



COMMENT



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Where to after COVID-19? Systems thinking for a human-centred approach to pandemics

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Whilst policymaking will always remain a highly political process, especially amidst crises, evidence-based pandemic management can benefit from adopting a socioecological perspective that integrates multi- and trans-disciplinary insights: from biology, biomedicine, mathematics, statistics, social and behavioural sciences, as well as the perspectives and experiences of non-scientific stakeholders. We make a case for an “integrated inter- and transdisciplinarity” that overcomes the typical additive nature of current interdisciplinary work and better captures the inherent complexity of public health and other public policy problems. We propose systems science and systems thinking approaches as a useful meta-theoretical, self-reflecting approach for such integration to take place. Enabled by systems thinking, the praxis of “integrated inter- and transdisciplinarity” allows for an understanding of public health crises in a human-centred socio-ecological perspective. This grounds more holistic policy responses, which by mobilising the whole of government and whole of society, put individuals, groups, governments and society at large in critical dialogue to co-produce and co-design interventions that address crises in all their physical, social, psychological, economic and political dimensions.

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Introduction

The COVID-19 pandemic was the biggest public health crisis that the world experienced on a global scale in recent history. It exposed systemic weaknesses and fragilities in health, economic, political, environmental and social systems (Haley, Paucar-Caceres, and Schlindwein, 2021). Since the early days of the crisis, governments around the world sought evidence-based management strategies, turning to science to inform decisions (Yu et al., 2021). Interventions took the form of ‘technical fixes’ (quarantines, social distancing, border closures, contact-tracing apps, etc.) and contributed to economic recession (Taylan, Alkabaa, and Yilmaz, 2022), the further straining of already fragile health systems (Arsenault et al., 2022) and the entrenchment of existing social inequalities (Sidik, 2022). Some countries acted swiftly and had some temporary success at early containment, thus minimising social disruption. Most countries, however, scrambled to implement measures that did not control adequately and proportionally the dynamics of the pandemic and failed to address holistically the social, ecological, and systemic aspects of the problem (Mormina, 2022), thus resulting in concurrent pandemic-related problems that fed off each other. The response to the COVID-19 crisis centred on the human-virus nexus without sufficiently considering the web of bio-psycho-social and ecological interrelations in which both humans and viruses are imbricated.

As attention shifts towards learning lessons to improve pandemic preparedness, it becomes imperative to reevaluate these science-based strategies, including data-intensive approaches to governance, from a more holistic perspective. The evolving landscape of health, society, and disease makes the prospect of future pandemics a matter of *when*, not *if*. Therefore, it is essential to develop comprehensive intervention approaches that take a socioecological perspective. In this commentary, we propose systems thinking as an ideal analytical tool to facilitate the process of designing such approaches. Systems thinking allows us to (1) look at different systems (social, biological, ecological) as interrelated parts of a complex whole; and (2) broaden the focus to encompass the unintended consequences of intentional actions to identify optimal solutions. Adopting systems thinking for future pandemic management will require widening the knowledge base beyond data-intensive disciplines in order to develop a socio-ecological understanding of the problem and enable the identification of policy options that address the crisis as a complex dynamic system.

In the remaining of this commentary, we develop our argument as follows: in Section “The narrow knowledge base of the COVID-19 response”, we offer a critique of what we consider the narrow knowledge base that underpinned the public health response to the pandemic. We see this narrowness not merely, but largely resulting from trends in the last decade or so towards data-driven governance and data-driven policymaking. This has shaped a policy mindset, particularly in the health domain, for which evidence-based policy is often equated to data-based policy. This creates an overreliance on certain forms of quantification whose practical and epistemological limitations are not always sufficiently appreciated. In the Section “Understanding pandemics through a socio-ecological lens”, we suggest that future pandemic responses need to build upon a broader knowledge base that enables a situated socio-ecological understanding of health crises and pays attention to the full range of determinants, from biological to social. Conceptualising such an understanding and operationalising appropriate holistic responses, entails a shift to systems thinking, which we discuss in Sections “The contribution of systems thinking to pandemic management” and “Where to from here?”.

