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Hypothesis Open Access

The Concept of Dynamic Physical Hyperconnectivity through Travel Mobility: An Explanatory Hypothesis for the Emergence of the COVID-19 Pandemic

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Abstract

Pandemics, such as the emergence of COVID-19, have their roots in the intricate interplay across animals, humans and the environment. The transition from epidemics to full-blown pandemics can be visualized as the proliferation and spread of transmissions across a web of interlinked networks. These networks encompass not only human-human interactions but also encompass animals, inanimate objects, and elements within the environment. Human civilization has seen an unprecedented increase in the mobilities of humans, animals and artefacts, and formation of innumerable interconnections across them as well as with the environment. Furthermore, there is widespread expansions of these networks, and a global reach. These are in a state of constant flux due to increasing mobilities of their individual nodes as well as their corresponding networks. The interactions occur across predefined pathways (eg. along transport routes) or more randomly (eg. floating atmospheric pollutants). The concept of "Dynamic Physical Hyperconnectivity" is proposed to capture the situation when there is synchronization or approximation of these high-mobility networks, creating the environment for very close physical connectivities of nodes across adjacent networks. If multiple networks coincide, the connectivities can occur across the globe. This hypothesis could explain the swift worldwide spread of COVID-19 virus during the pandemic, and is supported by preliminary data. If this is proven with modelling, it implies that mitigation of pandemics such as COVID-19 requires a multifaceted approach that curtails the velocity of agent mobility, minimizes interaction frequencies, reduces node mobility scope, and disentangles interwoven networks.

Keywords: Dynamic Physical Hyperconnectivity; Mobility; Pandemics; COVID-19

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Background

The COVID-19 pandemic and widespread epidemics of HIV, Ebola and have emerged from human-wild animal interactions, driven by socio-economic, environmental and ecological factors [1]. Several phases are observed during emergence and generation of such epidemics: mutation for viruses, animal-human interactions, cross species transmission, self-limiting human epidemics, and an explosive pandemic [2]. Though the concept of zoonosis was used to explain the cross-species transmission, subsequently, the One Health approach has widened the scope and proposed integration of human-animal-environmental system, their socioeconomic and ecological determinants [3]. A systems approach was even wider, and has been used describe the COVID-19 pandemic as emergent properties of complex systems that encompass concepts of One Health and recognizes interacting sub-systems within (e.g ecological system, the physical environment, the total human species and its social systems), as well as those open to a wider external environment [4]. Accordingly, the emergence of the pandemic is explained as adaptations in the global system, and its patterns of spread due to its interconnected networks. These concepts and explanatory models need further elaborated in light of the explosive and unprecedented pandemic of COVID-19.

In the case of COVID-19, it is well recognized that over a period the corona virus was rapidly mutating in the wild [5]. The interactions among species of wild animals, and their interactions with humans in several locations provided reservoirs of mutates corona viruses with the potential for cross species transmission [5]. At the molecular level, one such mechanism identified was the receptor binding domains of spike proteins that enabled binding of virions and membrane fusions. The appropriate mutations in the spike proteins led to their ability to invade human respiratory and oro-nasal epithelial cells led to a series of self-contained mini epidemics from infections in susceptible contacts [2]. Such mini-epidemics were observed with Middle East respiratory syndrome (MERS) (another corona virus) in the Middle East region[5]. After reaching a critical threshold number of infected persons in a locality, it spread to widening circles. A similar phenomenon was also observed in the case of waves of dengue cases moving away from Bangkok, Thailand, towards rural areas [6]. Closer examination revealed another facet to the spread of dengue with some of the spread occurring along multiple networks (e.g. travel routes) that promoted physical proximities of humans [7]. We explore this with the concept termed Dynamic Physical Hyperconnectivity.

Mobilities in Networks

Recent times have seen an extremely rapid growth of mobilities of the nodes in networks. We observe a multitude of novel transport modalities, such as vehicles, trains, airlines, and ships. They form networks (e.g. road or rail networks) and overlap. The frequencies of movement, pace and directions have as well as contacts across human and non-human agents or environments have augmented and increased exponentially. Other mobile nodes include transport of livestock or animal migrations. Natural mobilities of artefacts and biological matter could occur via wind, rivers and streams. The latter include pollutants, floating pollen, or insects.

