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The Mathematics of Marital Conflict: Dynamic Mathematical Nonlinear Modeling of Newlywed Marital Interaction

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This article extends a mathematical approach to modeling marital interaction using nonlinear difference equations. Parameters of the model predicted divorce in a sample of newlyweds. The parameters reflected uninfluenced husband and wife steady states, emotional inertia, influenced husband and wife steady states, and influence functions. The model permits separation of uninfluenced parameters—that is, what is initially brought to the interaction by each person's personality or the relationship's history—from where the interaction heads once influence begins. In the present model, a theoretical shape of the influence functions is proposed that permits estimation of negative and positive threshold parameters. Couples who eventually divorced initially had more negative uninfluenced husband and wife steady states, more negative influenced husband steady state, and lower negative threshold in the influence function.

The application of mathematics to the study of marriage was presaged by von Bertalanffy (1968), who wrote a classic and highly influential book titled *General System Theory.* This book was an attempt to view biological and other complex organizational units across a wide variety of sciences in terms of the interaction of these units. The work was an attempt to provide a holistic approach to complex systems. Von Bertalanffy's enterprise fit a general Zeitgeist, with Wiener's (1948) *Cybernetics,* Shannon and Weaver's (1949) information theory, and VonNeumann and Morgenstern's (1947) game theory. Von Bertalanffy inspired many major thinkers of family systems and family therapy. Unfortunately, the mathematics of general systems theory was never developed, and theorists of family interaction kept these systems concepts only at the level of metaphor. Even at the level of metaphor these concepts were tremendously influential in the field of family therapy (see Rosenblatt, 1994). However, they were never really subjected to experimental processes, and so they became frozen and reified. Systems concepts came to be considered true without evidence. This was highly unfortunate, and it was the direct consequence of not making the ideas testable or at least disconfirmable.

Von Bertalanffy (1968) viewed his theory as essentially mathematical. He believed that the interaction of complex systems with many units could be characterized by a set of values that change over time, denoted Q_1, Q_2, Q_3, and so on. The Qs were variables each of which indexed a particular unit in the system, such as mother, father, and child. He thought that the system could be best described by a set of ordinary differential equations of the following form: $dQ_1/dt = f_1(Q_1, Q_2, Q_3, \ldots)$, $dQ_2/dt = f_2(Q_1, Q_2, Q_3, \ldots)$, and so on. The terms on the left of the equal sign are time derivatives, that is, rates of change of the quantitative sets of values Q_1, Q_2, and so on. The terms on the right of the equal sign are functions, f_1, f_2, . . . , of the Qs. There was no suggestion of how to operationalize the "Q-variables." Von Bertalanffy thought that the functions, the fs, might generally be nonlinear.

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The equations that von Bertalanffy selected have a particular form, called "autonomous," meaning that the fs have no explicit function of time in them, except through the *Q*s, which are functions of time.

Von Bertalanffy thought that for practical solution, the equations had to be *linear.* He presented a table in which these nonlinear equations were classified as "impossible" (von Bertalanffy, 1968, p. 20). Rapoport (1972) suggested that investigators apply von Bertalanffy's linear equations to an analysis of marriage, but he presented no data, no suggestion of how to operationalize von Bertalanffy's *Q*-variables, and no explanation of how to apply the equations to real data. Unfortunately, linear equations are not generally stable, so they tend to give erroneous solutions, except as approximations under very local conditions near a steady state. Von Bertalanffy was not aware of the mathematics that Poincare and others had developed in the last quarter of the 19th century for the study of nonlinear systems. The modeling of complex deterministic (and stochastic) systems with a set of nonlinear difference or differential equations has now become a productive enterprise across a wide set of phenomena and across a wide range of sciences, including the biological sciences. The use of nonlinear equations forms the basis of our modeling of marital interaction.

