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RESEARCH ARTICLE

Commentary on Leveraging Systems Science to Understand COVID-19 and Its Public Health Sequelae

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ABSTRACT

We advocate for the use a systems science approach to uncover and understand the systems affecting and affected by COVID- 19 and conducted a group model building project to create a causal loop diagram illustrating the relationships between COVID-19 and multiple health issues. The diagram includes 16 variables and multiple feedback loops in our causal loop diagram of the impact of COVID-19 on people's lives and well-being. This commentary highlights three loops to illustrate the complex interrelationships within the system of factors. The first loop highlights the impact that structural interventions. such as closing all bars or restricting capacity/operating hours, can have on COVID-19. The second loop illustrates the reason that school closures are a good idea for controlling the spread of COVID-19, and also highlights the consequence that closing schools has on social isolation. The final loop addresses how social isolation to protect against infections contributes to poor mental health and the varied associated responses. Our fairly straightforward and simple exercise can serve as an example for others committed to addressing public health challenges and improving community health and well-being. We believe that public health researchers and practitioners must move beyond what is easy and known, embrace complexity and leverage systems science to understand COVID-19, its public health sequelae and intervention opportunities.

INTRODUCTION

Efforts to flatten the curve of the COVID-19 epidemic significantly affected the lives of individual and communities around the world. The mitigation efforts resulted in economic uncertainty and shifted routine behaviors and activity patterns. Preliminary evidence documents simultaneous increases in stress, mental health symptoms, intimate partner violence, and substance use [1-4].

While it is tempting to adopt a narrow approach to intervention development and implementation, the consequences of doing so during the on-going COVID-19 pandemic are catastrophic for population health and well-being. Because individuals and the world they live in are multifaceted and complex, we must use a systems science approach to uncover and understand the systems affecting and affected by COVID-19. As highlighted in the 2020 *Health Education & Behavior* themed issue on systems science[5], systems thinking and science methods are inherently designed to identify causal mechanisms and connections between components within a system and can serve as critical decision support tools to assist public health professionals assessing response strategies and policies as well as the potentially unintended consequences of intervening on specific leverage points[6,7]. We believe that systems science thinking and methods can offer critical guidance to researchers and practitioners seeking to protect and promote health during the COVID-19 pandemic. In order to explore and support the utility of using group modeling building and causal loop diagrams to better understand COVID-19 and its public health sequelae, the four of us designed and participated in a group model building project to create a causal loop diagram illustrating the relationships between COVID-19 and multiple health issues. We are part of the Center for Social Dynamics and Community Health and the Department of Behavioral and Community Health Sciences at the University of Pittsburgh

Group model building allows for the direct involvement of groups or stakeholders to create informal maps that may lead to simulation models[8,9]. Causal loop diagraming is a systems science tool, often utilized as a step in system dynamics modeling, that visualizes the variables, feedback structures, and intervention opportunities within a system[10]. Causal loop diagrams have been utilized to better understand systemic relationships across a wide range of health topics including obesity[11], HIV transmission[12], and depression[13].

METHODS

Informed by a group-based modeling approach, we designed and participated in a project over a series of meetings in Summer 2020. Using MURAL, an online collaboration platform, and Zoom, an online video conferencing platform we conducted a connection circle exercise to create the causal loop diagram. We first worked independently to generate responses to the prompt: What facets of people's lives have affected and been impacted by COVID-19? We then placed the facets/items around the outside of a circle. Next, our group discussed the items and worked together to draw single-headed causal arrows to connect each item to COVID-19 and to the other items on the circle and described the causal relationships between the connected variables. Finally, we examined the circle for loops to include in a causal loop diagram, and a member of our research team rendered the connection circle results into the causal loop diagram presented in Figure 1a. Our team then discussed the figure and identified the three loops to highlight for this paper (Figures 1b, 1c, 1d). We then classified the loop according to the two types; in reinforcing loops, change in one direction will result in greater change in the same direction, while balancing loops maintain equilibrium[10].

RESULTS

There are 16 variables and multiple feedback loops in our causal loop diagram of the impact of COVID-19 on people's lives and well-being (Figure 1). The arrows presented in Figure 1 describe the direction of effect between two factors and the sign of the loop indicates the nature of the relationship; a positive (+) causal link indicates that the change in variable X produces change in the same direction for variable Y, and a negative (-) causal link indicates that the change relationship goes in the opposite direction. The number of negative (-) links determines if the loop is reinforcing or balancing. If there are zero or an even number of negative links, then the loop is reinforcing. If there are an odd number of negative (-) links, then the loop is balancing. Figures 1b, 1c and 1d highlight three loops, and the text below uses the variables and links to explain the complex interrelationships within the system.

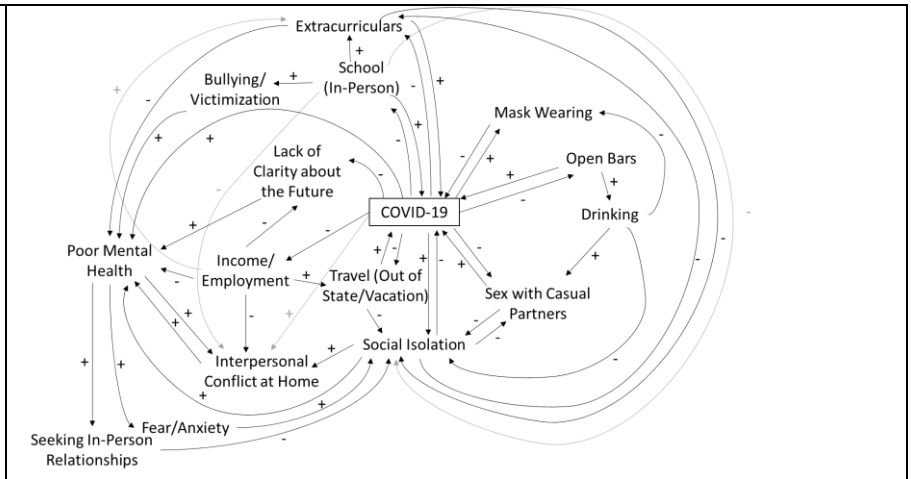
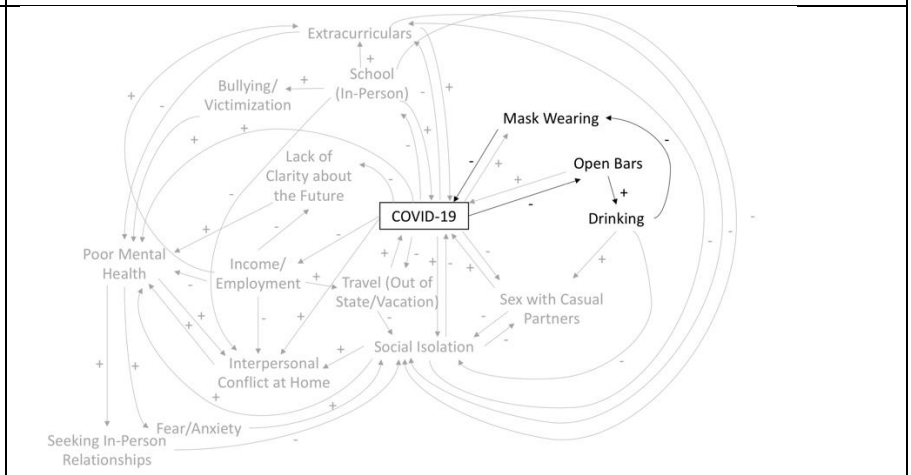
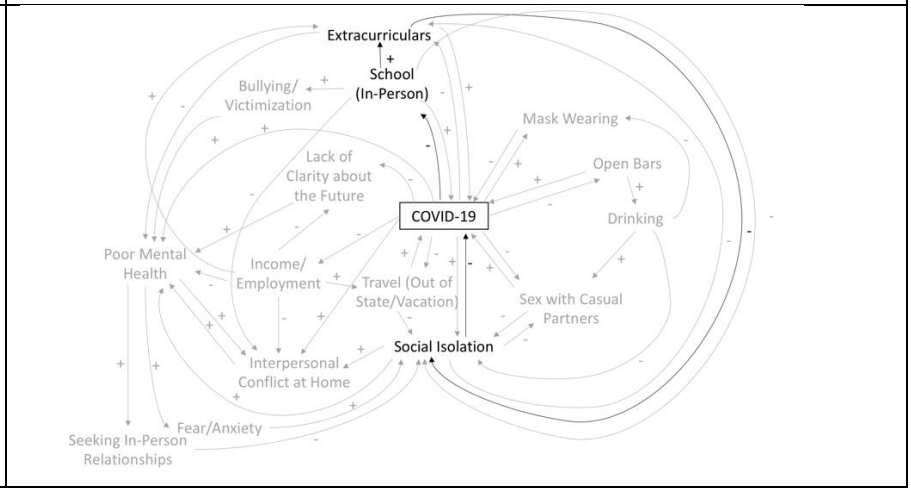
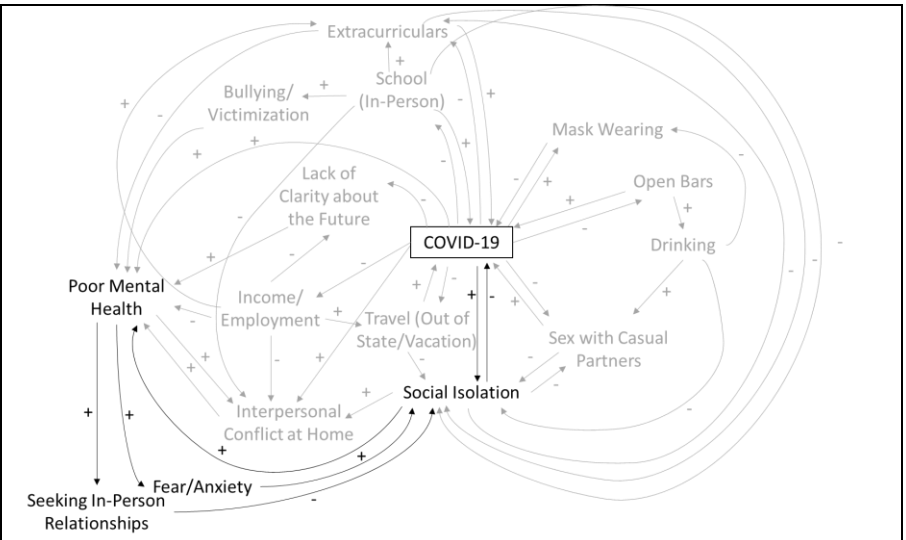
Figure 1a. Complete Causal Loop Diagram	
Figure 1b. Bars – Drinking – Mask Wearing Loop	
Figure 1c. Schools – Extracurricular Activities – Social Isolation Loop	

