Adaptive Behavior

KAMA: A Temperature-Driven Model of Mate Choice Using Dynamic Partner Representations

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KAMA is a model of mate-choice based on a gradual, stochastic process of building up representations of potential partners through encounters and dating, ultimately leading to marriage. Individuals must attempt to find a suitable mate in a limited amount of time with only partial knowledge of the individuals in the pool of potential candidates. Individuals have multiple-valued character profiles, which describe a number of their characteristics (physical beauty, potential earning power, etc.), as well as preference profiles, that specify their degree of preference for those characteristics in members of the opposite sex. A process of encounters and dating allows individuals to gradually build up accurate representations of potential mates. Individuals each have a "temperature," which is the extent to which they are willing to continue exploring mate-space and which drives individual decision making. The individual-level mechanisms implemented in KAMA produce population-level data that qualitatively matches empirical data. Perhaps most significantly, our results suggest that differences in first-marriage ages and hazard-rate curves for men and women in the West may to a large extent be due to the Western dating practice whereby males ask women out and women then accept or refuse their offer.

Keywords mate choice · mate selection · sexual selection · computational temperature · mating strategies · emergence · mate-choice modeling · first-marriage age · first-marriage hazard rates · males-ask/females-decide · dating · marriage

1 Introduction

Marriage, at least in the West, is generally the culmination of a long process of searching for an appropriate mate. The process leading up to marriage is a complex one, requiring numerous encounters with members of the opposite sex, an initial selection of potentially compatible individuals, further contacts, possibly leading to dating, breaking off of relationships and beginning new ones—in short, exploring in breadth and in depth various avenues of the vast space of potential mates—until gradually two individuals settle into a stable relationship that leads to marriage.

We are interested in the mechanisms underlying mate selection. From an evolutionary point of view, the adaptive value of good mate-selection mechanisms is clear. The genes that code for mate-choice mechanisms that allow individuals to select high-quality mates are more likely to end up in offspring and, ultimately, propagate through a population than genes for bad mate-choice mechanisms, which, in the words

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of Miller and Todd (1998) "usually end up in fewer or lower-quality offspring, who take them to evolutionary oblivion."

In this article we develop a model of mate choice that is based on a gradual, stochastic process of building up representations of potential partners over time through encounters and dating, ultimately leading to marriage. Our model, KAMA, attempts to reproduce empirically verifiable population-level demographic trends based on mate-choice mechanisms implemented at the level of individuals in the population and involving the interplay of a number of simple, competing pressures and constraints. Specifically, individuals must attempt:

1. to find a suitable mate
2. to do so in a limited amount of time
3. to do so with only partial knowledge of the individuals in the pool of potential candidates.

Individuals, when they first enter the mating pool, do not have an accurate idea of the kinds of people already present in the pool and, crucially, do not know the kinds of individuals likely to agree to go out with—and, ultimately, marry—them. The process of encounters and dating allows them to gradually build up more accurate representations of individuals in that population.

In spite of these constraints on search time and information gathering, most individuals are generally able to find a mate. Although decisions involved in mate choice are highly personal, there are nonetheless constraints that all members of the population are subjected to, such as limited reproductive lifetime, social norms, and so forth. Demographic studies have shown that there are regularities across populations in the pattern of ages at which people first get married (e.g., Coale, 1971; Kreider & Fields, 2001; Eurostat, n.d.). We will attempt to show that a limited number of relatively simple mechanisms at the individual level are sufficient to enable individuals to find mates and, in so doing, generate realistic (i.e., similar to those found in the empirical literature) population-level behavior. This has been shown before in other models (e.g., Simão & Todd, 2003; Todd, Billari, & Simão, 2005), but in what follows, we develop a model of mate choice that differs with respect to current mate-choice models in the four major aspects listed here.

