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A model for computing genes governing marital dissolution through sentimental dynamics

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HIGHLIGHTS

- Martial dissolution can be described by the turbulences of sentimental dynamics.
- Sentimental dynamics obeys the second law of thermodynamics.
- We propose a model for mapping genes regulating sentimental dynamics.
- The model provides a means of studying the genetic diversity of human populations.

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ABSTRACT

Adverse sentimental relationships that cause marital dissolution may involve a genetic component composed of genes from a couple, which interact with cultural, sociological, psychological and economic factors. However, the identification of these genes is very challenging. Here, we address this challenge by developing a computational model that can identify specific genes that impact on sentimental relationships of couples. The model was derived by implementing the second law of thermodynamics that quantifies sentimental relationships within a dynamic gene identification framework, called systems mapping. The model is equipped with a capacity to characterize and test the pattern of how genes from a couple interact with each other to determine the dynamic behavior of their marital relationships. The testing procedure is based on comparing genotypic differences in mathematical parameters of sentimental dynamics described by a group of ordinary differential equations (ODE). The model allows the test of individual parameters or a combination of parameters, addressing specific details related to martial relationships. The model may find its implications for designing an optimal effort policy and therapy to maintain a harmonic family in light of genetic blueprints of individual couples.

1. Introduction

Happiness is the fundamental need of an individual, a family and a society. A happy couple largely relies on sentimental relationships of the two partners (Myers, 1999; Easterlin, 2003). Although couple disruption, as an epidemic phenomenon in modern societies, especially in western societies (Martin and Bumpass, 1989; Kreider and Fields, 2002), has long been attributed to economic issues (Ruggles, 1997), there is a general agreement that it can also be explained by sentimental dynamics (Myers, 1999; Rey, 2010). Strogatz (Strogatz, 1998) pioneered the use of nonlinear differential equations to study sentimental relationships of a couple from the interactions between two partners. Gottman et al. (2002) provided an overview of how mathematical theory can be employed to understand couple relationships.

From a biological standpoint, a sentimental relationship may be initiated owing to some chemical reactions (Fisher, 2005), but its maintenance needs a rational effort and commitment. Rey (2010) used the second law of thermodynamics to derive a group of differential equations to understand the dynamics of love and the stability of relationship. By viewing sentimental relationships of a

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couple as a dynamic unit, he implemented optimal control theory (Seierstad and Sydsæter, 1999) to model sentimental dynamics and mathematically identify the point at which the system's equilibrium is violated, leading to marital dissolution.

In a system of sentimental relationships for a homogamous couple, two important variables are defined as its constitutive elements. The first one is the "feeling variable", $x(t)$, which describes the state of sentimental relationship of the partners. At an initial stage of romantic love, people have a very strong feeling towards each other; i.e., $x(0)$ is very large. However, there is a general trend for the initial feeling to decay with time, a trend which obeys the principle of the *s*econd law of thermodynamics. According to this law, we assume that $x(t)$ will decrease in a relationship with the passage of time and $x(0)$ is larger than $x(t)$ at all the times. For $x(t)$, there exists a critical value at which the relationship falls apart.

The second element of the system is the "effort variable", $y(t)$, which represents the amount of efforts required to counter the fading sentiment, including a small gesture or a big sacrifice. These efforts can reinforce the relationship on a day to day basis, but they come at a cost to an individual because this is an energy-consuming process. In terms of the second law of thermodynamics, dynamic sentimental relationships specified by feeling (x) and effort variables (y) at time t can be described by a system of differential equations (ODE) (Rey, 2010), expressed as

$$\begin{aligned} \frac{dx}{dt} &= ay - rx \\ \frac{dy}{dt} &= \frac{1}{D''(y)}((r+\rho)D'(y) - aU'(x)) \end{aligned} \qquad (1)$$

where a (> 0) is a parameter for effort y's efficiency; r (> 0) is feeling x's constant degenerating parameter; ρ is the parameter indicating impatience for effort's contribution; U and D are the utility from feeling and the disutility of effort, respectively, which are both differentiable, expressed as

$$U(x) = \lambda\sqrt{x}$$

$$D(y) = (y - C)^2 + b$$

with C being a parameter indicating optimal effort for its utility, and λ and b are the parameters that adjust for the utility and disutility functions, respectively. The group of ODE (1) constitutes an optimal system of feeling–effort dynamics.

