Report from Dagstuhl Seminar 24091

Reflections on Pandemic Visualization

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Abstract

This report documents the program and the outcomes of Dagstuhl Seminar "Reflections on Pandemic Visualization" (24091). The fight against COVID-19 has highlighted the crucial role of data visualization and analytics, prompting significant innovations and collaborations. This Dagstuhl Seminar brought together experts from various fields to reflect on the lessons learned. The aim is to document and disseminate these insights, enhancing preparedness for future global health crises.

Seminar February 25 – March 1, 2024 – https://www.dagstuhl.de/24091
2012 ACM Subject Classification Applied computing → Health care information systems; Applied computing → Health informatics; Human-centered computing → Human computer interaction (HCI); Human-centered computing → Visualization application domains; Human-centered computing → Visualization techniques
Keywords and phrases Epidemiology, Pandemic, Preparedness, Visualisation
Digital Object Identifier 10.4230/DagRep.14.2.191

1 Executive Summary

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During the recent SARS-CoV-2 pandemic, visualizations were omnipresent, playing a central role in communicating with the public, drawing from multiple data sources, and serving diverse goals. In a short period, public health messages spread globally. In this Dagstuhl Seminar, we brought together 37 experts in visualization, mathematics, modeling, public health, infectious diseases, and psychology from Europe, Asia, Australia, and North America to summarize and discuss their personal insights gained over the three years of the pandemic.

Due to the heterogeneity of expertise and different tasks performed by each individual during the pandemic, and despite intensive collaboration and contact between experts in both fields over the past three years, it was felt necessary to establish some common ground

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Reflections on Pandemic Visualization, *Dagstuhl Reports*, Vol. 14, Issue 2, pp. 191–205
Editors: Daniel Archambault, Fintan McGee, Simone Scheithauer, and Tatiana von Landesberger
Dagstuhl Reports
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

for the work and concepts of both medical and visualization experts. The first two days of the seminar included short talks on public health, infectious diseases, modeling, big data, and an overview of visualizations that participants used or appreciated during the SARS-CoV-2 pandemic. These introductory talks were specially designed to foster discussions and personal exchange, allowing significant time for in-depth conversations. After engaging discussions during and after the sessions, several key topics emerged across the medical and visualization fields that require deeper reflection. The organizers then clustered these relevant topics into five overarching areas of interest: the use of dashboards during the pandemic, communication to the public, preparedness, data visualization methodology in emergency responses and users tasks and medium.

Over the last two days of the seminar, breakout sessions of six participants were created to work on these key issues. The fruitful discussions in the breakout sessions had as their first output a presentation by each group summarizing their discussions. These discussions will be extended into a second output in the form of several publications that will appear in a Computer Graphics and Applications issue later this year which are now in preparation. Important connections were made between experts in healthcare-related disciplines and visualization specialists, addressing a significant need. As a result, one of the organizers was invited to participate in a symposium on automated surveillance of bloodstream infections in Germany, which was promptly accepted. We look forward to hosting more interdisciplinary seminars, which are extremely rewarding and valuable.

2 Table of Contents

3 Overview of Talks

3.1 Reflections on Pandemic Visualisation: An Introduction

Daniel Archambault (Newcastle University, GB)

Welcome to Dagstuhl! I hope you enjoy your seminar. This talk is an introduction to the seminar and its participants. We hope to facilitate time for writing retrospective articles in the area of pandemic visualisation to better respond to public health crises such as COVID-19. I hope you have a productive stay!

3.2 Aspects of pandemic preparedness

Johannes Dreesman (Niedersächsisches Landesgesundheitsamt – Hannover, DE)

The SARS-CoV-2-Pandemic brought many challenges to societies and governments. These challenges are highlighted from a public health agencies perspective. The lecture is structured according to the German pandemic preparedness plan, which adresses many aspects of the experiences made during the pandemics. Concerning surveillance, the mandatory surveillance system had to fulfill many tasks, which was not possible to completely fulfill with one system. In the course of the pandemic several more surveillance systems were established. Dashboard presentations are affected by the "rural district fallacy", leading to incident rates in districts with small populations having very high volatility and producing the most eyecatching results with little public health meaning. Concerning pandemic measures we have learned that non pharmaceutical interventions and particularly contact reducing measures have to be carefully evaluated to allow for withdrawal if they are not effective. Another challenge was the priorization of the vaccine provision and the monitoring of vaccine coverage and adverse effects. It requires well designed additional surveillance systems to fulfill these requirements. Visualisation methodology is key to support all these requirements coming up during a pandemic or comparable types of emergencies.