The narrow knowledge base of the COVID-19 response

COVID-19 was the most disruptive public health crisis in recent history, which put governments under intense time pressure. Across much of the world, the political response was chaotic. Many countries, especially in the Global North, had well-developed pandemic action plans, yet they found themselves unprepared to implement them. With no or poor prior experience of dealing firsthand with infectious disease outbreaks at such a scale, decision makers turned to the experts for guidance. Due to a pervasive culture of data-driven governance (van, Ooijen et al., 2019), experts were sought among the data-intensive sciences (epidemiology, molecular biology, etc.). Thus, despite recognising the complex interlocking biological and social dimensions of the crisis, the response to COVID-19 followed a data-driven command-and-control approach that hinged on readily available and largely biomedical quantitative metrics.

Data-intensive approaches such as statistical modelling are valuable tools for designing public health interventions, but their methodological and epistemological limitations must be appreciated. On a practical level, the robustness of these methods depends on the ability to utilise fine grained data, which is always difficult to acquire, more so during a crisis. On an epistemological level, such methods are good at capturing phenomena involving short and relatively simple causal chains but are less well suited to the modelling of complex behaviours and systemic relationships with many feedback loops, uncertain inputs from different knowledge domains, and multiple outcomes. They are necessarily mechanistic and do not consider the relational subject—physically, socially, narratively, and culturally situated – as an explanatory level in its own right (Engebretsen and Baker, 2022; Kelly et al., 2021). Moreover, an overreliance on certain methodologies can skew understanding towards those particular aspects of the problem that such methods can measure while concealing others. For example, certain forms of data aggregation typical of some epidemiological approaches obscure the heterogeneity of social determinants. This was evident during the COVID-19 pandemic when reliance on epidemiological models favoured a biomedical understanding of the crisis and obscured its psycho-socio-ecological aspects (Tretter et al., 2021). A good illustration of this last point can be found in some of the models used to map population spread, which assumed uniform social behaviour and susceptibility without accounting for social factors (e.g., people changing behaviour in response to [mis]information), differing risks based on social stratification and the mediating and moderating role of different contexts.

These limitations suggest that other inputs are also needed if a more holistic understanding of complex, interconnected, and interdependent phenomena is to be achieved. The lessons from the pandemic and the near certainty of similar future crises invite a rethink of health-related sciences (Caniglia et al., 2021) and an epistemological turn towards a conception of health and disease that both is genuinely relational, value-based and contextually grounded and provides, in addition to the biomedical perspective, a psycho-social and ecological one (hereafter, we refer to this additional perspective as the ‘socio-ecological lens’ for short). This requires knowledge integration at the level of concepts (Rod et al., 2023) and methods (Rutter et al., 2017).

At the conceptual level, integrating multiple forms of knowledge within a socio-ecological lens allows us to duly account for the presence of multiple individual and collective actors and their interactions with their unique contexts. Furthermore, integrating empirical evidence and theory is essential to attain a comprehensive, system-wide understanding of both biological and social realities (Pfaff and Schmitt, 2023). At the methodological level, there is a pressing need to harmonise experimental evidence with mechanistic studies, as well as quantitative and qualitative

research (Greenhalgh et al. 2022; Greenhalgh and Engebretsen, 2022; Pfaff and Schmitt, 2021).

At all of these levels, a praxis of integrated inter- and trans-disciplinarity—that is, cooperation extending across and beyond disciplinary boundaries—is necessary (Tretter and Marcum, 2023). In other words, diverse strands of scientific evidence (‘horizontal interdisciplinarity’), as well as the experiences and viewpoints of relevant stakeholders, such as health professionals, patients, and their relatives (‘vertical interdisciplinarity’) are all important and need to be harmoniously integrated through the epistemic process that constitutes ‘transdisciplinarity’ (Klein et al., 2001; Nicolescou, 2008). Transdisciplinarity as a pluralistic epistemic method can potentially deliver public health measures that are better tailored to the particular features of the situation and the specific needs of the population, also resulting in better adherence to public health measures and preventing social polarisation.