1. It incorporates "computational temperature" as a measure of the amount of energy willing to be devoted to finding a mate.
2. It uses, for each individual, a multi-dimensional vector of values for a variety of characteristics to describe an individual's mate value, rather than a single, overall mate value. Some of these values, in particular, those associated with wealth and beauty, evolve with the age of the individual.
3. It employs a fluid representational structure for a potential mate that evolves over time as new information about that person becomes available.
4. It uses subjective mate values, since mate value is largely, although certainly not completely, subjective ("beauty is in the eye of the beholder") incorporating empirical findings on male–female preference profiles for various characteristics found in their mates (Buss & Barnes, 1986).

Our motivation for these choices was two fold. First, and most importantly, we wanted to increase the power of the model by incorporating the above features. Using preference-weighted multi-dimensional mate values allows KAMA to make predictions about the potential effects of changes, not only in the values of individual features such as, attractiveness, wealth or being a good housekeeper, but also in the preferences people associate with these values (e.g., as women earn more, a decrease in the importance of wealth in a male partner). The use of temperature gives us a context-dependent means of modeling individuals' willingness to devote time, energy and resources to finding a mate. An individual's temperature, therefore, fluctuates depending on his/her age or involvement in a relationship. As a woman's biological clock is ticking longer and longer in the 21st century—a 66-year-old Romanian woman recently gave birth to a healthy baby girl!—it is reasonable to suppose that the shape that we have given to the temperature curve could well change. Our second motivation for developing the present model was that we wanted to develop a more behaviorally plausible model in which mate value is *subjective* ("beauty is in the eyes of the beholder") and in which the *manner* of dating in the Western world (i.e., males ask females out, females accept or refuse the males' offer) is taken into account. As we will show later in this article, simulating this men-ask/women-decide manner of Western dating allowed us to show that male–female marriage-age differences are, at least in part, simply a product of this Western dating practice.

2 Recent Human Mate-Choice Models

The recognition that sexual selection emerges as the combined effect of many low-level (i.e., individual) decision-making processes has led to the development of mate-choice models that incorporate individual strategies (Bergstrom & Real, 2000). Many of these mate-choice models involve non-human mate choice, undoubtedly due to the traditional focus on non-human animals in many early studies in evolutionary biology. In what follows, however, we will focus only on a small subset of human mate-choice models, with a particular emphasis on the family of models by Todd and colleagues (Simão & Todd, 2002, 2003; Todd et al., 2005; Todd & Miller, 1999).

One of the earliest mate-choice procedures was presented by Gale and Shapely (1962) in a paper provocatively entitled, "College admissions and the stability of marriage." They developed a simple, stable "match-making" algorithm for a population with an equal number of males and females. In their match-making procedure each individual begins by making an ordered preference list of all members of the opposite sex. Each male then asks the female at the top of his list to become "engaged." Each female who receives one or several proposals says yes to the male highest on her own preference list (who thereby becomes "engaged" to her) and rejects the others (who thus remain "unengaged"). Each unengaged male then removes from the top of his preference list the female who rejected him and the process is repeated. Each unengaged male asks the female now at the top of his list to become engaged. If a female who is already engaged gets a proposal from a male higher up on her preference list than her current partner, she rejects the latter (who then becomes "unengaged" and will then participate in the next round of proposals) and accepts the new male's engagement proposal. It is easy to prove that this procedure allows all males and females to pair up in a "stable" manner, which means that there will never be A–X and B–Y pairings for which Y is higher on A's preference list than X, while at the same time X is higher on B's preference list than Y. In a number of ways this algorithm resembles the KAMA model presented in the present article and, in particular, it implements the "beauty is in the eyes of the beholder" philosophy of KAMA in that each individual has his or her own preference list of the members of the opposite sex. The notion of temporary pairing and rejection of one's current partner if something more attractive comes along also resembles what happens in KAMA. The Gale–Shapely algorithm, however, requires perfect information by all members of the population of all members of the opposite sex, a highly unrealistic assumption. It is possible that the Gale–Shapely algorithm, appropriately modified to incorporate temperature and restricted preference lists that evolve based on encounters, would be a close cousin to KAMA.