3.3 Visualization for Pandemics and Public Health: Review and Opportunities David Ebert

David S. Ebert (University of Oklahoma – Norman, US)

In this talk, I discussed the key roles in developing visualizations for public health, focusing on the data, who is using it, when they are using it, and what they are trying to do. This was highlighted with examples for each case. I then reflected on useful visualizations, their features, and how they were used. Finally, discussion on the challenges and opportunities of new sources of data and challenges in transforming this data into actionable information through visual analytic interfaces led to lively discussions.

3.4 Compartmental Modelling and the Pandemic Response in Wales

Biagio Lucini (Swansea University, GB)

The COVID-19 pandemic has resulted in huge strains on various aspects of our life. In Wales, the need to understand, adapt, and respond to the evolving situation has generated unprecedented challenges for the devolved health policies. As a first urgent response, the Technical Advisory Cell was created, which identified modelling as a high priority. This request led to the formation of the Swansea Modelling Team, a multidisciplinary team of Epidemiologists, Mathematicians, Biologists, Computer Scientists, and Research Software Engineers. Through numerical simulations that produce likely scenarios under evolving conditions, this modelling effort has been the main forward-looking input that has informed government policies and containment measures. In this talk, I will review how the team formed and went on to produce the earliest set of scenarios. Then, I will provide an overview of the underlying mathematical and computational methods and discuss the key results and findings. Finally, I will reflect on lessons learned and give an overview of the challenges that we are likely to encounter in a potential future pandemic.

3.5 COVID-19

Mathias Pletz (Universitätsklinikum Jena, DE)

This talk gave an overview about 5 medical topics related to the pandemics evolution of the virus, non-pharmaceutical interventions, differences between COVID-19 and influenza, medical management and vaccination. It gave insight about my experience with the implementation of mandatory masking in our hospital and the city of Jena – the first German city to implement masking. I explained the different medical strategies related to the time period of infection: early →antivirals, late state → steroids. Furthermore, it explained pros and cons of the vaccine and the impact of the selective pressure by immunity on the emergence of escape variants. Some key insights included that human behaviour and related cultural differences are hard to measure, but had a huge impact on viral spread and the death toll for different countries. In this regard, the impact of visualizations for public decision makers and the right communications strategy, e.g. how to communicate scientific insecurities to lay persons, was discussed.

3.6 Probably not famous last words...

Simone Scheithauer (Universitätsmedizin Göttingen, DE)

Now it's time for the probably not-so-famous last words. I have the honor of moderating the conclusion of our joint Dagstuhl Seminar. I have divided my contribution into three parts. I would like to start with a narrative that ran through our discussions and, I believe, through

all the groups. It also seems to me to symbolize the pandemic: Time. Time as a resource, time as a symbol for working under pressure. But time is also an essential parameter that can influence the pandemic when it comes to when decisions are made or not. We had the quote that "Speed trumps perfection." This quote describes a long-known fact that I researched 10 years ago and used for an editorial during the pandemic. The quote is about doing the right thing instead of doing things right. It was written by Peter Drucker in 1963. It fundamentally captures the confusion between effectiveness and efficiency–between doing the right things and doing things right. I think we have struck a good balance between the two. My second part is an assignment that I, as co-organizer, would of course like to fulfill–I may and would like to remind us all to deliver our reports and, later on, manuscripts. I think all the Dagstuhl reports are already in. Nico can say something about that in a moment. We all received valuable information about the publications from Daniel yesterday and today. If you have any questions, please do not hesitate to ask us by email or other means. I am convinced that together we will succeed in delivering a good collection on our common theme. Now I come to the conclusion, which also revolves around the topic of time. Unfortunately, our time together here has come to an end, and I truly regret that. I had no idea what I was getting myself into and was a little apprehensive, even though I have already organized two congresses as president. But this is something completely different and unique. I have been able to meet many great people and learn a lot. I would like to say thank you for that. I would also like to thank Fintan, Daniel, and Tatiana for giving me the opportunity. And a big thank you to Tom, Max, and Nicolas, without whom we would not have managed the organization. And of course, my thanks go to you, because Dagstuhl can only be as good as the group is. From my point of view, this is fundamentally true, and I hope that only our time together ends here and that we stay in contact while working on the manuscripts and beyond. Thank you for everything, have a safe journey home, and please stay in touch!