Other than the possibility of stability, an advantage of nonlinear equations is that by using nonlinear terms in the equations of change some very complex processes can be represented with very few parameters. Unfortunately, unlike many linear equations, these nonlinear equations are generally not solvable in closed functional mathematical form. For this reason, the methods are often called "qualitative," and visual graphical methods and numerical approximation must be relied on. For this purpose, numerical and graphical methods have been developed such as *phase space plots.* These visual approaches to mathematical modeling can be very appealing for engaging the intuition of a scientist working in a field that has no mathematically stated theory. If the scientist has an intuitive familiarity with the data of the field, our approach may suggest a way of building theory using mathematics in an initially qualitative manner. The use of these graphical solutions to nonlinear differential equations makes it possible to talk about "qualitative" mathematical modeling. In qualitative mathematical modeling, one searches for solutions that have similarly shaped phase space plots, which provide a good qualitative description of the solution and how it varies with the parameters.

There are many excellent introductions to this general approach to qualitative nonlinear dynamic modeling and its subtopics of chaos and catastrophe theory (e.g., Baker & Gollub, 1996; Beltrami, 1993; Berge, Pomeau, & Vidal, 1984; Glass & Mackey, 1988; Gleick, 1987; Lorenz, 1993; Morrison, 1991; Peters, 1991; Vallacher & Nowack, 1994; Winfree, 1990). An introduction to catastrophe theory may be found in works by Arnold (1986), Castrigiano and Hayes (1993), Gilmore (1981), and Saunders (1990). The currently vast and expanding area of mathematical biology was introduced by Murray's (1989) classic text.

Our modeling of marital interaction using the mathematical methods of nonlinear difference equations is an attempt to integrate the mathematical insights of von Bertalanffy with the general systems theorists of family systems (Bateson, Jackson, Haley, & Weakland, 1956) using nonlinear equations. In modeling marital interaction, Cook et al. (1995) developed an approach that used both the data and the mathematics of differential or difference equations in conjunction with the creation of qualitative mathematical representations of the forms of change. Our approach was unique because the modeling itself generated the equations, and the objective of our mathematical modeling was to generate theory. We suggested that the data be used to guide the scientific intuition so that equations of change were theoretically meaningful.

In finding a practical example of von Bertalanffy's *Q*-variable, we used a report by Gottman and Levenson (1992) that one variable descriptive of specific interaction patterns of the balance between negativity and positivity was predictive of marital dissolution. Gottman and Levenson used a methodology for obtaining synchronized physiological, behavioral, and self-report data in a sample of 73 couples who were followed longitudinally between 1983 and 1987. Applying observational coding of interactive behavior, they computed, for each conversational turn, the number of positive minus negative speaker codes and plotted the cumulative running total for each spouse. An observational system (the Rapid Couples Interaction Scoring System [RCISS]) was used to code the salient behaviors; this system had been developed by reviewing literature on the behavioral correlates of marital satisfaction. A behavior was considered negative if it correlated negatively with marital happiness and positive if it correlated positively (Krokoff, Gottman, & Haas, 1989). The slopes of these plots determined a risk variable, low risk if both husband's and wife's graphs had a positive slope and high risk if not. Computing the graph's slope was guided by a balance theory of marriage, namely, that those processes most important in predicting dissolution would involve a balance, or a regulation, of positive and negative interaction. Four years after the initial assessment, the original participants were recontacted. The high–low risk distinction was able to predict the cascade toward divorce, which consisted of marital dissatisfaction, persistent thoughts about divorce and separation, and actual separation and divorce.

The modeling began with a sequence of Gottman–Levenson scores for each couple over the 15-min conversation: $W_t, H_t, W_{t+1}, H_{t+1}, \ldots,$ and so on. These scores were numbers obtained by giving a numerical weight to each categorical observational code, with the turn at speech as the unit (ignoring vocal backchannels; Duncan & Fiske, 1977). The weights were determined and were positive or negative by depending entirely on their correlations with marital satisfaction in previous research. In the process of modeling, two parameters were obtained for each spouse. One parameter was his or her "emotional inertia" (positive or negative), which is each person's tendency to remain in the same state for a period of time, and the other parameter was his or her natural uninfluenced steady state, which was each spouse's average level of positive minus negative when the other spouse's score was zero, that is, equally positive and negative.