An early human mate-choice simulation was done by Kalick and Hamilton (1986). The aim of their model was to resolve two conflicting findings in human mating behavior. According to studies in mate preferences, individuals tend to prefer individuals of the opposite sex that are highly physically attractive regardless of the individual's own physical attractiveness. On the other hand, it was found that there is a correlation in physical attractiveness among married couples (Kalick & Hamilton, 1986). Based on this, others theorized that people tend to prefer mates to whom they are physically similar. Kalick and Hamilton set up a social simulation where they used these two findings and managed to demonstrate that it was possible to achieve a high intra-couple physical-attractiveness correlation, even when individuals preferred the most attractive individual. The simulation revealed that, since high-value mates seek high-value mates as well, they accept only high-value mates and tend to leave the population early. Mid-quality individuals follow, with low-quality individuals taking the longest to find mates. Although their model has subsequently been criticized for the overly high number of dates for each individual and the low percentage of the population who got married (Aron, 1988; Simão & Todd, 2002, 2003; Todd et al., 2005), it was originally designed to resolve what was perceived to be a contradiction, and it was, indeed, able to show how this could be possible.

Todd and Miller (1999) proposed and tested a number of simple search heuristics in both one-sided search (i.e., search by either males or females in the population) and mutual search. In their model there is a learning period that corresponds to the adolescent period where the individual learns about its own mate value and the values of potential mates. They learn this through feedback from individuals (i.e., offers and rejections) whom they encounter in the population. They showed that the heuristics they tested could achieve satisfactory results while making use of very little information.

Recently a number of human mate-choice models have been developed by Simão, Todd, and colleagues (Simão & Todd, 2001, 2002, 2003; Todd et al., 2005). These models are based on realistic assumptions drawn from findings in psychology and have realistic outputs that have been validated against sociological and demographical findings. Some of them include a courtship period, thereby changing the mating decision from a single yes/no decision to a process in which the decision forms gradually over time. Each individual's aspiration level for various characteristics in potential mates is determined by a series of encounters. Simulation results were tested against empirical findings on intra-couple correlations, first-marriage age patterns and a sociological theory based on the effect of sex ratios to the rate of marrying.

An approach by Kenrick, Li, and Butner (2000) uses dynamic social influence networks as a means of propagating "influence" throughout a population. The population model that Kenrick et al. used represented individuals by their location and orientation with respect to their neighbors, a concept that we hope to implement in later versions of the present model. The perceived mate values of individuals by members of the opposite sex were able to change over time. Their model implemented the idea that males are inclined to take advantage of unrestricted relationships whereas females prefer restricted relationships and examined how males and females were affected by each other's mating options.

Finally, an animal mate-choice model by Luttbeg (1996) should be mentioned because of its structural similarity to our model. This model relaxes the assumptions of random encounter and perfect information during mate assessment. Females repeat visits to males and concentrate subsequent efforts on those males that earlier had appeared the most promising. This is reminiscent of some of the key mate-exploration mechanisms implemented in the present model.

This review is not meant to be exhaustive, but rather focuses on models that include some of the mechanisms that we have incorporated in our model. We wish to relax assumptions about unique mate value descriptors of individuals. Further, it is unimportant for individuals to assign a mate value to themselves and thus there is no learning period during which this occurs. There is no topology on the space of individuals and therefore any given individual is equally likely to encounter any other available person of the opposite sex. The notion of aspiration levels is largely incorporated in our temperature mechanism, and we have, like Luttbeg, relaxed the notion of perfect information transfer when two individuals meet.

3 The Need for a New Model of Mate Choice

The present model is an attempt to develop a more "fine-grained" model of mate choice than those that currently exist. KAMA does not use a single number to characterize an individual's mate value, but rather a number of real-valued characteristics (the "characteristic profile") that, together, constitute the individual's "inherent" mate value. Because mate value varies significantly depending on the beholder, however, each individual in the population has a "preference profile" that defines his or her degree of appreciation of each of the attributes in the characteristic profile of a potential mate.

Replacing a single mate value by a vector of values allows KAMA to simulate the population-level effects of the modification over time of particular characteristics of individuals. So, for example, the model can simulate the effect of both men and women becoming richer or becoming less attractive with age. It can also simulate the effect of changing preference values over time.