3.7 Visualisation examples in the pandemic: The Good, the Bad and the Effective

Max Sondag (Universität Köln, DE)

Throughout the pandemic, a whole host of different visualisations were used. All participants of the seminar collected and submitted a collection of these that drew their interest or attention, with the goal of reflection on it as a whole and highlighting what made some special. Within the talk, we will identify what potential was there, where problems existed, and to find patterns in how and when they were used. The session focuses on facilitating and encouraging an open-ended discussion from the different perspectives of the participants. This will allow us to collect opinions and topics for the working groups.

Based on the results of this discussion, as well as the presentations and previous discussions, we will then identify the salient topics within pandemic visualisation that are worthwhile to reflect upon. After filtering, these topics will form the basis of our working groups in which we will report, reflect and publish upon in the days afterwards. Using the Tatiana-method of group selection, we then divide the participants into groups, reconvening at regular moments to realign and obtain perspectives for the group as a whole.

3.8 Pandemics: A case in point for Big Data

Antje Wulff (Universität Oldenburg, DE)

With the onset of the COVID-19 pandemic, Big Data was recognized as a "potentially powerful weapon" in the fight against the virus. Over time, researchers have realized that it is indeed possible to use data science and visualizations to help – however, we also have realized that it is not as easy as we might have thought in the beginning: Big Data is not available "out-of-the-box". In this talk, the characteristics and challenges of Big Data in pandemics are discussed by going through the Big Data V's and the Big Data pipeline. In particular, routine hospital data is discussed: it is heterogeneous, non-standardized and proprietary formatted, making it initially unsuitable for secondary uses such as pandemic visualizations. Standardized and (inter)national data platform approaches are needed to effectively use routine data. Current German and international initiatives cover this topic but, in the end, it remains highly intensive, interdisciplinary and resource-intense work. Based on such sharing platforms, innovative algorithms and visualizations can be developed and implemented in valuable decision-support tools. Finally, this talk leads to the question and discussion of what a "readiness" Big Data platform for pandemic visualization might look like, and what are the implications of these aspects for visualizations.

4 Working groups

4.1 Dashboard Group

Alessio Arleo (TU Eindhoven, NL), Rita Borgo (King's College London, GB), Jörn Kohlhammer (Fraunhofer IGD – Darmstadt, DE), Roy Ruddle (University of Leeds, GB), Holger Scharlach (Niedersächsisches Landesgesundheitsamt – Hannover, DE), and Xiaoru Yuan (Peking University, CN)

The Dashboard group united varied expertise from the visualization and medical informatics communities. The scope of this group is to reflect on the practical implications following the extensive use of dashboards during Covid-19 pandemic. During that time, dashboards have been used for different purposes and were designed for a wide variety of audiences. For example, they have been developed to inform the public about the spread of the pandemic in terms of cases and deaths since the very early stage of the pandemic. During the same time, they were also used by experts, e.g., for decision making and disaster mitigation. In the course of the pandemic more and more data sources were added e.g. patients in intensive care units, wastewater treatment data or genome comparison (variant identification). Besides dashboards internal daily or weekly reports were set up to inform decision makers.

For visualization researchers, this has been a massive challenge – and the collaboration with medical experts represented a great opportunity, but it wasn't short of misunderstandings and labored development. Overall, it is possible to conclude how dashboards played a pivotal role in informing people about the pandemic at every level: however, among several success stories, a few "monsters" spawned as well.

Within this context, the group investigated the impact of dashboard visualizations during the pandemic from an holistic perspective. The purpose of this group's work is not to draw a comprehensive landscape of the research on the dashboards developed and published during and shortly after the pandemic. Instead, our objective is to comment, dissect, and elaborate on the experience of experts, and how they worked with visualizations actually used on the front line.

Taking advantage of the unique setting of this Dagstuhl Seminar, we conducted semi-structured interviews with five fellow participants who worked in four distinct roles during the Covid pandemic – as clinicians, epidemiologists, health authorities, and communicating with journalists and the general public. They shared with us the types of dashboard they used, the aims and audience of their work, details of the dashboards and the data, issues and successes that occurred, the time required to learn how to use the dashboards, and how their general experience has fed through to their work today. We recorded their interviews and spent the remaining time discussing and clustering the commonalities and divergences of their respective stories.

