

Risk Behavior, Backward Bifurcation, and Vaccine Effectiveness in Disease Dynamics

Jorge Velasco-Hernandez

National Autonomous University of Mexico (UNAM)

Many studies have shown that vaccines are not completely effective, meaning that a vaccinated population includes both people who develop immunity from the vaccine and those who, despite being vaccinated, do not. This can be problematic, as some vaccinated individuals may mistakenly believe they are fully protected and cannot acquire the disease. This perception can significantly influence behavior, leading some vaccinated people to be less diligent in following preventive or mitigation measures. Motivated by the above, we examine how behavioral changes in vaccinated people who do not develop immunity influence the dynamics of a directly transmitted disease and key indices such as the basic reproductive number and vaccine effectiveness. We propose a model that considers a vaccine with three facets of failure: “take”, “degree”, and “duration”. Additionally, the behavioral change of non-immune vaccinated individuals is modeled through a parameter that adjusts their contact rate based on compliance with mitigation measures. Our results allow us to visualize the role of behavioral change in various factors influencing disease transmission dynamics. First, we demonstrate the existence of a backward bifurcation common in models for not fully effective vaccines. Second, we define a behavioral index threshold, which serves as a key indicator for determining whether the disease persists due to behavioral effects. Finally, our results highlight that both the behavioral index and the initial value of the infected population can play a decisive role in determining whether vaccine effectiveness reaches negative values.

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