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Dynamical Properties of Epidemics: From Steady States to "Electrocardiograms"

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ABSTRACT

In a previous paper, we established a general evolution equation ruling epidemics infection rates. This differential equation was based on the well-known SEIR (Susceptible Exposed Infected Recovered) assumptions. We showed that, for reproduction factors R_0 larger than 1, the system always converges to an "attractor", i.e., a stable state at which the infected people proportion X keeps a constant value $X^*=1-1/R_0$, usually ascribed to an "immunity threshold", which it is not. This constant value results from a balance between infection and recovery rates. This means that the people in the "infected box" are never the same ones, being continuously refreshed.

We explore here the various properties of such attractors. One of them is that the constant flux of new infections, balanced by an equal number of recoveries (or deaths), should appear on cumulative contamination curves as straight lines with positive slopes. This prediction is now widely verified in COVID-19 infection data (e.g., Johns Hopkins University), showing several straight segments, connected by transients corresponding to changes in sanitary policies.

Another interesting property of attractors is the way in which the system travels toward the attractor. We expected a smooth convergence for low R_0 values, replaced by a hierarchy of multi-stable cycles as R_0 increases, eventually leading to a chaotic behavior. These last features were not observed during the first contamination wave, due to low R_0 values, but recent available data corresponding to the second contamination wave, with significantly higher R_0 levels, show oscillations reminiscent of those usually found in electrocardiograms (ECG). Such & quot; ECGs & quot; are shown to correspond to bi-stable states followed by 4-stable ones, approximately above resp. 200 and 400 daily contamination rates per million in France and Germany. Such thresholds may be used to renormalize contamination data and associated R 0 values between different countries.

Keywords: Epidemic evolution, Reproduction factor, Attractor, Instability, Chaos

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