Conceptually, such praxis helps us understand pandemics through a socio-ecological lens, as we explain in Section “Understanding pandemics through a socio-ecological lens”. Methodologically, an inter- and transdisciplinary praxis that is truly integrated and not simply additive is both pivotal to and enabled by the systems thinking approach we propose in Section “The contribution of systems thinking to pandemic management”. Systems thinking, underpinned by an inter- and transdisciplinary socio-ecological conception of health, can help develop the knowledge and policy tools needed to address the urgent, complex challenges of constructing resilient post-COVID-19 societies, as we argue in Section “Where to from here?”.

Understanding pandemics through a socio-ecological lens

COVID-19 was a highly disruptive event, which, like many other natural or human-induced crises, disproportionately affected poor and vulnerable groups, reflecting and exacerbating pre-existing socioeconomic and health inequities (Sidik, 2022).

In many countries, opportunities for attending to health more systemically were clearly missed. For example, protracted lockdowns without adequate social protection plunged already vulnerable groups further into poverty (Buheji et al., 2020). Quarantine orders also increased the incidence of domestic violence (Kourti et al., 2023) and mental health issues arising from social isolation (Green et al., 2022). There is increasing evidence of the damage that school closures caused to children’s psychosocial development (Pietrabissa et al., 2021) and educational attainment (Christakis, Van Cleve, and Zimmerman, 2020). These interventions, supported by epidemiological models, were based on a biomedical, disease-focused understanding of health that prioritises the physical dimension. This understanding has been long de-emphasised in favour of a more holistic conception that acknowledges the crucial importance of a wider set of determinants of health—environmental, social, economic, behavioural, and political (Dahlgren and Whitehead, 2021). The interplay of these determinants in the context of the pandemic was poorly understood at the time and, therefore, not sufficiently accounted for. The economic, social, and psychological fallout of the crisis is a direct consequence of a virus-centred pandemic response, that is, a response largely driven by the perceived need to contain population spread at all costs rather than to protect health and well-being in all their dimensions. More transdisciplinary approaches, e.g., from urban health studies (Gutzweiler, 2020) may help to integrate the missing dimensions, e.g., by identifying conditions for disease spread and appropriate interventions based on local socio-ecological environment factors.

Of course, readers may argue that when faced with such a dynamic crisis, the focus must be, rightly, on the immediate

threat to human life—in this case, a potentially deadly virus. This is true, but whilst we agree that the COVID-19 virus was life-threatening for certain groups, we contend that for many people, the greater threat to health came not from the virus itself but from the disruption to social life (e.g., social isolation, suspension of essential services, loss of job security, etc.). Therefore, the need for models and interventions that understand and are sensitive to differing levels of risk and susceptibility to disease is key. Pandemics, as it became obvious during the COVID-19 crisis, are complex problems with social, economic, as well as health dimensions. This calls for a socio-ecological lens that provides a conception of health that starts with the individual rather than with the disease and captures the contextuality and multidimensionality of well-being (Paul et al., 2020). In practice, this means adopting—even in the midst of a deadly pandemic—multi-level health interventions involving broader sets of actors to address the systemic interconnectedness of different determinants (Sturmberg and Martin, 2020).

Designing multi-level and person-centred health interventions requires a wider conceptual and methodological framework able to integrate different sources of information in order to address the full set of determinants (environmental, social, economic, behavioural, political) at play during a crisis. At the conceptual level, we need to complement biomedical knowledge with the relational, socio-ecological lens we endorse here. We are not the first to advocate for knowledge integration. Different schools of social ecology and similar approaches seek to integrate the ecological dimension of health. Within the field of sustainability science, the well-established (new) social ecology (Haberl et al., 2016) and human ecology (Dyball and Newell, 2023) approaches entail the integration of natural and social sciences and offer a good scientific framework to address new health challenges emerging from environmental change. In addition, new and more pragmatic orientations, such as ‘One Health’, ‘Eco Health’, ‘Planetary Health’ and ‘Global systems approaches’ envisage a holistic perspective on global health. These connect human-nature relations, ecosystemic performance, social inequity, and planetary boundaries as intersecting and mutually reinforcing aspects of health promotion and disease prevention in a globalised world (e.g. de Castaneda et al., 2023, Thoradeniya, Jayasinghe, 2021). Our argument runs along similar lines, but unlike these pragmatic approaches, it emphasises the need for a conceptually and methodologically grounded integration of social and human ecological knowledge through formalised systems approaches. Furthermore, it explicitly requires epistemic diversity and transdisciplinarity as a methodology for achieving systemic understanding, which the above approaches do not.