The mathematical model involved breaking down the rate of change of the Gottman–Levenson variable for each spouse into the sum of three terms, a constant term related to the uninfluenced value that each spouse brought to the interaction, an autoregressive term related to that person's past, and an influence function describing the spouse's influence on the rate of change of the partner. If, at time t, the husband's quantitative variable is represented by H_t the wife's variable by W_t, and r represents the emotional inertia parameter, the difference equations are as follows:

$$W_{t+1} = a + r_1 W_t + I_{HW}(H_t), \tag{1}$$

$$H_{t+1} = b + r_2 H_t + I_{WH}(W_t). \tag{2}$$

The parameters a and b and the rs were estimated from the data. The constants a and b are related to the initial uninfluenced level of positivity minus negativity that each spouse brings to the interaction. [The uninfluenced steady states are actually $a/(1 - r_1)$ and $b/(1 - r_2)$, respectively.] These parameters were thought to reflect the past history of the relationship and aspects of each partner's personality (that is, modal affectivity). The rs then reflect the influence of each person's immediate past on that person; that is, they are autoregressive parameters.

The Is are the *influence functions,* and they are the nonlinear part of the equations. I_{HW}, for example, is the influence of the husband on the wife at time t. This dismantling of the Gottman–Levenson variable into "influenced" and "uninfluenced" behavior represented a theory of how this dependent variable may be decomposed into components that suggest a mechanism for the successful prediction of marital stability or dissolution. For example, for the wife, once the r_1, r_2, a, and b are estimated from the data (see Cook et al., 1995), at each time point, t, $(a + r_1 W_t)$ is subtracted from W_{t+1}, and the remainder is the influence function, $I_{HW}(H_t)$. These data points for the influence function are then averaged across specific values of H, and a plot is made of H as the x-axis and $I_{HW}(H)$ as the y-axis. A similar procedure holds for the other influence function.[1]

The "qualitative" portion of the equations involved writing down the mathematical form of the influence functions. Two influence functions were used to describe the nature of the couple's influence on one another (see Figure 1). They can potentially link power and affective parts of the couple's relationship in the following

[1] We could model cycles by including a delay parameter between husband and wife responding (see Murray, 1989, Section 1.3, p. 8).

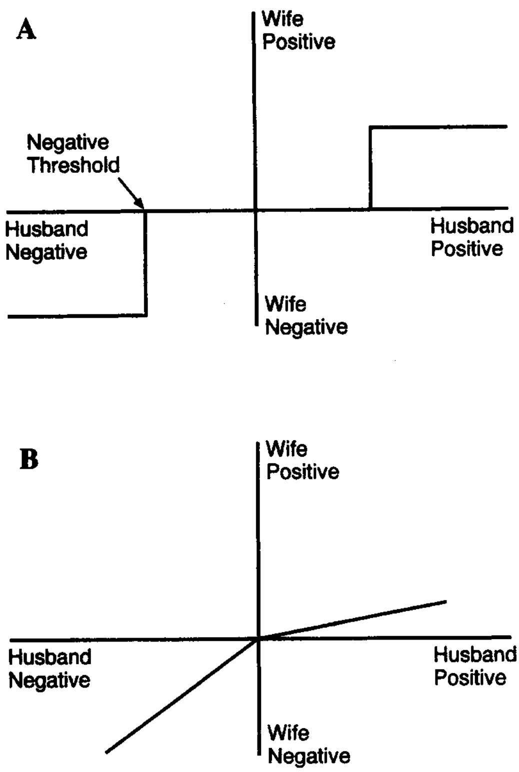

Figure 1. Two possible functional forms for the influence functions: For the influence function of the husband on the wife, the x-axis is the husband's previous score, H_t, and the y-axis is the influenced component, I_{HW} (H_{t+1}), of the wife's following score, W_{t+1}. The wife's influence on the husband, I_{WH} (W_{t+1}), could be graphed in a similar way. In (A) O-Jive or sigmoidal shape, there is no influence unless the partner's previous score lies outside some range. Outside that range the influence takes either a fixed positive value or a fixed negative value. In (B) bilinear shape, influence increases linearly with the value of the previous score, but negative scores can have either a stronger or less strong influence than positive scores. In both graphs, a score of zero has zero influence on the partner's next score (one of the assumptions of the model).