The seminar atmosphere at Schloss Dagstuhl offered a rare and invaluable opportunity for its participants to not only engage in intellectual exchange but also foster an environment where social interaction and collaboration go hand in hand. This has had a direct impact on the quality and richness of material that was collected during interviews. Interview setting was both technical and colloquial, with both parties at ease in prompting questions as well as sharing experiences.

4.2 Data visualization methodology in emergency responses

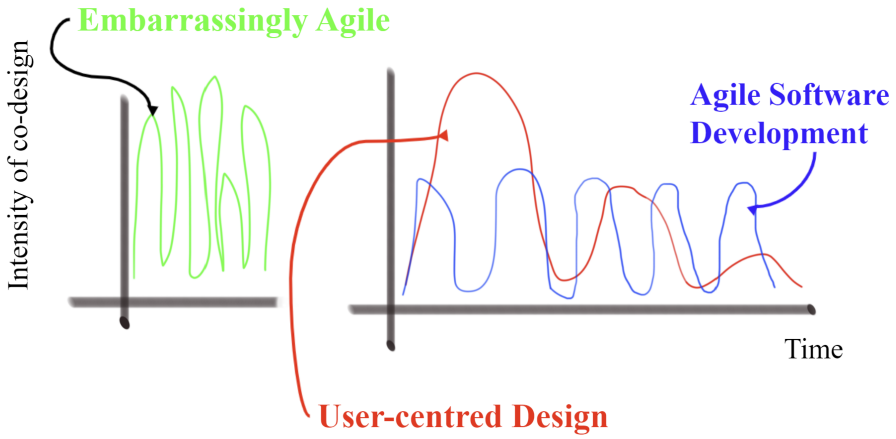
Barbora Kozlíková (Masaryk University – Brno, CZ), Daniel Archambault (Newcastle University, GB), Johannes Dreesman (Niedersächsisches Landesgesundheitsamt – Hannover, DE), Andreas Kerren (Linköping University, SE), Biagio Lucini (Swansea University, GB), Huamin Qu (HKUST – Hong Kong, HK), and Cagatay Turkay (University of Warwick – Coventry, GB)

Speed trumps perfection. Perfection is the enemy of the good when it comes to emergency responses – Dr Mike Ryan, March 14, 2020.

The main topic and goal of this group was to discuss the specifics of responding to an emergency situation (inspired by the COVID-19 pandemic case) by designing dedicated visual representations in a very limited time and with limited resources. In the discussions, we decided to focus solely on the target group of experts in epidemiology and infectious diseases in general, rather than on the general public, as these target audiences require very different solutions.

When designing appropriate visual representations in a standard visualization research project, we are always posing questions about the most suitable methodology for given data, tasks, and users. However, in an emergency response, when there is no time to select the most appropriate methodology from the existing ones, the questions we are posing are rather similar to "Has this methodology any chance to work reasonably well?".

Our discussions were inspired and based on three existing publications that focused on design study methodologies. In the paper by Sedlmair et al. [1], the authors discuss when the



Based on this observation, we built our proposed methodology on the concept of time *t* available for development, entitled *Agile(t) - visualization methodology as a function of time t*.

design study methodology is appropriate and propose a nine-stage framework that describes a linear but iterative process of designing visual representations. In a follow-up paper [3], a "lite" version of the previous methodology was proposed, where the first precondition stages collapsed into one and the core and analysis stages were partially overlapping. Publication [2] emerged as a reaction to the COVID-19 pandemic, where the authors designed a visual analytics approach for contact tracing policy simulations during an emergency response. Our aim within the seminar and also in the planned upcoming publication is to retrospectively evaluate the existing methodologies, summarize the lessons learned, and discuss the impact of time pressure on the methodology.

From experience, the development in an emergency situation follows the agile methodology. In the very first stage, it is crucial to build initial trust between the experts in infectious diseases and in visualization. To do so, the initial sketches and early prototypes should be developed as soon as possible. Inspired by diagrams in [4], we concluded that the development under time pressure resembles a very chaotic and almost randomly distributed intensity of co-design (meaning the intensity of collaborative efforts between the experts for infectious diseases and the visualization designers). We call this phase the embarrassingly agile one (green line in the graph below). The second graph shows a situation when already more time for development is available. Here, we can still see differences in the patterns – when still having limited time resources, the process resembles agile software development (blue line), whereas the red line captures the user-centered design approach, when there is enough time for discussions the designs and the created prototypes with the experts for infectious diseases. In this case, the iterations are converging to the final deployed solution much faster.

Based on this observation, we built our proposed methodology on the concept of time t available for development, entitled Agile(t) – visualization methodology as a function of time t.