These mobilities are random or traverse pre-determined paths such as highways, and have a wide range of frequencies of movements, individual speeds, traveling distances and directions. These dynamism and mobilities enable individual nodes to encounter multiple contacts or connectivities with other nodes in a very wide area. As a result an immeasurable number of contacts or interactions are simultaneously occurring across these nodes all over the planet. These lead to connectivities, defined as abilities of two or more nodes to transfer or exchange information, energy, mass or agents across to each other. In epidemics or pandemics, the transfer is an organism.

At a planetary level, the overarching network encompassing all these mobile nodes is the social-ecological-technical system (SETS) [8]. These interactions across different types of nodes enable the spread of infections such as viruses. Systems thinkers believe this unprecedented connectivities has made human civilization more susceptible to pandemics [9,10]. This concept of increased and unprecedented connectivity in relation to epidemics was first explored by the author using the term physical hyperconnectivity in relation to COVID-19 pandemic, a concept that can be traced to the software industry which defined it as the instant ability to communicate anywhere and anytime using multiple means [12].

Growth and augmentation of connectivities due to internet of things (IoT), led to the concept of ‘digital hyperconnectivity’ defined as “the condition in which everyone is (potentially) connected to everyone, to an exponentially growing array of sensor-embedded things, and to an infinity of digital content, everywhere and all the time” [13]. The original concept of hyperconnectivity was explored in relation to the COVID-19 pandemic and term ‘physical’ was added to recognize that objects are the nodes in the network and to distinguish from the intangible hyperconnectivity of information [11]. The objects include humans, animals, inanimate artefacts, goods, and particulate matter in air pollutants.

Dynamic Physical Hyperconnectivity

In the current paper, the adjective ‘dynamic’ is added to capture a particular state of these dynamic interactive systems, ie. the state of Dynamic Physical Hyperconnectivity. This is applicable when there are alignments across multiple networks enabling rapid spread of a contagion across multiple networks in the social-ecological-technical system. This critical phase is reached when random or deliberate movements of individual nodes and the inherent cyclical changes of whole sub-systems coincide. For example, the seasonal changes in airline traffic, vehicular mobilities and movements of individual humans and their artefacts all coinciding to enable unprecedent numbers of individual nodes to connect across and within large areas of the systems.

The author has presented this graphically in Figure 1. It depicts the mobilities of nodes in several systems including random fluctuations or deliberate movements and cyclical shifts of whole networks. These mobilities have the potential to converge or coincide the nodes across multiple subsystems of the social-ecological-technical system, (shown in Figure 2). The existence of this critical stage for an adequate time period will enable a suitably placed contagion to spread rapidly and widely across multiple networks throughout the planet, shown as thick dotted lines in Figure 2, ie. a state of Dynamic Physical Hyperconnectivity.

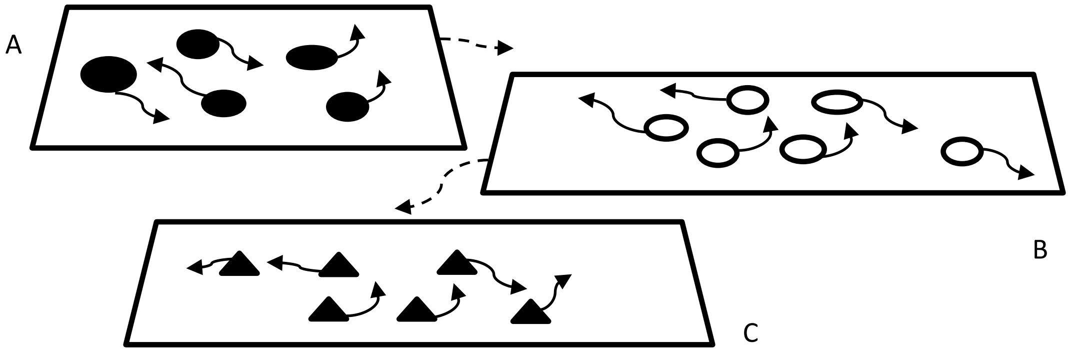

Figure 1. Mobilities of nodes in 3 networks (A, B and C) functioning in different levels. Dotted arrows indicate fluctuations of the complete network. Figure conceptualized and drawn by the author.