manner: They present a precise function of how one partner's affect (e.g., the husband's) at time t affects the other's (the wife's) affect at time t + 1, as a function of the entire range of affect displayed (by the husband). This influence of the husband is determined by the equations controlling for autocorrelation, that is the wife's prior influence on herself ($r_1 W_t$), controlling for her baseline level of affectivity (a). Hence, we can use the influence function to compute what the average effect is of the husband on the next affective behavior of his wife when he is positive at level +6 on our affect scale, or at −17, and so on. The mathematical form of the influence function is represented graphically with the x-axis as the range of values of the dependent variable (positive minus negative at a turn of speech) for one spouse and with the y-axis as the average value of the dependent variable for the other spouse immediately following behavior, averaged across turns at speech.

Negative Threshold and the "Marital Negativity Detector"

In this study, we extended Cook et al.'s (1995) work by selecting a particular theoretical form of the influence functions. The form we selected was the O-Jive. We selected this function because it permitted us to create four important new parameters in the model: the thresholds for negativity and the thresholds for positivity for each spouse. The threshold for negativity implies that this is the point at which negativity has an impact on the partner's immediately following behavior. The threshold for negativity in the influence function is thus a function of both a couple's perception of the relationship and the partner's subsequent action. If the threshold for negativity is set lower (a smaller negative number on the x-axis) for newlywed marriages that eventually wind up stable and happy, this could be called the *marital negativity detector effect:* Some spouses are having a negative response to lower levels of negativity from their partner; they are noticing and responding to negative behavior when it is less escalated. In other marriages, people are adapting to and trying to accept this negativity, setting their threshold for response at a much higher or more negative level. It's as if they have said to themselves, "Just ignore this negativity. Don't respond to it until it gets much worse (that is, more negative)." It may be the case that this kind of adaptation to negativity is dysfunctional because having a lower threshold for negativity implies that people would discuss issues before they escalate too much. People with lower thresholds may follow the biblical principle from Ephesians (Eph. 4:27), "The sun must not go down on your wrath." This advice has typically been taken by many couples to detect negativity quickly and repair the marriage before retiring for the evening.

The introduction of the negativity thresholds relates to an important effect recently discovered by Baucom and his associates (Baucom, Epstein, Rankin, & Burnett, 1996). Lederer and Jackson (1968) had originally suggested that marriages may become dysfunctional if spouses have too high expectations for the marriage, but Baucom et al. reported that, on the contrary, couples who held the highest expectations for their marriage generally scored higher on every index of positive marital outcome that was studied. This may mean that the couples whose marriages were doing well detected, responded to, and attempted reasonably immediate repair of interaction before it became too negative. This may be contrasted with a style in which couples decide to adapt to levels of negativity expressed by their partners. The direction of causation, however, is unclear.

This point of view is currently controversial in the marital therapy literature. It is not at all obvious that adapting to one's partner's negativity is not functional. In fact, many therapists have suggested that couples cultivate an empathetic response to their partner's negativity. Hendrix (1988) suggested a therapy that would train people to have an "X-ray vision" in which they see their partner's childhood wound behind the hostility, and then they are able to respond empathetically even when they have been attacked. This could lead to people setting their negative threshold at a more negative level. Many other therapies have proposed a similar model for effective conflict resolution (e.g., Guerney, 1977). On the other hand, Wile (1993) disagreed. He recommended that people should hold high standards for their marriages and that they should feel "entitled" to their complaints:

> It is the adjustments, accommodations, and sacrifices that partners make without telling each other or fully recognizing it themselves—that is, their automatic and unverbalized attempts to compromise and be reasonable—that may lie at the root of the difficulty. What these partners may be needing is to stop compulsively compromising and to develop an ability to complain. (p. 73)

We set out to test these two alternative points of view by selecting the O-Jive form of the influence functions. If Wile's point of view were correct, newlywed couples in marriages that have a less negative threshold would be less likely to divorce than couples in marriages that have a more negative threshold. However, if Hendix's point of view were correct, newlywed couples in marriages that have a less negative threshold would be more likely to wind up divorced than couples in marriages that have a more negative threshold.

