MAX PLANCK SOCIETY

Press Release

B / C / 2006 (9) January 25th, 2006

Embargoed: January 25th, 2006, 19:00 CET

Trace the Money

Max Planck researchers in Goettingen find universal rules governing the way humans travel - a breakthrough for the mathematical prediction of the spread of epidemics

Increasing human mobility is a key cause of the geographic spread of modern epidemics. Bacteria and viruses can be transported across great distances and transmitted to other people. In order to understand and predict the spread of disease, we need to know the statistical rules that govern human travel - in the light of an imminent flu pandemic a knowledge of great importance. Quantitative studies, however, prove to be very difficult, because people move over short and long distances, using various means of transportation (planes, trains, automobiles, etc.). Scientists from the Max Planck Institute for Dynamics and Self-Organization in Göttingen, the University of Göttingen, and the University of California, Santa Barbara, have found a trick to determine these rules. They had the idea of evaluating data from a popular US internet game in which participants can register a dollar bill for fun and monitor its geographic circulation. Like viruses, money is transported by people from place to place. Surprisingly, the scientist found that the human movements follow what are known as universal scaling laws. They developed a mathematical theory which describes the observed movements of travellers amazingly well over distances from just a few kilometres to a few thousand. The study represents a major breakthrough for the mathematical modelling of the spread of epidemics (Nature, 26 January 2006).

Max Planck Society
for the Advancement of Science
Press and Public Relations Department

Hofgartenstrasse 8
D-80539 Munich

PO Box 10 10 62
D-80084 Munich

Phone: +49-89-2108-1276
Fax: +49-89-2108-1207
presse@gv.mpg.de
Internet: www.mpg.de

Responsibility for content:
Dr. Bernd Wirsing (-1276)

Executive Editor:
Dr. Andreas Trepte (-1238)

Online-Editor:
Michael Frewin (-1273)

ISSN 0170-4656

The worldwide spread of disease - particularly, pandemics with disastrous consequences for human health and economics - has become a serious threat in the globalised world of intense international trade, growing mobility, and increasing traffic intensity. Bird flu (avian influenza A), the possible emergence of a new human "supervirus", and a potential worldwide flu pandemic, have all made headlines in the last weeks and months - for good reason.

The prime cause of the geographical spread of disease is the movement of infected individuals from place to place. Historical pandemics, like the 14th-century plague, only moved slowly in wave fronts across geographical areas, because in the middle ages people could typically only travel a few kilometres a day. The speed with which epidemics could spread was thus kept in check. It took the plague three years to move up the European continent, south to north, with an average rate of spread of about two kilometres a day.

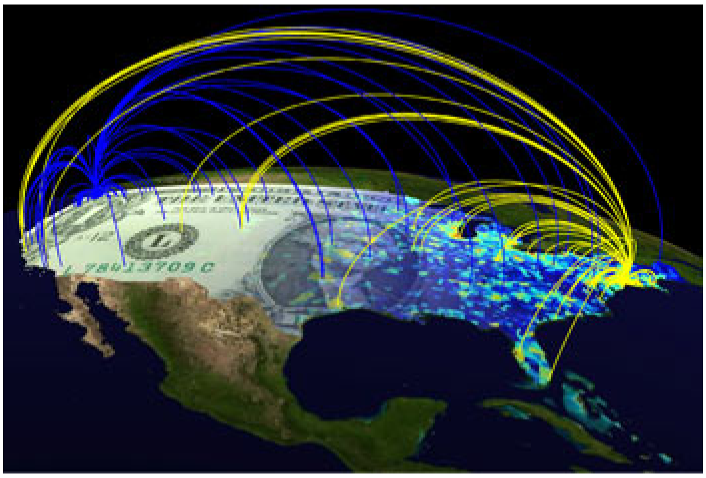

Image: *The movement of banknotes in the United States. Each line symbolises the geographic movement of a single banknote between the place of origin (blue: Seattle, yellow: New York) and various destinations. Each banknote travelled for less than a week.*

Image: Max Planck Institute for Dynamics and Self-Organization

But today people move great distances in short time periods. Thus we can expect that future pandemics will spread according to other rules, and more quickly. The rapid worldwide spread of SARS (severe acute respiratory syndrome) has already demonstrated this.

In order to describe the spread of modern disease using mathematical models, and to develop a way of predicting that spread, we need a quantitative knowledge of people's travelling behaviour at various scales of distance. Unfortunately, until now, one has not been able to quantify the characteristics of human travel. That is not surprising, because today, people use very diverse means of transportation. Over short to medium distances, people use bicycles, cars, and trains. Over longer ones, airplanes are typical. In order to obtain a comprehensive dataset on human travel, transportation flow would have to be measured, nationally and internationally, over a long period of time. This seems to be almost impossible.

D Brockmann, L Hufnagel, and T Geisel, theoretical physicists at the Max Planck Institute for Dynamics and Self-Organization in Göttingen, the University of Göttingen, and the University of California Santa Barbara, have now found an innovative way around these difficulties, and determined the rules governing human travel with a high precision.

Instead of the movements of individuals, the researchers investigated the geographical circulation of banknotes which travellers carry from place to place. The physicists analysed the data from a US bill-tracking internet game. The idea of the game is simple: a large number of banknotes is marked and brought into circulation. If a person receives a marked banknote, he/she can register its current location online and return the bill to the pool. Meanwhile website has become so popular that some 50 million banknotes have already been registered this way.

Dirk Brockmann of the Max Planck Institute for Dynamics and Self-Organization says, "we recognised that the enormous amount of data, as well as the geographical and temporal resolution of bill-tracking, allow us to draw conclusions about the statistical characteristics of human travel, independent of which means of transportation people use. We were hoping to determine the typical characteristics of this behaviour indirectly and with high precision."

This hope was borne out beyond expectations. In the data about movement, the scientists discovered universal scaling laws which lie at the root of human travel behaviour. Scientists are already familiar with similar scaling laws from physical and biological systems - for example, turbulent flow and chaotic systems. Lars Hufnagel of the University of California, Santa Barbara, says "what is amazing about these particular scaling laws is the fact that they are determined by two universal parameters only. This result surprised us all."

Until now, numerous models of the geographic spread of disease were based on the assumption that viruses disperse over geographic areas in a way similar to the diffusion of fine dust particles on the surface of water. These standard models can describe the wavelike spread of historical pandemics quite successfully. But the investigations by the scientists in Göttingen now clearly show that we cannot use the standard models to understand the spread of modern epidemics. Dirk Brockmann concludes that "the consequence of these results is that new theoretical concepts must be developed to understand the geographic spread of modern diseases."

Based on this analysis, the physicists were able to develop a mathematical theory of human travel which coincides accurately with the observed scaling laws from a distance of a few kilometres to a few thousand. Because the mechanisms of transmission of diseases from human to human are already well understood, the scientists can use the new theory to investigate new models which describe the global spread of disease much more realistically. Professor Theo Geisel, Director of the Max Planck Institute for Dynamics and Self-Organization, says that "we are optimistic that this will drastically improve predictions about the geographical spread of epidemics."

[EC]

Related Links:

[1] Project Website

Original work:

D Brockmann, L Hufnagel and T Geisel
The scaling laws of human travel
Nature, 26 January 2006

Contact:

Dr. Dirk Brockmann
Max-Planck-Institute for Dynamics and Self-Organization, Göttingen
Tel.: +49 551 5176-411
Fax: +49 551 5176-409
E-mail: brockmann@ds.mpg.de