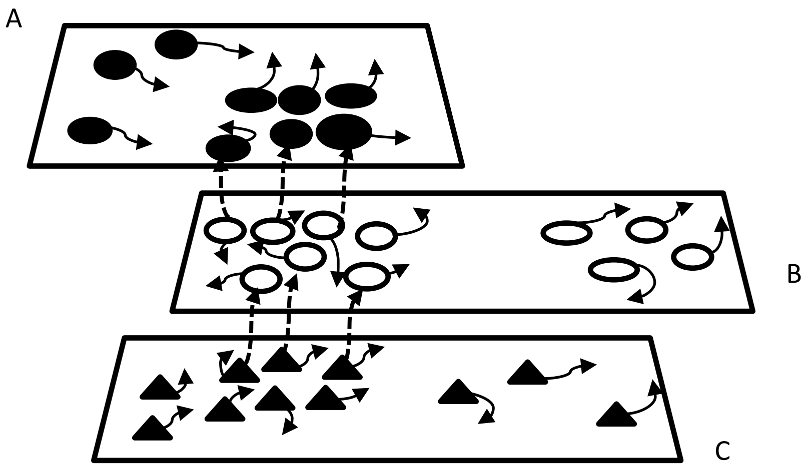

Figure 2. Alignments of nodes in the networks leading to hyperconnectivity. Thick vertical dotted arrows show the potential for explosive spread across networks from C to B to A. Figure conceptualized and drawn by the author.

Applying Dynamic Physical Hyperconnectivity to COVID-19

In the next section we apply Dynamic Physical Hyperconnectivity hypothesis to COVID-19 pandemic, to briefly explore its validity. We begin by identifying specific factors in the major social-ecological-technical system and trace their dynamism at the beginning of the pandemic. In the social system, the factor is human mobilities, in ecological systems, the animal and particulate connectivities and in the technological system it is the connectivity through artefacts human mobility

Human Connectivities

By late 2019 and early 2020, Wuhan had accumulated several ingredients to achieve a state of Dynamic Physical Hyperconnectivity. It is a highly populous and large city (population of 11.08 million) having a borderless transport hub for multiple human networks linked to other cities in China and overseas [14,15,16, 17]. Travel and transport are through trains, vehicles, internal shipping and airlines. There was evidence of human-to-human transmission among close contacts in mid-December 2019, but these outbreaks did not generate a pandemic [18]. The city exhibits cyclical changes due to seasonal patterns of travel, largely dependent on holidays and festivals. During the period 1st to 24th January 2020, there were 11.5 million counts of movements from the city Wuhan, of which 8.7 million were to prefectures within Hubei Province and 2.8 to other areas. This count further increased and peaked around mid-January 2020 prior to the lockdowns [19]. The correlation between total population flow and the number of infections in each prefecture ranged from r = 0.522 on 24 January 2020 to r = 0.919 on 5 February 2020 demonstrating a positive relationship between travel and spread of COVID. The loads of passengers in domestic travelling by train positively correlated with the number of COVID-19 cases in other cities [20,21]. The cyclical nature of such passenger throughput is observed with relative peaks in January-February and July-August. During January 2020, almost 7 million people had left Wuhan through the different modes of transport [22,23,24].

Animal Connectivities

Wild and domestic animals are frequently transported within China and its neighboring countries. The deeply rooted cultural practices of consuming wild animal meat, some for apparent therapeutic benefit, facilitates spread of infections. Meat consumption and therefore their transport follows a cyclical pattern. Numerous legal and illegal paths transporting trapped wild animals and their meats to and from Wuhan contribute to significant degree of animal connectivity [25]. There is increased consumption closer to the Lunar New Year during February and the demand for wild meat was further increased by falling supplies of pork due to swine flu in 2019 [26]. These events could have promoted more widespread humans to animal contact during the period approaching January 2020.