The negative threshold parameter could be important because it might explain two mysteries in the area of marriage. The first effect we call here the *delay effect*. In many areas of public health, one concern is decreasing the "delay time" to getting competent medical help from the time a patient notices a symptom, such as chest pains or a lump in the breast. Notarius and Buongiorno (1995) found that the average amount of time a married couple waits to get professional help from the time one of them detects serious problems in the marriage is 6 years! The second mystery we call here the *relapse effect*. This refers to a pervasive finding that initial gains in marital therapy relapse after 1 to 2 years (e.g., see Jacobson & Addis, 1993). How could the mathematical model explain these two effects? We proposed that this particular parameter of our mathematical model of marriage, the negative threshold, could explain both of these effects. A finding with the negative threshold parameter would suggest that people delay getting help for their marriage because they have inadvertently raised the negativity threshold. In marriages that work, spouses do not do this adapting to negativity. The negative threshold effect could also explain the relapse effect in marital therapy. It suggests that relapse occurs because people adapt to increasingly higher levels of negativity, instead of repairing the relationship. Relapse and delay become parts of the same phenomenon, namely adaptation to increasingly higher levels of negativity.

We might find that spouses who do not adapt to negativity will fairly quickly bring up an issue about which they are unhappy, within days of things becoming negative. This would be an example of longer term repair. So, this finding would suggest that the key to avoiding decay in marriages is for the therapy to reset what could be called "the marital negativity detector" to a lower level of negativity and build in some formal mechanisms for the couple to do repair on a continual basis. The finding about threshold for negativity could also suggest an hypothesis for the pervasive marital therapy relapse effect. It would suggest that people relapse after initial therapeutic gains because the therapy has affected the overall levels of positivity and negativity in the marriage, but it has not reset the negative threshold. This then could become one of the goals of therapy: to reset the marital negativity detector so that couples notice the negativity, do not adapt to it, and instead make continual repairs in the marriage. It is also conceivable that couples who put off making repairs to their marriage also erode the overall amount of positivity in the marriage through the process of carrying grudges that are not addressed.

Steady States and Stability

As Cook et al. (1995) noted, for each couple we plot a *phase plane* containing the model's *null clines* (see Figure 2). The phase plane refers simply to the plane with the husband's and the wife's scores as coordinates. Hence, a point in this plane is a pair representing the husband's and the wife's scores at a particular time block in the interaction; using the RCISS data, this unit was a particular interact (a two-turn unit). As time progresses, this point moves, and charts a trajectory in phase space. In phase space there are sometimes points called *stable steady states.* These are points that the trajectories are drawn toward, and if the system is perturbed away from these states, it will be drawn back. Unstable steady states are the opposite: If perturbed, the system will drift away from these points. Hence, it is of considerable importance to find the steady states of the phase plane. This is accomplished mathematically by plotting the null clines of the marital system. Null clines involve searching for steady states in the phase plane; they are theoretical curves where things stay the same over time, where the derivatives are zero (see Cook et al., 1995). Cook et al. (1995) derived the functional form of the null clines in terms of the influence functions. In Figure 2 the filled black dots indicate stable steady states and the white dots indicate unstable steady states.

