Research Digest

New England Complex Systems Institute

Starting with the Spring 2023 issue of the *Journal on Policy and Complex Systems*, we will be featuring recent research done at complex systems centers around the world. This initiative aims to share the excellent work done at the centers while explaining its real-world impact to an audience outside academia: the general public and practitioners.

In this edition, we have selected three papers related to healthcare policy, one related to industrial policy, and one related to social policy. You can find more information at the research center website: New England Complex Systems Institute, www.necsi.edu.

The New England Complex Systems Institute (NECSI) is a non-profit research and educational organization based in Cambridge, Massachusetts. It was founded in 1999 with the aim of promoting research and education in the field of complex systems, which is the study of systems composed of many interacting parts that exhibit collective behavior and phenomena not easily reduced to the behavior of individual components. NECSI's research covers a wide range of topics, including network science, economics, biology, and social systems, among others, and the institute is known for its interdisciplinary approach to complex systems research. NECSI is led by physicist Dr. Yaneer Bar-Yam.

Why is this research relevant?

Compartmental models in epidemiology are significant because they aid in analyzing the transmission of infectious illnesses and give crucial insights into how to effectively contain and control them. Compartmental models enable epidemiologists to simulate the intricate interactions between people, groups, and surroundings that comprise the transmission cycle of disease. These models may be used to estimate the future prevalence of a disease within a community, enabling public health professionals to take the necessary preventative actions. In addition, compartmental models may assist governmental choices on containment measures like quarantine or school or workplace closure. Compartmental models in epidemiology are crucial for comprehending the dynamics of infectious illnesses and directing preventative methods.

Anticipatory analytics for diabetes is significant because it may assist healthcare practitioners in anticipating and predicting the occurrence of specific health problems. For instance, a predictive analysis of a patient's data may be used to calculate the likelihood that he or she would develop difficulties as a result of their blood sugar levels or other indications. It is also possible to utilize predictive analytics to detect risk factors for diabetes, such as lifestyle

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choices and environmental effects, so that patients and healthcare professionals may take measures to avoid or minimize these risks before they become a problem. In the end, anticipatory analytics contributes to the health of persons with diabetes by allowing them to obtain better treatment earlier in the process and has a material impact on healthcare policymaking.

Developing proper **sodium consumption** recommendations and regulations is essential since a high sodium intake may raise the risk of developing health issues such as high blood pressure and stroke. An increased risk of chronic illnesses, such as heart disease, stroke, and renal disease, has been associated with excessive salt consumption. Public health professionals may lessen the impact of these illnesses on people and society by instituting sodium reduction programs.

Understanding **how people self-organize into teams** is crucial because it enables us to comprehend the variables that impact team performance. By comprehending how people connect and collaborate with one another, we can construct more effective teams. Self-organization also enables us to better identify critical positions within a team, allowing us to build teams more efficiently and distribute resources accordingly. In addition, by comprehending how individual personalities and preferences influence the manner in which individuals collaborate, we may more effectively handle disagreements among members. Understanding how people self-organize into teams offers important insights for enhancing team effectiveness. This topic is of great importance for industrial and organizational policy.

Numerous factors make the **stability of democratic elections** crucial. It guarantees that people are able to choose their leaders via an open and transparent process, therefore protecting their rights and liberties. It gives governments credibility and holds them responsible for their actions. Additionally, stable elections foster the growth of civil society since individuals are more inclined to engage in peaceful protest and civic participation when they are certain that their votes will be counted. Stability in democratic elections is crucial for supporting economic development by setting circumstances in which firms may invest with confidence in the future of a nation.

Featured Papers

Modeling complex systems: A case study of compartmental models in epidemiology, New England Complex Systems Institute (October 6, 2021).

Authors: Pratyush K. Kollepara, Alexander F. Siegenfeld, and Yaneer Bar-Yam

Full paper available at: https://necsi.edu/modeling-complex-systems-a-case-study-of-compartmental-models-in-epidemiology

Abstract

Compartmental epidemic models have been widely used for predicting the course of epidemics, from estimating the basic reproduction number to guiding intervention policies. Studies commonly acknowledge these models' assumptions but less often justify their validity in the specific context in which they are being used. Our purpose is not to argue for specific alternatives or modifications to compartmental models but rather to show how assumptions can constrain model outcomes to a narrow portion of the wide landscape of potential epidemic behaviors. This concrete examination of well-known models also serves to illustrate general principles of modeling that can be applied in other contexts.