Computational temperature, the mechanism that drives the model, corresponds to the amount of energy that people put into encountering and dating potential mates (i.e., the higher the temperature, the greater the energy expended in mate-finding). For example, unmarried women approaching their mid thirties (i.e., the end of the period during which they can bear children) have more aggressive mate finding strategies (i.e., higher temperature) than younger women (Pawlowski & Dunbar, 1999) and men of the same age. We have modeled this by having somewhat different temperature curves for males and females.

By giving all males and females identical temperature curves as well as identical preference profiles, we were able to show, somewhat surprisingly, that the Western dating strategy of "males-ask/females-decide," by itself, produces a male–female first-marriage age shift in which older males marry younger females.

In addition, empirical data for various Western countries shows a significant change in first-marriage ages in the final quarter of the last century. Part of this change could be due to the documented decrease in societal pressure to marry early (Qu, 2003). In KAMA this decrease in pressure to marry early can be simulated by a lowering of the marriage temperature threshold, and when we do this, the model shows an overall lowering and rightward shift of first-marriage hazard rates, an effect that can be seen in data from Norway between 1978 and 1998.

4 KAMA: An Overview

In the following sections we will begin with a brief description and justification of the fundamental mechanisms of our model of mate choice. We will then proceed to a more detailed description of these processes.

4.1 Dating in the West, a Fundamental Asymmetry: Males-Ask/Females-Decide

Darwin (1859, 1871) observed that, in general, in nature males display themselves ostentatiously before a female in order to be chosen as her mate and the female makes the final mating decision. In our model, we implement a similar mate-choice asymmetry because this reflects a fundamental dating practice in Western society—namely, the male selects someone to ask out among a number of available alternatives (we call this a "parallel" decision process since he is considering a number of alternatives simultaneously); the female then accepts or declines his invitation immediately upon receiving it (we refer to this as a "serial" decision process since she must make a yes/no decision immediately for each individual who asks her out; she cannot accumulate offers and then choose one of them, which would constitute a parallel decision process). This necessarily implies that the female's "serial" strategy for accepting or refusing a date proposition is fundamentally different from the male's "parallel" strategy for deciding whom to ask out among a number of alternatives. We will show that this has a significant effect on the differences in male and female first-marriage hazard rates.

This distinction between "parallel" versus "serial" decision-making procedures is crucial to the present model. This difference engenders a fundamental asymmetry in the courtship process, one that has received little or no attention in the human mate-choice literature. One way that courtship symmetry could be established would be by allowing women to "accumulate" dating propositions and when she had a given number of offers, to choose among them. Or, alternatively, symmetry could be achieved by women asking men out. Later in this article we compare the standard asymmetric courtship procedure with the latter means of establishing courtship symmetry. This latter procedure is, in fact, what occurs in "speed dating" (Kurzban & Weeden, 2005).

4.2 Computational Temperature

The willingness to invest resources in the search for a mate is implemented in KAMA by a feedback-driven internal parameter called *temperature*. In the area of analogy making, Hofstadter (1984) proposed context-dependent computational temperature as a means of driving parallel search. Further development of this notion can be found in Mitchell (1993) and French (1995). One important difference in temperature as implemented in KAMA compared to its implementation in previous work on analogy making is that in the latter models it is a global parameter reflecting the quality of the structures (i.e., groups of similar objects, correspondences between objects, etc.) being built or discovered by the program when solving a particular analogy problem. In contrast, in KAMA each agent has its own temperature that regulates its behavior.

Temperature is a function of both an individual's recent dating history and his/her age (see Figure 3 below). The higher the temperature, the more willing an individual is to explore mate-space for a mate; the lower the temperature, the less willing he/she is to do so; this generally means that he/she is concentrating on one particular relationship, largely to the exclusion of others. When both individuals in a dating relationship have low enough temperatures, "marriage" occurs and they drop out of the mate pool.

Temperature is a measure of the energy (i.e., time, resources, physical effort, etc.) that one is willing to expend to find a partner. First, this affects the number