We call the set of points that approaches a stable steady state the "basin of attraction" for that steady state. Consider a sequence of scores approaching a more positive steady state. A "theoretical conversation" could be constructed by simply applying Equations 1 and 2 iteratively from some initial pair of scores. Cook et al. (1995) showed that the final outcome (positive or negative trend) of a conversation could depend critically on the opening scores of each partner. Where one begins in the phase space is determined by the couple's actual initial conditions. We have generally found that the end points can indeed depend critically on starting values. In addressing the issue of stability of the steady states, we asked whether the mathematical equations implied that the reconstructed series would approach a given steady state. Analytically, we asked the question of where a steady state would move once it was slightly perturbed from its position. The theoretical (stable or unstable) behavior of the model in response to perturbations of the steady states is only possible once we assume a functional form for the influence functions. For example, as we have noted, for the sigmoidal influence function, we can have one, three, or five steady states. From the null-cline plot, we can see that there are three stable and two unstable states. In most of our data, there was only one influenced steady state per couple.

Is the "Uninfluenced" Steady State Influenced by Prior Relationship History, by Lasting Characteristics of Individuals, or by Both?

Kelly and Conley (1987), in a 35-year longitudinal study, reported that neuroticism predicts divorce. Kurdek (1991a, 1991b, 1993) obtained similar results in his longitudinal study. Karney and Bradbury's (1995) review of 115 longitudinal studies also identified what they called "enduring vulnerabilities" within individuals as risk variables for predicting negative marital outcomes. However, personality dimensions, when they have predicted marital outcomes, have tended to be weak predictors, and, as Karney and Bradbury noted, the field has shifted "from predicting outcomes to explaining chains and patterns of events at different outcomes" (p. 28). There also is a trend toward greater precision in the predictor variables (Gottman, 1994). We raised the question of whether it was possible to use the parameters of our mathematical model to tease out the separate contributions of individual characteristics that both spouses bring to the marital interaction from the interaction and influence the process itself.

The parameters that we call the "uninflu-

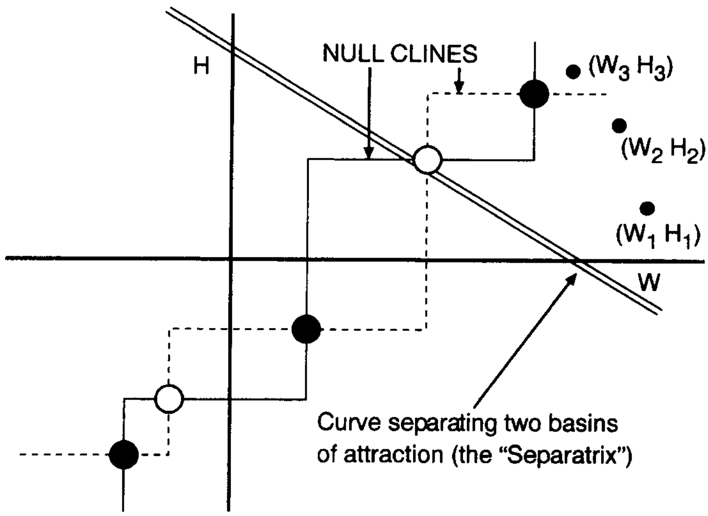

Figure 2. The null-clines to graphically determine the steady states and separate the phase space into two basins of attraction (the separatrix). Stable steady states (large filled circles) are separated by unstable steady states (large open circles). The pairs of husband and wife scores (W_1, H_1; W_2, H_2; W_3, H_3) gradually approach one of the stable steady states, the exact trajectory depending on the basin of attraction in which the initial pair of scores lies. H = husband; W = wife.

enced" steady states might actually contain varying degrees of information about the relationship's prior history, perhaps due either to remaining good feelings, to unresolved conflict, or to both. In fact, this "spillover effect" of prior interactions can be assessed by dividing the interaction into two halves and attempting to predict the second half's uninfluenced parameters from the first half's parameters. If there is a spillover effect of negativity, predictability would be greatest for couples who eventually wind up in unhappy marriages or who wind up divorced. If it is a spillover effect of good feelings, predictability would be greatest for couples who wind up in happy stable marriages. To assess these possibilities, we divided the interaction into two equal halves and investigated the predictors in the first half of the interaction of the second half's uninfluenced steady state parameters. In this way, what we have been calling the "uninfluenced" steady state might be explainable, at least in part, in terms of the prior interaction.