Keywords: epidemic behaviors, compartmental models, intervention policies

Modelado de sistemas complejos: un estudio de caso de modelos compartimentales en epidemiología

Resumen

Los modelos epidémicos compartimentales se han utilizado ampliamente para predecir el curso de las epidemias, desde estimar el número básico de reproducción hasta orientar las políticas de intervención. Los estudios suelen reconocer los supuestos de estos modelos, pero con menos frecuencia justifican su validez en el contexto específico en el que se utilizan. Nuestro propósito no es abogar por alternativas o modificaciones específicas a los modelos compartimentales, sino más bien mostrar cómo las suposiciones pueden restringir los resultados del modelo a una porción estrecha

del amplio panorama de posibles comportamientos epidémicos. Este examen concreto de modelos bien conocidos también sirve para ilustrar los principios generales de modelado que se pueden aplicar en otros contextos.

Palabras clave: comportamientos epidémicos, modelos compartimentales, políticas de intervención

复杂系统建模：流行病学中房室模型的案例研究

摘要

从估计基本传染数到指导干预政策，房室流行病模型已广泛用于预测流行病的进程。研究通常承认这些模型的假设，但很少证明这些假设在特定情境中的有效性。我们的目的不是主张对房室模型进行特定的替代或修改，而是表明假设如何能将模型结果限制到“广泛的潜在流行病行为”中的一小部分。这种对著名模型的具体分析也有助于阐述建模的一般原则，后者能应用于其他情境。

关键词：流行病行为，房室模型，干预政策

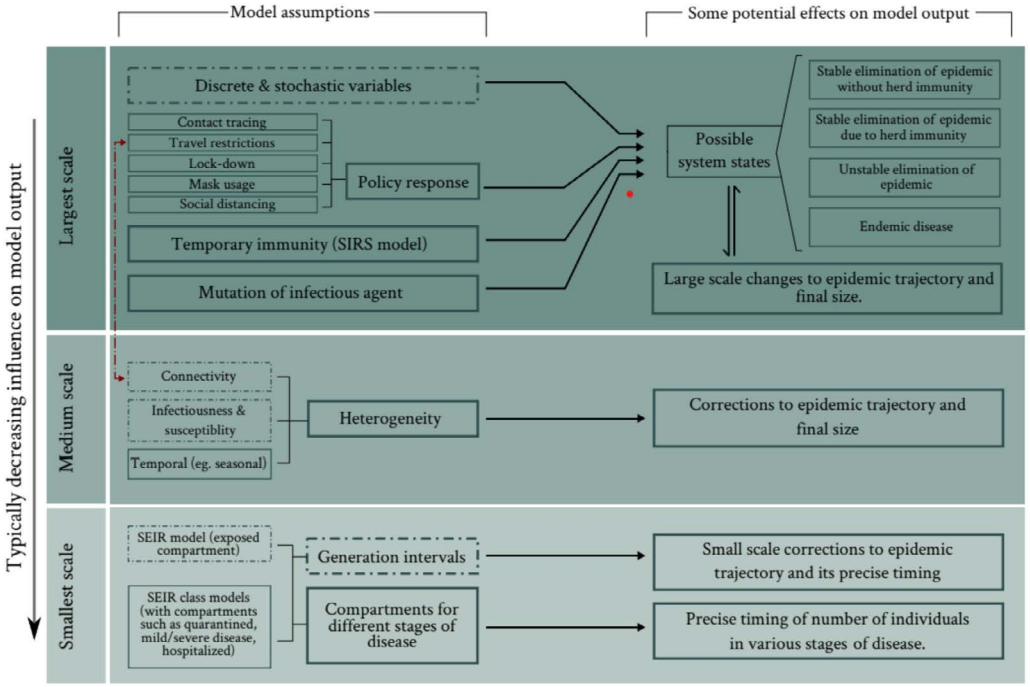

Figure 1. Schematic representation of the impact of various modeling choices/assumptions. The left column lists various details that can be incorporated into a compartmental

model (boxes with dashed borders indicate modeling choices that are analyzed in section III), and the right column lists typical potential impacts on the model output. The three panels classify the system details by 'scale,' with the largest scale details typically having the most impact on model output and the smallest scale details typically having the least impact, although the impact of any given assumption ultimately depends on precisely what purpose the model is being used. For instance, a SIRS model may not be needed if only the initial growth of the epidemic is being modeled. Furthermore, various assumptions can compound non-linearly to affect the model output. For instance, policy interventions such as travel restrictions, which both rely on and affect heterogeneity in geographical connectivity, can play a decisive role in determining whether or not a stable elimination is achieved. Of course, the actual effect of any assumption depends on its precise mathematical implementation, as well as the presence or absence of other assumptions within the model, and so this figure should be considered as a rough schematic rather than as a definitive guide.

Toward Prevention of Adverse Events Using Anticipatory Analytics

Authors: Joseph Norman, Amir Akhavan, Chen Shen, David Aron, Luci Leykum, and Yaneer Bar-Yam

Link to full article: https://necsi.edu/toward-prevention-of-adverse-events-using-anticipatory-analytics

Published in: *Progress in Preventive Medicine* (June 2020).

Electronic Medical Records provide new opportunities for studying the historical condition and dynamics of individual patients and populations to enable new insights that may lead to improved care and treatment. Diabetes is a prime target for new analyses as it is a chronic condition that affects 1 in 10 of the U.S. adult population and causes substantial disability and loss of life.

Keywords: anticipatory analytics, healthcare systems, multiscale methods

Compendio de investigación de complejidad: Instituto de Sistemas Complejos de Nueva Inglaterra

Los registros médicos electrónicos brindan nuevas oportunidades para estudiar la condición histórica y la dinámica de pacientes in-

dividuales y poblaciones para permitir nuevos conocimientos que pueden conducir a una mejor atención y tratamiento. La diabetes es un objetivo principal para los nuevos análisis, ya que es una afección crónica que afecta a 1 de cada 10 de la población adulta de los EE. UU. y causa una discapacidad considerable y la pérdida de la vida.

Palabras clave: análisis anticipatorio, sistemas de salud, métodos multiescala

我们应摄入多少钠？

钠是一种重要的饮食需求，对许多生理过程至关重要。高钠摄入会影响严重的健康问题，例如高血压和心血管疾病，这是全球最大的死亡原因。因此，许多健康组织建议大幅减少钠摄入量，低至 1,500 毫克/天。不过，对于钠在高摄入量和建议摄入量之间的整个影响范围而言，人们的理解还很有限。

关键词：计算模拟，医疗保健系统，医疗保健政策

Abstract

Introduction:

Electronic Medical Records provide new opportunities for studying the historical condition and dynamics of individual patients and populations to enable new insights that may lead to improved care and treatment. Diabetes is a prime target for new analyses as it is a chronic condition that affects 1 in 10 of the U.S. adult population and causes substantial disability and loss of life.

Methods:

We take typical physiological measures from 3 healthcare appointments of 1,711 diabetic patients and extract combined measures that capture the overall conditions of patients and the structure of the population. Further, we examined the dynamics of individual patients across appointments in this combined measure space and examined regions associated with variability in clinical measures.

Results:

Our results suggest that the dynamics of standard measures may aid the evaluation of the risk of adverse events, and their utility should be tested in medical trials.

Conclusions:

Dynamic variability of vital signs and standard measures may reflect a loss of homeostasis, associated physiological instability, and potential for adverse events that can be estimated using the proposed method.