Particulate Connectivities

Air pollutants and spatial patterns of COVID-19 spread suggests its spread through particulate matter of pollutants [15]. There are natural movements of airborne microbiomes due to atmospheric movements [27,28]. The jet-streams surrounding the planet may have transported the airborne virus from Wuhan to the southern areas of USA, and then across the Atlantic to Portugal and Spain. The seasonal variations of these jet streams suggest the optimal positions for global spread from Wuhan to have been around December 2019.

Connectivity Through Artefacts

In addition to human mobilities, there are mobilities of large numbers of artefacts. Wuhan has 2.19 million vehicles which in 6 days completes 4.9 million trips or 254 million per year [29]. The frequency of flights, trains, and buses from Wuhan and the daily as well as the cumulative numbers of COVID-19 cases in other cities showed a positive correlation ($P < 0.001$) [30]. Within these vehicles they provide opportunities for human-to-human contacts and thereby generate spread of COVID.

Implications of Dynamic Physical Hyperconnectivity

The generation and spread of novel infections or re-emerging infections and pandemics is often explained on systems approached. An example is the 'One Health' which recognizes the importance of states in equilibria across multiple systems, such as human society, animals and their environments. It gives less emphasis to the dynamic nature of these systems. The paper proposes an advancement of this concept by recognizing the importance of mobilities of humans, animals and artefacts, in interdependent networks [31]. The dynamic and periodic fluctuations of human mobilities, superimposed on lower frequency cyclical changes in human mobilities, animal and particulate connectivities lead to an closer contacts and alignment of connectivities across the multiple systems. This is called a state of Dynamic Physical Hyperconnectivity allowing for extremely rapid spread of infections across the planet.

The preliminary data suggests that Wuhan reached a state of Dynamic Physical Hyperconnectivity around December 2020. The concept leads to a better understanding of pandemics. It recognizes a key role for connectivities arising through the mobilities of systems and their nodes. Mathematical models and simulations would be required to capture the dynamism of the mobilities of these systems, their hyperconnectivity and whole-of-system approaches [32]. Analyses based on Big Data are an approach to capture wide-spread mobilities across networks and explore their convergences, alignments and synergies [33]. The existing models of disease transmission could be refined by using the concept of Dynamic Physical Hyperconnectivity [34, 35]. If empirically proven, Dynamic Physical Hyperconnectivity based prevention strategies will require dampening cycles or mobilities (e.g. avoiding surges in travel), restricting mobilities within systems (e.g. reducing dependency on long supply chains) and disrupting interconnections between systems (e.g. minimizing animal-human links in wet markets and factory farming). Long term prevention will need measures to reduce physical hyperconnectivity, and therefore curtailing dependency on inter-continental or cross-border travel and globalization that generates it [10]. Futurists need to consider alternative developmental models that promote locally based economies requiring less global connectivity and a new balance between globalization and localization[36].

Highlights

What Is Already Known?

Covid-19 pandemic led scientists to propose an unprecedented number of explanatory hypotheses and mathematical models. At the core of these approaches is to view the behaviours of multiple systems that enabled the spread of the virus.

What Does This Study Add?

The paper highlights the importance of mobilities of nodes in systems of humans, artefacts and vehicles or vectors. These form multiple networks that are also dynamic in shape, shifting their positions and interacting with each other. The hypothesis proposes that we view the spread of the virus across networks (ie when the wider global system reaches a state of dynamic physical hyperconnectivity. At this state, the mobilities of nodes and networks have enable the nodes to be in close physical contact across multiple networks, enabling infections to spread globally.

Ethics approval and consent to participate

Not applicable

Consent for publication

As the author I wish to give consent to publish this paper

Availability of data and materials

None

Conflicts of interest

The author has no conflicts of interests to declare

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Authors' contributions

The author conceptualized and wrote the manuscript

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