There were two parts of the analysis. In the first part, we assessed whether the first half's influence function parameters (influenced steady states and influence function thresholds) could predict the second half's uninfluenced steady states, controlling for the first half's uninfluenced parameters. This analysis assessed whether the prior relationship's *interaction and influence* history alone could predict the immediately following uninfluenced steady states. This must include a statistical control for the prior uninfluenced parameters. This was intended simply as an assessment of prior relationship spillover. In the second part of the analysis, we focused on whether there was predictability from the uninfluenced steady states in the first half directly to the uninfluenced steady states in the second half, controlling for interaction and influence in the first half of the interaction. This analysis attempted to assess to what extent the uninfluenced steady states in the second half of the interaction were a function of enduring qualities in the individual, independent of interaction and influence. We further assessed how these issues might vary with the eventual fate of the marriage, dividing the entire sample into two groups: (a) those who were divorced or stable but unhappy and (b) everyone else. This comparison should provide adequate power for the analysis in both groups. We expected that the second half's uninfluenced steady state would have components of both interaction and the enduring qualities of the individual. Further-more, we expected both the interaction's influence and the enduring qualities of the individual to matter more in troubled marriages than in happy marriages.

Method

Participants

Between 1989 and 1992, a two-stage sampling procedure was used to draw a sample of newlywed couples from the Puget Sound area of Washington. Couples were initially recruited with newspaper advertisements. To be eligible for the study, the couples had to meet requirements (a) that it was a first marriage for both partners, (b) that they were married within 6 months of participating in the study, and (c) that they were childless. Couples were contacted by phone, were administered the telephone version of the Marital Adjustment Test (MAT; Krokoff, 1987; Locke & Wallace, 1959), and were surveyed to determine their eligibility on the other subject selection criteria. The MAT measures marital satisfaction. Higher scores on the MAT represent higher marital satisfaction. There were 179 newlywed couples who met the research criteria and who participated in the initial survey phase of the study. In the survey phase of the study, both the husbands and wives received separately mailed sets of questionnaires to fill out. The questionnaire included measures of demographic characteristics and indices about the couples' marriage, well-being, and health.

In the second phase of the study, 130 newlywed couples, who represented an even distribution of marital satisfaction, were invited to participate in a marital interaction laboratory session and to complete additional questionnaires. These couples fit the demographic characteristics of the major ethnic and racial groups in the greater Seattle area, using the Seattle City Metropolitan Planning Commission Report. The demographic characteristics for these newly married couples were (a) wife's age, $M = 25.4$ years ($SD = 3.5$); (b) husband's age, $M = 26.5$ years ($SD = 4.2$); (c) wife's marital satisfaction, $M = 120.4$ ($SD = 19.7$); (d) husband's marital satisfaction, $M = 115.9$ ($SD = 18.4$). Couples were seen in three cohorts of approximately 40 couples per cohort and were followed for 6 years, so that the follow-up period varied from 3 to 6 years.

3–6-Year Marital Status and the Criterion Groups

Once each year the marital status and satisfaction of the 130 couples in the study were assessed. At the end of the 6-year period (Time 2), there had been 17 divorces: 6, 6, and 5 in the first, second, and third cohorts, respectively. Only 13% of the couples had divorced after 3–6 years. The divorce rate in this sample may be somewhat lower than one would expect at this point in the marriage trajectory; one would expect about 22 divorces by this point (Cherlin, 1981; U.S. National Center for Health Statistics, 1986, 1988).[2] Some of the analyses were concerned only with marital stability, in which case the entire sample of 130 couples was used (with 17 divorces). However, we were also interested in the current marital satisfaction of the stable (i.e., nondivorced) couples. To create similar-sized criterion groups of stable couples, we used the lowest of each couple's Time 2 Locke–Wallace marital satisfaction scores to form two criterion groups of 20 stable couples each, those 20 most happily married and those 20 most unhappily married. The mean Time 2 marital satisfaction score of the stable, happily married group was 128.30 ($SD = 27.65$) and the mean Time 2 marital satisfaction score of the stable, unhappily married group was 90.70 ($SD = 16.08$).