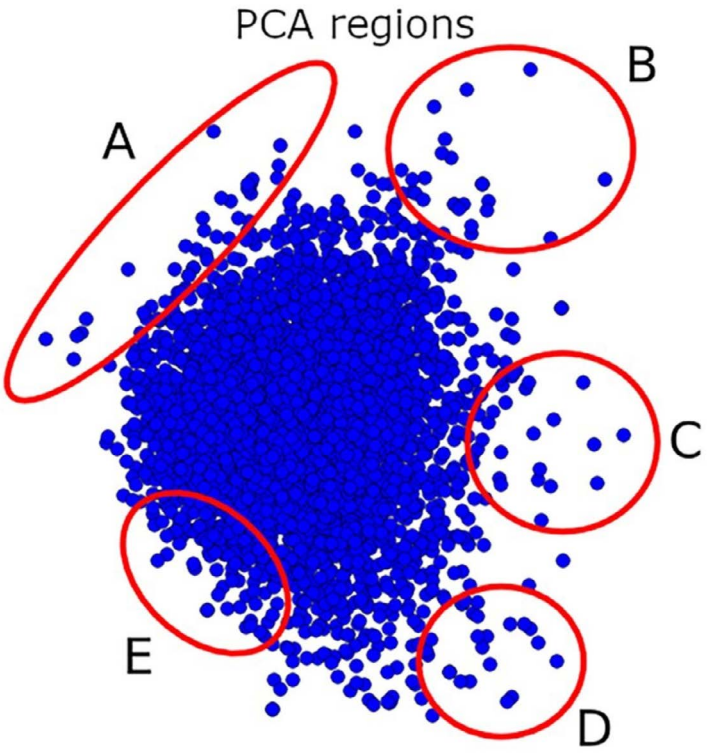

Figure 2. Scatter plot showing individual appointments as points in the two combined measure dimensions that capture the most variation across the population. Areas with particular clinical measure signatures are circled. A, Anomalously low blood pressure, accompanied by low to normal LDL and A1c values. B, Young adults with very high LDL and/or Hemoglobin A1c values. C, Overweight with high blood pressure and raised LDL and A1c values. D, Very high blood pressure, yet normal BMI and other values. E, Oldest members of the population, who have normal values overall. Of note is the relative sharpness of the boundary of E with the unpopulated region compared with the rest of the periphery. BMI indicates body mass index, LDL, and low-density lipoprotein.

How Much Sodium Should We Eat?

Authors: Chen Shen, Peggy J. Bowers, and Yaneer Bar-Yam

Link to full article: https://necsi.edu/how-much-sodium-should-we-eat

Published in: *Progress in Preventive Medicine* 5(1): e0026 (February 2020).

Sodium, an important dietary requirement, is essential to many physiologic processes. High sodium intake affects serious health issues such as hypertension and cardiovascular disease, the largest cause of death globally. Consequently, many health organizations have recommended substantial reductions in sodium intake, to as little as 1,500 mg/d. Yet limited understanding exists for the entire range of the effect of sodium between high intake and the recommendations.

Keywords: computational simulations, healthcare systems, healthcare policy

¿Cuánto sodio debemos comer?

El sodio, un requerimiento dietético importante, es esencial para muchos procesos fisiológicos. El alto consumo de sodio afecta problemas de salud graves, como la hipertensión y las enfermedades cardiovasculares, la principal causa de muerte en todo el mundo. En consecuencia, muchas organizaciones de salud han recomendado reducciones sustanciales en la ingesta de sodio, a tan solo 1500 mg/día. Sin embargo, existe una comprensión limitada de todo el rango del efecto del sodio entre la ingesta alta y las recomendaciones.

Palabras clave: simulaciones computacionales, sistemas de salud, política de salud

产业背景下的职能性和社会性团队动态

与其他社会系统一样，公司包含个体组成的网络，这些个体共享信息并在其行为之间建立相互依赖关系。这些网络的属性对于公司的成功至关重要。了解个人如何自我组织成团队以及这与绩效之间的关系，对于寻求方法以增强公司任务的经理和管理软件开发人员来说是一个挑战。本文中，我们分析了产业生产工厂的职能性沟通网络和社会性沟通网络，并

将它们的属性与绩效联系起来。我们使用内部管理软件数据来揭示员工之间的职能沟通和社会沟通。我们发现，职能性沟通网络和社会性沟通网络出现了不同特征。前者是不对称的，后者是按职位划分的，即高管、经理、主管和操作员。我们表明，绩效与职能性沟通量呈负相关，但与新兴沟通网络的密度呈正相关。鉴于企业任务和管理流程的数字化和自动化程度不断提高，揭示工作场所的社会动态一事至关重要。

关键词：社会系统，产业政策，沟通网络

Abstract

Introduction:

Sodium, an important dietary requirement, is essential to many physiologic processes. High sodium intake affects serious health issues such as hypertension and cardiovascular disease, the largest cause of death globally. Consequently, many health organizations have recommended substantial reductions in sodium intake to as little as 1,500 mg/d. Yet limited understanding exists of the entire range of the effect of sodium between high intake and the recommendations.

Methods:

We built a simulation using equations from the Uttamsingh model of the renal system to simulate the long-term mean arterial pressure (MAP) across sodium intake ranges. We used another existing physiology simulation platform, HumMod-3.0.4, for comparison. We compared the simulation results with empirical studies done on the global population.

Results:

We find a linear increase in MAP for consumption above 4,000 mg/d but a nearly constant MAP between 1,200 and 4,000 mg/d. Below 1,200 mg/d, the system cannot maintain homeostasis.