Figure 1d. Social Isolation – Poor Mental Health loop



Bars – Drinking – Mask Wearing

Around the world, we witnessed that reopening bars after periods of lockdown increases the number of COVID-19 cases in the region, and Figure 1b illustrates the relationship between bars, alcohol consumption, and COVID-19. As COVID-19 cases decrease, authorities open up bars and, in doing so, contribute to increased alcohol consumption. Because of alcohol myopia and lowered inhibitions, as well as needing to remove a mask to eat or drink, increases in alcohol consumption contribute to in-the-moment decreased mask wearing. As bar patrons are less likely to wear masks (while indoors and interacting in close proximity to others), COVID-19 transmission goes up and COVID-19 cases increase. This is a balancing loop that highlights the impact that structural interventions. such as closing all bars or restricting capacity/operating hours, can have on COVID-19.

Schools – Extracurricular activities – Social isolation

Decisions about school closures during the pandemic are partially based on local COVID-19 case counts. Figure 1c illustrates how as the number of COVID-19 cases increase, the opportunities for in-person school attendance diminish. As in-person school attendance decreases so does participation in extracurricular activities. As participation in extracurricular activities decreases, social isolation increases. As social isolation increases, COVID-19 cases decrease. This balancing loop maintains equilibrium. While this loop helps to illustrate the reason that school closures are a good idea for controlling the spread of COVID-19, it also highlights the (perhaps unintended) consequence that closing schools has on social isolation, an issue that is of particular concern for the mental health and development of school-aged children.

Social Isolation – Poor Mental Health

As COVID-19 cases rise, social isolation increases as people act to protect themselves from infection. Increased social isolation contributes to increased poor mental health. Two different responses can result from increased poor mental. If the increased fear and anxiety leads to increased social isolation, COVID-19 cases decrease. However, if people seek more face to face and interpersonal contact to mitigate social isolation, then COVID-19 rates increase. This illustrates how poor mental health can lead to both balancing and reinforcing loops in this causal loop diagram. This loop illustrates demonstrates how tailored and multi-pronged interventions are needed to achieve sustainable impact on COVID-19 case counts; in addition to the need for accessible mental health programming, some individuals need help navigating how to access interpersonal contact safely in order to prevent the spread of COVID-19.

CONCLUSIONS

It is a challenging period in our lives, and we believe that the use of system science tools and methods to provide critical opportunities for exploration of the complexities associated with the COVID-19 pandemic as well as potential ways to build models and simulations to understand the importance of intervention opportunities and related consequences. Systems science tools, such as

the causal loop diagraming presented here, can stimulate consideration of the impacts of the shifts in our lives in response to COVID-19. While our causal loop diagram only reflects the thoughtful perspective of the four of us and does not account for all the associated facets, it does successfully illustrate the complex relationship between factors. Sahin et al's[14]article advocates for the use of causal loop diagrams for understanding the complexity of the COVID-19 pandemic, yet like much of the existing discourse and discussion they focus on socio-economic and environmental systems and fail to address the multifaceted and interconnected secondary health issues associated with the pandemic. Systems science tool and methods have unfortunately remain largely underutilized by public health researchers and practitioners[5], and it is our hope that this straightforward and streamlined exercise can serve as an example for others interested in tackling the complexities associated with the current public health challenges and improving community health and well-being.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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