Missing data were created in two ways: (a) by couples for whom we could not estimate the mathematical model for either half of the data set, which occurred when there were fewer than 10 zeros in the seventy-five 6-s time blocks of data for estimating a, b, r_1, and r_2. Using this criterion, there were 125 couples for the divorce prediction analyses. (b) For some couples, the null clines did not intersect at all, and these couples had no influenced steady states.

Questionnaire

As described earlier, the MAT (Locke & Wallace, 1959) was administered during the initial telephone

[2] An exploratory analysis of the correlations of the negative threshold parameter with the questionnaire and interview data we collected in the newlywed study revealed the following. The negative threshold was set significantly lower if the husband rated the couple's marital problems as severe. Using our coding of our oral history interview, we found that the negative threshold was set significantly more negative (a) if the couple reported that their lives were "chaotic"; that is, if they reported that unexpected things kept happening to them that they had to continually adjust to rather than feeling in control of their lives; (b) if during the interview the husband or the wife spontaneously expressed negative affect toward the partner; (c) if the husband whined a lot during the marital conflict discussion; (d) if the husband or the wife was low on "we-ness." If a couple received counseling, a more negative threshold was associated with more months spent in counseling ($r = .35$, $p < .001$). Hence, overall, a more negative threshold was associated with a generally poorer marital quality as well as a poorer prognosis.

interview. The MAT is used to assess marital satisfaction and is frequently used in marital research because it reliably and validly distinguishes between happily and unhappily married couples (Cronbach's $\alpha = .92$). The telephone version of the MAT has strong psychometric properties as well (Krokoff, 1987). Lower scores on the MAT represent lower marital satisfaction.

Marital Interaction Laboratory Procedures

Behavioral observation. Two remotely controlled, high-resolution cameras filmed frontal views of both spouses and their upper torsos during the interaction sessions. The images from the two cameras were combined in a split-screen image through the use of a video special-effects generator. VHS videorecorders were used to record the behavioral data. Two lavaliere microphones were used to record the couple's audio interactions. The computer synchronized the physiological data with the video data by using the elapse time codes imposed on the video recordings. The Specific Affect Coding System (SPAFF; Gottman, McCoy, Coan, & Collier, 1996) was used to code the couples' conflict interactions. SPAFF was used to index the specific affects expressed during the marital problem resolution session. SPAFF focuses solely on the affects expressed. The SPAFF system draws on facial expression (based on Ekman and Friesen's Facial Action Coding System; Ekman & Friesen, 1978), vocal tone, and speech content to characterize the emotions displayed. Coders categorized the affects displayed using 5 positive codes (interest, validation, affection, humor, and joy), 10 negative affect codes (disgust, contempt, belligerence, domineering, anger, fear/tension, defensiveness, whining, sadness, and stonewalling), and a neutral affect code. Every videotape was coded in its entirety by two independent observers using a computer-assisted coding system that automated the collection of timing information; each coder noted only the onsets of each code. The coders were paid staff in our laboratory, or they were undergraduate volunteers who worked in the laboratory for 3 quarters; the 1st quarter was training, and then they coded for 2 quarters; a seminar of readings, discussion, and a required paper were also part of the volunteer's activity. The time to code a videotape independently twice was three times real time. First, the two independent observers (who could not see each other's coding) watched the interaction through, then they both coded 1 spouse and then the other spouse. Reliability was computed on all tapes, not a subsample of the tapes, and on 100% of each tape. A time-locked confusion matrix for the entire videotape was then computed using a 1-s window for determining agreement of each code in one observer's coding against all of the other observers' coding (see Bakeman & Gottman, 1986). The diagonal versus the diagonal-plus-off-diagonal entries in these matrices were then entered into a repeated measures analysis of variance (ANOVA) using the method specified by Wiggins (1977): The Cronbach's alpha generalizability coefficients were then computed for each code as the ratio of the mean square for observers minus the error mean square and the mean square for observers plus the error mean square (see also Bakeman & