. *(International Partnership and Cooperation)*	6.21	Ignoring the early scientific calls for action ends up being costlier in the long run and creates worse scenarios. *(Research and Innovation)*	6.45
5	We are able to reduce harm to the environment through changes in habits and resource use. *(Environmental Health)*	6.16	Social differences are underlined in a crisis. *(Socio-economic Inequalities)*	6.40

While the public survey generated a general overview of public opinion, the experts' opinions can be used also to validate and/or challenge the public's perception. Statistical analysis of the results shows that the agreement between non-experts and experts is quite high. Even though there were differences in rank and score of the individual lessons, after an independent T-test there was only once shown a significant difference. This indicates that either the public is well educated concerning the issues, or that the education or level of the profession, does not account for a different opinion regarding those topics. Even though not statistically significant, the differences in average ratings for various lessons are visible. The lessons that showed the biggest discrepancy between experts and non-experts were the following (note: values in brackets indicate average differences between expert and non-experts ranking).

1. "Investment choices need to pursue a green economic recovery and can set the track for reaching long-term sustainability goals" (expert value is non-expert value +0.65) 2. "Geographical as well as temporal distance can make a crisis be perceived to be less grave, and only affecting faraway people or ecosystems." (+0.63) 3. "Collective behavioral changes can lead to regeneration in nature even in the short term" (-0.62) 4. "Masses and societies need to be educated to change their behavior." (-0.59) 5. "Climate goals must be negotiated multilaterally, but also need pioneers." (+0.51)

As can be seen, the public appears to prefer more idealistic approaches. This can be seen in lessons 3 and 4 listed above, where the experts acknowledge more difficulties in simply educating people and changing behavior to combat both global crises.

It has to be acknowledged that with all similarities and shared potential global implications, climate change and COVID-19 represent fundamentally different crises on many levels. This is true, e.g., for the required timeframe of implementing action and the response time of the system. There are therefore lessons that are more appropriate for either of the two. Science communication should take this difference into account, and suggestions for change should be made on an individual rather than on a general basis

4. Summary and conclusion

The current research identified and evaluated the most critical lessons and areas of concern of the public and experts regarding COVID-19 and climate change. It highlighted the most important lessons from the COVID-19 pandemic that are relevant to climate change crises. Lessons learned from public input in the first survey and the literature review were gathered and evaluated according to their potential contribution to guide fighting the climate crisis. To verify these lessons, a subsequent survey was conducted. To validate the results and to involve scientific opinion, experts from relevant fields concerning either climate change or the COVID-19 pandemic were consulted. The findings of the expert survey validate and support the results that have been derived from the main surveys. This is evidenced by the lack of significant differences in the opinion of both groups. The lessons learned with the highest score included lessons on policy, decision-making, and how scientific facts should guide and be integrated more into the decision-making process and on long-term strategies, including green investments and risk reduction measurements. Although there were differences in the judgments on the relevance of different thematic areas, such as economy, and perception and behavior, the overall ratings for both the categories and lessons learned were relatively high and, therefore, underline the importance of this research's findings. On average, the scores from the experts were relatively higher, but this could be explained by the experts having more experience in the areas of COVID-19 and climate change compared to the public and, therefore, are more aware of the risks and the urgency of action. The findings of this research convey important messages on which thematic areas and action measures of the COVID-19 pandemic and put together the most critical lessons that, if tackled, would have the greatest positive impact along the way of fighting climate change. To expand the findings made within the research of this paper, future research could focus on investigating which of the methods endorsed by the public are effective measures against climate change.

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