At the operational level, this necessitates an integrated whole-of-government (WoG) and whole-of-society (WoS) approach to pandemic management (Ortenzi et al., 2022). Both, conceptualisation and operationalisation may be better achieved with a shift to systems thinking.

The contribution of systems thinking to pandemic management

The heightened uncertainty and complexity of socio-ecological crises make evident the value of systems thinking for policy-making (Ison, 2010). We define system thinking as a perspective that regards the fabric of social and natural reality as an amalgamation of social, ecological, and various other types of systems, collectively forming the backdrop for human existence, actions, and health. These systems operate with their inherent logic, maintaining a loose interconnection and coupling, and are primarily self-sustaining or autopoietic in nature (Luhmann, 2008; Radosavljevic, 2008; Eshaghzadeh et al., 2017; Orton Karl, 1990).

According to actor-system approaches, humans engage within natural and social systems, both enabled and constrained by the structures and dynamics of those systems. Moreover, humans play an active role in the creation, configuration, and perpetuation of these systems, contributing to their ongoing development and evolution (Habermas, 1987; Giddens, 1984; Strauss, 1978). Both of these effects were readily apparent during the COVID-19 pandemic but were not represented in the models that prominently underpinned pandemic decision-making in many countries.

From a systems thinking perspective, social systems can be conceptualised on three main levels: (interpersonal) interaction systems, organisations, and society (Luhmann, 1995). All three types of social systems influence each other: lower-level interaction systems shape higher-level social systems, including organisations and society as a whole, while these higher-level systems, in turn, make concerted efforts to shape the behaviour of lower-level interaction. Underpinned by an understanding of health that integrates both the biomedical and the socio-ecological lens, systems thinking offers a holistic perspective, enabling us to view pandemics as an interconnected component of a larger, dynamic and complex system. It also provides the analytical tools and methodology to identify feedback loops, unintended consequences, and emergent properties within the complex web of systems and interactions (Meadows, 2008). These properties of health care systems, which must be managed both in normal times and during crises, are captured by the approach of systemic management in system diagnosis, decision making and implementation (for operationalisation, see, e.g., Sturmberg and Martin, 2013). Other frameworks for operationalisation exist (e.g. Snowden and Boone, 2007; Laur et al., 2021), and the most suitable choice will depend on context and require bottom-up feedback to tailor existing approaches to specific institutions.

From this perspective of systemic interactions, pandemics present two key challenges for both individuals and social systems. The first is developing effective pandemic measures, which entails the task of understanding and specifying the problem, identifying policy strategies to contain the spread, and anticipating the full range of expected effects. The second is effectively implementing those measures in order to change individual and collective behaviour in the short term by modifying the actions of both individuals, as personal systems, and collectives, as social systems.

The first challenge underscores the pivotal role of the science-policy interface in facilitating understanding of the problem and devising appropriate and proportionate pandemic responses (Greenhalgh and Engebretsen, 2022; Pfaff and Schmitt, 2023). Here, systems thinking provides a framework for achieving the integrated inter- and transdisciplinarity that crises require. By focusing on the problem as a whole rather than its individual symptoms, systems thinking acts as a meta-theoretical approach that helps bring together multiple and diverse knowledge and perspectives in a non-rivalrous fashion. This avoids competition between different explanatory models and fosters integration through collaboration, thus providing a better, shared understanding of policy problems and the potential impact of interventions. In this way, systems thinking can deliver a much-needed improvement to the epistemic quality of evidence-based policy (Caniglia et al., 2021).

