

Co-Evolution of Behavior Change and Infectious Disease Transmission Dynamics: A Modelling Review

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Abstract. During infectious disease outbreaks, the dissemination of information and the dynamic adjustment of intervention strategies trigger psychological and behavioral changes among individuals, which significantly influence disease transmission. Mathematical models have played a crucial role in analyzing the interplay between behavioral changes and disease spread. In this review, we revisit research studies that model behavioral changes during epidemics and classify the literature based on different modeling approaches. Specifically, we categorize these models into three main types: (1) modifying the incidence function to incorporate behavior-driven changes, including a novel approach that utilizes neural networks to describe the incidence rate; (2) introducing additional compartments to represent subpopulations with different behaviors; and (3) employing game-theoretic modeling to study the interactions between infectious disease dynamics and behavioral changes. In the game-theoretic framework, we also examine how key epidemiological metrics – such as the peak size and peak time of the first wave, as well as the final epidemic size – are affected when behavioral changes are incorporated into the classic SIR model. For each category, we introduce the classical modeling frameworks and their extensions, analyzing their advantages and limitations. Finally, we summarize the key findings and outline several promising directions for future research.

AMS subject classifications: 92D30, 92B05

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1 Introduction

Infectious diseases pose significant threats to individual health, while also exerting profound impacts on social stability and economic prosperity. Tracing back to the 14th cen-

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tury, the Black Death ravaged Europe, claiming over 20 million lives – approximately one-third of the continent’s total population [54]. Throughout history, pandemics such as the Spanish flu, HIV/AIDS, and Ebola have resulted in countless fatalities, political instability, and substantial financial and psychosocial burdens [57]. Most recently, the COVID-19 pandemic caused more than 10 million deaths globally [52], triggered massive economic expenditures, surged unemployment rates, and severely disrupted social stability [9]. Consequently, understanding the various factors influencing the spread of infectious diseases, analyzing the dynamics under these factors, and identifying effective intervention strategies are of critical importance.

The impact of infectious diseases on society is profound and far-reaching, extending beyond public policy and control measures to influence individual behavior and psychological responses. For instance, during the 2009 H1N1 influenza pandemic, self-protective measures, including increased handwashing, covering one’s mouth and nose while coughing, and minimizing contact with others, significantly reduced infection risks [74]. Home isolation has proven to be an effective method for reducing disease transmission and maintaining social distancing. However, severe influenza pandemics necessitate stricter social distancing measures [22]. Recently, several studies have investigated behavioral changes as effective strategies to mitigate the spread of COVID-19. Kucharski *et al.* [34] demonstrated that combining self-isolation, contact tracing, and moderate social distancing could effectively control the transmission of COVID-19. Buonomo and Della Marca [12] highlighted the decisive role of strict adherence to preventive measures in significantly reducing both mortality and new infections. Tang *et al.* [77] pointed out that, to prevent subsequent pandemic waves, sustained and effective behavioral changes are critical, particularly during the early stages of vaccine rollout. During outbreaks, individuals adjust their behavior based on perceived infection risks, and these behavioral decisions, in turn, influence disease transmission dynamics. Therefore, analyzing the interplay between behavioral changes and disease transmission, and identifying key factors driving pandemic spread, are essential for understanding the dynamical patterns of infectious diseases and developing effective control strategies. Behavioral shifts may arise from voluntary or passive decisions, or from the cost-benefit trade-offs associated with specific actions [24, 78]. This heterogeneity in behavior presents significant challenges in accurately quantifying behavioral responses and understanding the complex interactions between behavior change and disease transmission dynamics.

A variety of mathematical models have been developed to explore human behavior dynamics, including models of panic-driven escape [27], pedestrian path choice [28], and traffic congestion phenomena [88]. In the context of behavior change during epidemic outbreaks, one of the most straightforward approaches is to evaluate the effectiveness of public health interventions, such as assessing the impact of school closures on disease spread [10]. Furthermore, the influence of behavioral evolution on transmission can be described by altering individuals’ epidemiological states during transmission, such as the transition from susceptible to immune status following vaccination, or by modifying the infection or recovery rates [24]. Numerous reviews have explored the impact of hu-