Based on the time available, we are moving along the following "timeline", with a fully agile approach on the left side and a thorough methodological approach on the right side.

Embarrassingly Agile <————————> Munzner Methodology [1]

As our methodology focuses on emergency response situations, we are focusing our interest on the left part of the above interval. To identify the presence and content of individual phases of the process described in Munzner's methodology [1], we looked at these phases from the perspective of available time. As already mentioned, if we have limited time for creating visualizations as an emergency response, we have to sacrifice several stages of the user-centered pipeline. We identified that only the most crucial stages – discover, design, and implement – are the core ones that are preserved in all situations. However, when the time available is very short (almost close to 0), we argue that even these stages are merged into one. This corresponds to the situation when the visualization designers with very limited input from the experts are trying to choose the most appropriate representation from the existing solutions. When time increases, the implementation stage starts to separate from the discover and design stages, as we start to utilize libraries and build more customized solutions. If we have even more time available, also the discover and design stages start to separate and we can incorporate more and more techniques that help to better analyze the problems and choose the most appropriate solution. However, the interconnection between the stages is still crucial, as it was proposed in the original Munzner's methodology.

Furthermore, we were discussing how to shorten time while preserving the quality of the solution. Here we identified that, for example, extracting guidelines for visual mapping that would guide the visualization developers to map certain tasks to appropriate visual encodings, would significantly contribute to this effort.

We also compiled a questionnaire asking about the experience with data, design, and development of visual representations and tools within the COVID-19 pandemic and distributed it among the seminar participants. The outcomes will be summarized as lessons learned in the upcoming publication.

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4.3 "Getting ready": a visualisation perspective on pandemics

Fintan McGee (Luxembourg Inst. of Science & Technology, LU), Muna Abu Sin (RKI – Berlin, DE), Min Chen (University of Oxford, GB), David S. Ebert (University of Oklahoma – Norman, US), Kazuo Misue (University of Tsukuba, JP), Panagiotis Ritsos (Bangor University, GB), Tatiana von Landesberger (Universität Köln, DE), and Antje Wulff (Universität Oldenburg, DE)

Scope

The World Health Organisation defines pandemic preparedness as: "continuous process of planning, exercising, revising and translating into action. . . " [1]. In the context of visualisation this can be expressed in two main pillars: to devise and deploy visualisation technologies that are available during a pandemic, that can be deployed in quick-response mechanisms. to devise and deploy visualisation technologies for supporting operations and activities before and towards a future pandemic, to facilitate preparedness for when it arrives.

During the COVID-19 pandemic, we experienced a misbalance between perfection and speed [2]. As emergency situations were unfamiliar, mindsets were still prone to deliver perfect visualisation solutions rather than deploying a quick start. The time until the next pandemic hits can be used to prepare for a quicker response but also to expose shortcomings in advance, bringing us one step closer to perfection.

Our considerations of challenges include considerations on the difference in responses to the pandemic between low and high income countries. The approach followed in this report is to have an international outlook, as the synergies between populations and areas are impossible to ignore. Moreover, advances and lessons learned in different settings can inform the response and infrastructure at local, national and global level.

Challenges and opportunities In our working group, we identified the following challenges and opportunities for visualisation and related technologies towards improving our preparedness for the next pandemic:

Parameter optimisation for improved pandemic modelling, which can be improved by using visualisation approaches. The lack of standards-based data infrastructures and access that enables interoperability between different systems and services. Building awareness of the capabilities of visualisation in the expert domain remains an issue that affects the utilisation, adoption and development of visualisation tools. The need for in-depth requirements engineering including participatory visualisation methods and communication between stakeholders and developers. There are diverse methods for evaluating visualisation approaches with non-standardised indicators not quickly or automatically applicable. The integration of future technologies, ranging from mobile communications and tracking to Augmented Reality, personalised sensors, and pervasive / ubiquitous displays, which offer new opportunities for visualisation and public information. Ensuring the developed tools, approaches and solutions are transferable to other emergency situations, beyond pandemics.

For each challenge, we discussed the following three questions: What are the details of the challenge? Based on our experience and existing research in the current pandemic, why is it challenging? What approach could be proposed?