For this reason, a systems thinking approach is particularly suited for the management of complex public health crises. It helps capture the complexity and conceptualise the problem with its manifold contributing causes from the holistic biomedical and socio-ecological perspective we argue for. This provides a more complete, multi-level picture of pandemics (Sturmberg and Martin, 2020), where every event has an impact on processes at

different levels, from the bio-molecular to the socio-political (Tretter et al., 2021, 2022). Appreciation of pandemics in this way enables better theories of change to emerge and, consequently, the development of precautionary approaches to the prevention of coupled biological, social and environmental health challenges (Franco et al., 2022).

The second challenge concerns how to manage through effective policy implementation the transformation of values, norms, rules, interpretation patterns, and behaviour that is required within a specific social system to respond to the crisis. Systems thinking can help us develop a mental representation of societies as complex systems characterised by nonlinear patterns of social, ecological and economic relations. Because these relations are most of the time in equilibrium, social systems tend to be inert (Coiera, 2011), that is, with a finite degree of readiness for change (Weiner, 2020). When crises create perturbations that alter the system's equilibrium, resistance to change will be the default collective response (Oreg and Sverdluk, 2011; Johansson et al. 2014; Pardo del Val and Martínez Fuentes, 2003). To surmount this, governments may impose change through explicitly top-down social control to enforce (pandemic-related) behavioural rules. This can lead to unintended consequences, such as even greater resistance to change within specific subgroups of the social system. Systems thinking makes the complexity of social systems visible, allowing for the conceptualisation of feedback loops and providing a greater appreciation of the consequences of any proposed interventions across all levels, thus enabling better modelling of alternative 'what ... if' scenarios.

Whilst top-down command-and-control approaches may be necessary in certain circumstances, in most democratic societies, however, change is facilitated through consensus, in turn achieved through participatory negotiation to co-produce and co-create new rules, norms and order for the social system. Here too, systems thinking can help develop approaches to systemic management, including through the integration of objective data and the subjective views of different stakeholders. In other words, managing pandemics using the tools of systems thinking calls for the kind of transdisciplinarity that systems methodologies have the flexibility to accommodate. For a government trying to apply systemic management principles to complex problems, this means, in practice adopting a WoG/ WoS approach underpinned by a culture of cross-sectoral collaboration, and an ability to work across specialisms or policy portfolios connecting different strands of knowledge and bringing together transdisciplinary groups representing the heterogeneity of stakeholders to find leverage points towards system transformations.

Such a systemic approach to pandemic management fosters commitment but it does require time and effort for consensus-building and implementation. Moreover, it requires overcoming the fragmentation and siloed ways of working that is typical of current government and social institutions (including academia). For this reason, building a culture of inter- and transdisciplinary collaboration cannot be built when a crisis hits but must be created and nurtured in 'peace times', and we suggest it should be considered a key element of preparedness plans for future resilience.

Where to from here?

The pandemic may have formally ended, but we must not miss the opportunity to capitalise on its lessons. COVID-19 teaches us that addressing public health crises requires a conception of health that helps understand people not in isolation (biomedical model) or as data aggregates (epidemiological model) but as situated subjects embedded in a wider psychological, social, moral and physical environment (socio-ecological model).

In this sense, the lessons of the pandemic point us towards the need to embrace complexity in the practical business of designing and implementing evidence-based public policies for health (Franco et al., 2022). As attention now turns towards new strategies for preparedness and prevention (WHO, 2021), a conceptual framework is required for coordinating action at the local, regional, national and supranational levels, connecting domains of governance beyond health: climate and environment, trade, food production, urbanisation, economic development, etc. The challenge lies in achieving this without resorting to the kind of tight top-down management approaches that already proved to be of limited effectiveness in large-scale engineering projects (e.g. Levine Arnold 1982) but relying instead on a more distributed and participative approach. For this, the application of systems thinking is key, but it demands more than collaboration between and across scientific disciplines, and between and across policy areas.

Addressing complex problems with eco-systemic thinking requires more pluralistic approaches to defining what counts as relevant knowledge for policy (Mormina, 2022). In practice, this means harnessing not just the knowledge of subject experts, but implicit and embodied knowledge, including the perceptions and experiences of all those for whom the problem is a problem, as an important form of evidence. Fully utilising the potential of systems thinking also requires a reconsideration of the fragmented nature of academic institutions, from where expert science advisors are often drawn. These institutions reward disciplinary experts and forms of knowledge production organised around single disciplines, whereas the culture of multidisciplinary that systems thinking entails is difficult to foster (Arnold et al., 2021). In this regard, some innovative ideas are beginning to emerge in the form of new institutions offering interdisciplinary curricula organised around solving complex problems (Jack, 2019), but these forms of knowledge production remain largely experimental.

At the level of governance, the siloed structure of public administration remains a significant obstacle to the generation of useful knowledge for policy. WoG and WoS approaches (Christensen and Læg Reid, 2007), underpinned by systems thinking, are increasingly called for to address complex problems, yet many institutions lack governance mechanisms and resources for their implementation (Global Network for Health in All Policies, 2019). The difficulties that many countries experienced in trying to control the pandemic can be attributed to a lack of transparency, leadership, ideological policies, inability to convey consistent information, and above all, governance systems and institutionalisation of practices that were ill-suited to the task. Within these systems and practices, the absence of a holistic, systemic strategy does not come as a surprise. Instead, responses to the pandemic were fragmented, with patchwork policies often leading in opposite directions, and governments struggled to foster a sense of safety, direction, predictability and trust.

There were exceptions, however, that may serve to illustrate the value of transdisciplinary and the human-centred systems approach that we tried to outline here. In Germany, for example, some bottom-up ‘citizens COVID-fora’ were established where people could ask questions and offer suggestions to optimise regulations (Initiative Offene Gesellschaft e.V., 2022, Staatsministerium Baden-Württemberg, 2022). In Singapore, the ‘Emerging Stronger Conversations’ initiative (SG Together, 2021) sought to expand common spaces for government, scientists and citizens to collaborate in the design and implementation of social policies to recover from COVID-19. Whilst not examples of systemic management of the pandemic as such, these are the kind of initiatives for which a systemic approach has the potential to provide an effective tool for knowledge integration through co-production. Clearly, transdisciplinary co-production is not

without challenges (epistemological, practical, political), and space precludes a detailed discussion of those. Our aim here is simply to show how systems thinking principles demand and allow for the systematic gathering of pluralistic knowledge for policy: quantitative, qualitative, expert, and experiential. Guided by these principles, new frameworks can be developed, institutions reformed, and resources for policy implementation mobilised. In practice, this means creating spaces for critical dialogue that engage national, local and regional government agencies, local communities, experts, academic institutions, and civil society working across sectors to co-produce and co-design interventions. Such an inclusive environment will instil confidence, provide guidance, offer predictability, and foster trust among individuals and within society. We do not know who the guru will be to direct such efforts, although history tells us that the most radical societal reforms usually start from the bottom up. As West Churchman, one of the most influential systems thinkers, once said: “A systems approach begins when you first see the world through the eyes of another” (Churchman, 1968).

Conclusion

COVID-19 promised to usher in a ‘new normal’ in our social and political lives. It can also usher an institutional and conceptual shift towards a socio-ecological (relational) epistemology and a systemic approach to evidence-based policy for complex problems, with the ‘human’ firmly anchored at the centre.

Data availability

Data sharing is not applicable to this research as no data were generated or analysed. This paper is a theoretical and meta-theoretical position paper.

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Author contributions

All authors contributed to the conceptualisation of the paper; Tretter conceived the original idea. Mormina wrote, and Tretter co-wrote the original draft and revised drafts after peer review. Mormina, Müller and Tretter co-lead the editing process. All authors reviewed and edited the original draft.

Competing interests

The authors declare no competing interests.

Ethical approval

This study did not involve any research requiring ethical approval, but it is committed to the ethical standards of science.

Informed consent

This research did not involve human or animal subjects and, therefore, did not require any type of informed consent.

Additional information

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