Rey (2010) shows that the system of ODE (1) can reach a sentimental equilibrium $E = (x_s^{\heartsuit}, y_s^{\heartsuit})$ by setting the first order derivatives of x and y over time equal to zero (Fig. 1). The couple has a happy relationship when the system is in equilibrium. The equilibrium is located at the intersection of the nullclines. The vertical and horizontal nullclines are defined by $(dx/dt) = 0$ and $(dy/dt) = 0$, respectively, leading to the equations:

$$\begin{cases} ay = rx \\ (r+\rho)D'(y) = aU'(x) \end{cases} \qquad (2)$$

from which we can solve $E = (x_s^{\heartsuit}, y_s^{\heartsuit})$.

If we have the constant effort plan $y(t) = y_s^{\heartsuit}$, an equilibrium can remain in the long run, thus achieving maximal well-being. The equilibrium state of the feeling–effort configuration can be violated by small shocks – typically lowering effort. If the effort is lower than its absolute minimum level y^*, martial dissolution becomes unavoidable. The minimum effort level y^* is obtained by solving the deriving equation

$$D'(y^*) = 0 \qquad (3)$$

The difference between the effects at equilibrium ($y_s^{\heartsuit}$) and y^* is called the effort gap, which is larger than zero. This means that more efforts are always needed to make the relationship stable than what is perceived as a comfortable or tolerable effort level by the partners.

It has been recognized that most people tend to associate with, or fall in love, with individuals who have similar characteristics (Fisher, 2005; Byrne, 1971; Buston and Emlen, 2003; Rushton, 1989; Gonzaga et al., 2007). Genes may play a central role in decision making for establishing sentimental relationships (Serretti et al., 2007). In the National Longitudinal Study of Adolescent Health and the Framingham Heart Study, Fowler et al. (2011) identified genes that determine the pattern of how humans find their friends. However, these studies cannot study the genetic control of sentimental dynamics from a mechanistic perspective, limiting our understanding of sentimental relationships. In this article, we develop a computational model for sentimental gene identification by incorporating the ODE of sentimental relationships into a genetic mapping framework. Sentimental relationships as a complex phenotype can be viewed as a system composed of interacting components. Wu and group have developed a model, called systems mapping, to map specific genes that control a web of interactions between different components towards system function (Fu et al., 2010, 2011; Luo et al., 2010; Wu et al., 2011). The model to be developed is different from the previous models in the following areas. First, the previous models only consider the case in which genes and phenotypes are derived from the same individual, whereas the new model will incorporate genes from an individual that impact on the phenotype of its partner as well as complex interactions between genes from different genomes. Second, in the previous work, multivariate longitudinal covariance structure is modeled by an autoregressive process under the assumption of independence among different traits. Given that feeling and effort variables are likely to be correlated, the new model will capitalize on a bivariate structured antedependent process allowing the two variables to be correlated.

Third, more important, the new model presents a first study of using sophisticated models to map genes that control sociological events. It can not only provide an innovative tool to solve complex problems in sentimental dynamics, but also enable researchers to gain novel insight into the mechanistic underpinnings for sociological phenomena. It also serves as an excellent example to pursue cutting-edge research at interdisciplinary frontiers and interfaces. In the following sections, we describe the procedure of mapping genes that control sentimental relationships, their trajectories, their equilibrium points and their instability curves toward martial dissolution. We integrate classic quantitative genetic principles into the model to characterize individual–individual interactions and quantify the effects of this kind of interactions on the dynamic behavior of sentimental relationships. Computer simulation was performed to validate the usefulness of the model in practice. Finally, the model presented will provide useful information for designing an optimal gene therapy that

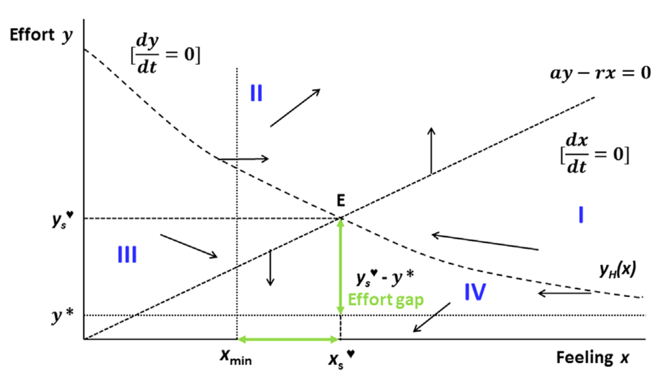

Fig. 1. Sentimental dynamics as a system determined by two constituent variables, effort y and feeling x. The equilibrium point ($E = (x_s^{\heartsuit}, y_s^{\heartsuit})$) of the ODEs system is shown. Adapted from ref. Rey (2010).