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4.4 Reflections on Pandemic Visualizations: Communication, Behaviour and Reactions

Nicolas Reinoso-Schiller (Universitätsmedinzin Göttingen, DE), Tatiana Losev (Simon Fraser University – Surrey, CA), Nicolas Medoc (Luxembourg Inst. of Science & Technology, LU), Klaus Mueller (Stony Brook University, US), Max Sondag (Universität Köln, DE), Yong Wang (SMU – Singapore, SG), Michael Wybrow (Monash University – Clayton, AU), and Hajo Zeeb (BIPS – Bremen, DE)

The main topic and goal of this group was to reflect on how pandemic (COVID-19) visualizations were communicated to the general public, especially with respect to how the communication happened, how they influenced behaviour and the reaction of the public. The group consists of a diverse team comprising epidemiologists, psychologists, data analysts, and experts in data visualization collaborates on infection prevention and control initiatives both within hospitals and in the public sphere. Their responsibilities extend to creating informative visualizations for public awareness campaigns, providing consultation to government officials, and delivering lectures at universities. This reflection's intended audience consists mainly of other visualization experts, but also government officials and anyone who wants to better understand what might be the key point of the pandemic reflection.

To explore the topic and the different perspectives from the various group members, we opted for an individualized reflection before discussing these reflections with the entire group to find larger and broader patterns. We used the following set of initial questions as a starting point for reflection, broadly categorized in experience, and future outlooks.

Experience:

- What is the relationship between your work and public behaviour / response during the pandemic?
- My thoughts, impressions, experiences?
- My experiences from my work?
- Who would I choose to work with for the next pandemic?
- What did you find to be an effective visualization? Example?
- How do you think visualization impacted misinformation?
- Future outlooks
- What would you change in communication to the public for next time?
- What would I change for the next pandemic if there were no constraints?

We discussed the individual reflections on these topics centrally over the next two days. From this, several core topics (Personalisation, Communication pathways, Intentions and actuality, Targeting) emerged, which we briefly highlight here:

(1) Personalisation. Visualizations during the pandemic were often aimed at abstract information and abstract target audiences. For example: How fast is the diseases spreading? What is the hospital bed occupation? How many people are currently infected? Which groups are getting infected most? However, a missed opportunity was to develop personalized visualizations taken the perspective of the individual. One could for example take in the group one belongs to and tailor the visualization to highlight their personal risks and COVID situation in their surroundings.

(2) Communication pathways. During the pandemic, we all noticed that we had to skip some steps in the standard methodologies for the purpose of speed. In particular, users were included only late in the design of the visualization. We discussed several ways that the group members encountered this, as well as potential solutions to establish communication pathways early and play to the strengths of the communities we are trying to reach.

(3) Intentions and actuality. Visualizations were used differently during the pandemic than how they were intended to be used by the designers. We discussed various situations where intentions did not match the actualities. While it is not always an issue if visualizations were differently, sometimes this can have severe consequences such as when taking visualizations designed for experts out of context and presenting it to the public to misinform.

(4) Targeting. Many visualizations were made and presented without specific target audiences in mind beyond the "general public". However, there is a very large breadth of audiences within the general public, and many visualizations could have benefitted from targeting more specific groups. We identified that specific communities within the general public have different needs for visualization information, as well as potential risks of stigmatization that can occur when developing for such a targeted audience.

We discussed these 4 core topics in depth during the group working sessions at Dagstuhl, and they will form the basis for envisioned People and Practices' article for Computer Graphics and Applications.

4.5 Empowering Communities: Tailored Pandemic Data Visualization for Varied Tasks and Users

Nikita Srivastava (Universitätsmedinzin Göttingen, DE), Tom Baumgartl (Universität Köln, DE), Mohammad Ghoniem (Luxembourg Inst. of Science & Technology, LU), Georgeta Elisabeta Marai (University of Illinois – Chicago, US), Silvia Miksch (TU Wien, AT), Sibylle Mohr (University of Glasgow, GB), and Simone Scheithauer (Universitätsmedinzin Göttingen, DE)

Data visualization concepts and methodologies were intensively leveraged during the COVID-19 pandemic. However, a systematic investigation into the needs of the particular users, their data, and their tasks, as well as the visual media, is still missing. We review our design experience working across six countries and over interdisciplinary COVID-19 pandemic projects.

We describe the challenges we met in these projects, characterize the user communities served by these projects, the goals, and tasks we supported, the data types and visual media we worked with. Furthermore, we instantiate these characterizations in a series of case studies covering the known purposes of visualization: exploratory analysis, confirmatory analysis, and presentation for communication during the pandemic. Finally, we describe the Visual Analytics lessons we learned, considering future pandemics.

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