Available online at www.sciencedirect.com

ScienceDirect

Cognitive Systems Research 52 (2018) 640–657

Cognitive Systems RESEARCH

www.elsevier.com/locate/cogsys

From physics to social interactions: Scientific unification via dynamics

Polemnia G. Amazeen *

Department of Psychology, Arizona State University, United States

Received 22 March 2018; received in revised form 16 June 2018; accepted 31 July 2018
Available online 14 August 2018

Abstract

The principle of dynamical similitude—the belief that the same behavior may be exhibited by very different systems—allows us to use mathematical models from physics to understand psychological phenomena. Sometimes, model choice is straightforward. For example, the two-frequency resonance map can be used to make predictions about the performance of multifrequency ratios in physical, chemical, physiological and social behavior. Sometimes, we have to dig deeper into our dynamical toolbox to select an appropriate technique. An overview is provided of other methods, including mass-spring modeling and multifractal analysis, that have been applied successfully to various psychological phenomena. A final demonstration of dynamical similitude comes from the use of the same multifractal method that was used to extract team-level experience from the neurophysiological data of individual team members to the analysis of a large scale economic phenomenon, the stock market index. Continual development of analytical methods that are informed by and can be applied to other sciences allows us to treat psychological phenomena as continuous with the rest of the natural world.

© 2018 Elsevier B.V. All rights reserved.

Keywords: Dynamics; Modeling; Nesting; Coordination; Social; Multifractal

1. Introduction

The application of dynamical systems to psychology offers both a means by which to demonstrate the continuity of psychology with the rest of science and the ability to characterize behavior, the subject of psychology, as a stable pattern of change. For the majority of the time that psychology has been a science, psychologists have used analytical methods that reduce the complex behavior exhibited by humans to only one (e.g., a mean) or a few (measures of central tendency) numbers. The implication of that approach is twofold: that behavior was unchanging and could be characterized statically and that observed variation was due to random influence.

Psychologists began to adopt dynamical systems methods during the 1980s by making a straightforward analogy between the rhythmic behavior of the limbs and the rhythmic behavior of pendulums. They adopted coupled oscillator models, meant to capture coordination across two physical oscillators, to better understand stable patterns of bimanual coordination (e.g., Haken, Kelso, & Bunz, 1985; Kelso, 1981, 1984; Kugler & Turvey, 1987). During the 1990s, cognitive, developmental, and social psychologists began to extend the application of dynamical systems thinking and methods to characterize patterns that they observed in social interactions and across development (e.g., Port & Van Gelder, 1995; Thelen & Smith, 1994; Vallacher & Nowak, 1994). The new millennium brought increased exploration of dynamical tools to capture those

---

* Address: Department of Psychology, P.O. Box 871104, Arizona State University, Tempe, AZ 85287-1104, United States.
E-mail address: Amazeen@asu.edu.

https://doi.org/10.1016/j.cogsys.2018.07.033
1389-0417/© 2018 Elsevier B.V. All rights reserved.

patterns of change, including the identification of fractal processes in reaction time data (Gilden, 1997, 2001; Gilden, Thornton, & Mallon, 1995) and the formulation of a singular model to capture all previously-documented effects in the classic “A-not-B error” in cognitive development (Thelen, Schöner, Scheier, & Smith, 2001). That short story is just a broad overview of the tremendous growth in the dynamical approach to psychology. A detailed review of the history of dynamical systems in psychology could easily fill an entire book.

As psychologists have access to methods of data collection that produce more detailed, continuous data streams—for example, the access to momentary diary data through smart phone apps or neuroimaging techniques—there is an even greater need for preserving in our analyses the processes that are revealed. One approach has been to extend repeated measures analyses common in statistical techniques to accommodate those longer data sets. However, there are assumptions common to traditional statistical techniques—that observed fluctuations are the influence of (random) noise around a true population mean—that become computationally burdensome when scaled up to data sets of hundreds, thousands, or even tens-of-thousands of values. An alternate approach is to treat the observed fluctuation as structured and potentially accommodated by low-dimensional dynamical equations. The focus of the present paper is to present a dynamical approach that captures with few parameters the details of complex human behavior that we wish to study. The principle of dynamical similitude—that the same behavior may be observed across very different systems—allows us to sample from a much broader selection of techniques as our search for new methods extends to fields of science beyond psychology. The emphasis on behavior over structure identifies dynamics as a truly multidisciplinary approach that sees commonalities across the sciences rather than restricting scientific inquiry to phenomena that appear the same structurally.

1.1. Metronomes and people

We often begin with our search for common dynamical principles in the field of physical models, but even those models are motivated by real-world behavior. A great example of dynamical similitude comes in the comparison of two online videos (available on YouTube and other sites): the synchronization of 32 metronomes and gait synchronization during Opening Day of London’s Millenium Bridge. In both cases, synchronization occurs across very many different rhythmic processes, but the entities generating those processes—physical objects and people—couldn’t look more different. In the first case, 32 metronomes rest on a flexible surface and are set ticking, one after the other. At first, the phasing of the metronomes is completely random, governed by when they were started up by the young YouTuber. There is no cohesive sound to 32 metronomes all beating at roughly the same frequency but not at the same time… it’s rather “clackety”.

Luckily, it doesn’t take long for some of the metronomes to start synchronizing their beats so that the pendula reach the endpoint at the same time. That sounds a little more cohesive to the listener. However, most of the metronomes continue to swing left and right seemingly not in time with the rest or each other. It doesn’t take very long before we notice all pendula swinging back and forth together, with the exception of one hold-out, a metronome whose pendulum swings right while the others swing left. Dynamicists call the former pattern *inphase* because the position of those pendulums in their cycles (i.e., their phasing) is the same as that of their neighbors at any given moment. Looking at one pendulum is the same as looking at any one of those other pendulums. The latter pattern is called *antiphase* because the position of that lone pendulum in its movement cycle is exactly opposite to that of its neighbors. At any given moment, that one pendulum looks like the mirror image of any of the other pendulums. Antiphase, in fact, can be rather stable. But the movement of the other metronomes on the flexible platform is too much for that one antiphase metronome, and, eventually, it switches to the same phasing as all of the other metronomes. By the end of the video, all of the metronomes are synchronized inphase and the viewer hears a strong, singular beat given by all metronomes reaching their endpoints at the same exact time.

Why does that synchronization occur? As the pendulum of each metronome moves back and forth, it generates a slight movement of the flexible platform below. That disruption is felt by the other metronomes on the same platform that are also perturbing the platform ever so slightly. Think about it this way: movement of one pendulum to the left disrupts the platform and other metronomes in a direction-specific way, influencing them to behave the same way as it. The coupling medium of the platform serves to connect all of the metronomes so that they can communicate with each other. That bidirectional influence—metronomes influencing and being influenced by each other—provides the conditions for synchronization. An understanding of the behavior of the whole system is not really given by understanding the behavior of one metronome alone but by understanding the relation of the metronome to its entire environment: the other metronomes and the platform on which they rest.

What does this have to do with humans walking across a bridge? The Millenium Bridge is a striking 320-m long steel suspension bridge that spans the River Thames in London. The bridge opened to pedestrians on June 10, 2000 and closed later that same day because of unpredicted sway. As a suspension bridge, a certain amount of sway was expected, but amplitude of that sway generated when the crowds walked across the bridge on opening day was alarming. Like the metronomes on the flexible platform, each person generated a little bit of direction-specific

Download English Version:

https://daneshyari.com/en/article/11002269

Download Persian Version:

https://daneshyari.com/article/11002269

Daneshyari.com