Conclusion:

Supporting the U-shape theory of sodium intake, which posits that too-high and too-low sodium intake rates increase cardiovascular disease risks, our results suggest that the homeostatic regulation by antidiuretic hormone and aldosterone transitions from sodium retention to sodium excretion at around 4,000 mg/d (a value that varies across individuals and conditions), indicating sodium saturation

and evolutionary optimality. Our findings are consistent with recent empirical studies on large populations globally. We suggest that the current low-level recommendations are not supported by this physiologic model analysis and would require more compelling evidence.

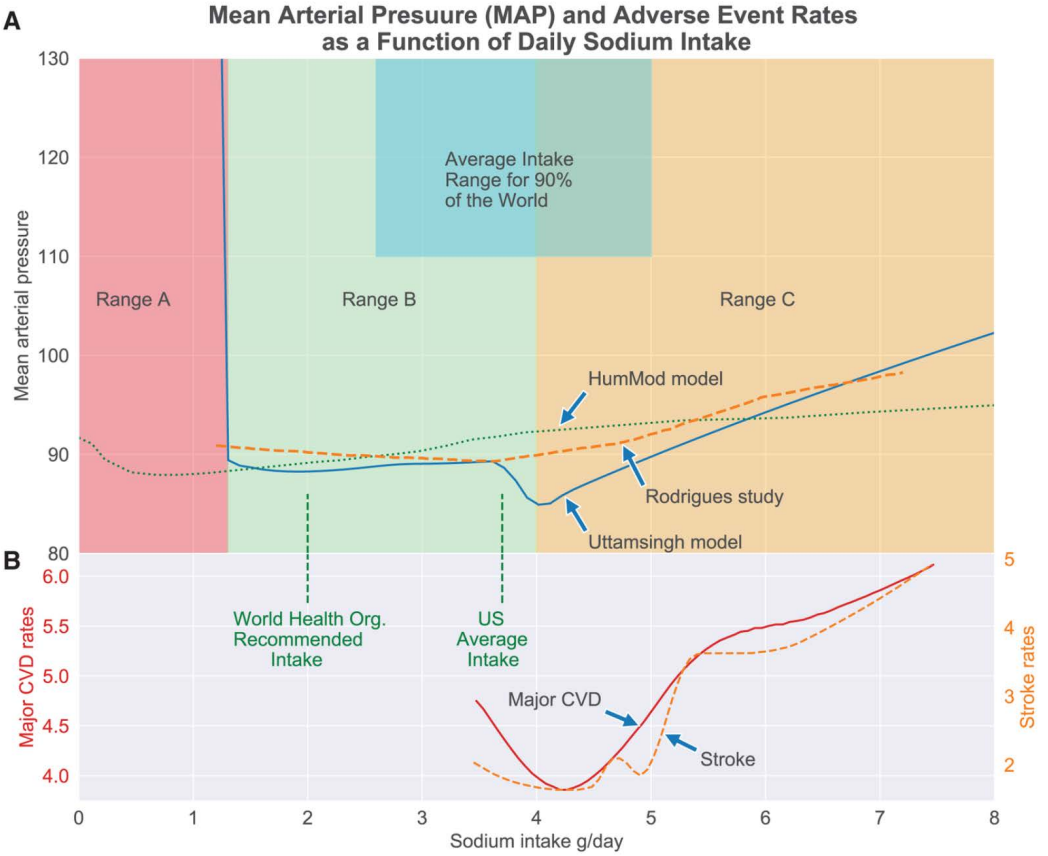

Figure 3. MAP and adverse event rates as a function of daily sodium intake. A, The simulated MAP of a 70-kg reference male after seven days is shown. HumMod simulation (green dotted line) and the Uttamsingh simulation after 100-mg range smoothing (blue curve) are compared with empirically observed, population-averaged MAP (orange dashed line). [27] The Uttamsingh model in range A (sodium intake <1,200 mg/d) shows unstable behavior (Section 3.3). MAP simulated with the Uttamsingh model is nearly constant in range B (1,200–4,000 mg/d), with a dip around 4,000 mg/d and almost linearly increasing in range C (>4,000 mg/d). MAP simulated with HumMod is decreasing in the range of 0–700 mg/d, comparatively rapidly increasing in the range of 700–3,500 mg/d, and then slowly increasing beyond the daily consumption of 3,500 mg/d. B, The result from a recent study by Mente et al. [19] is shown. The two curves represent the cardiovascular event rates (events per 1,000 person-years) for major CVD (red curve) and stroke (orange curve), respectively, based on dietary sodium intake.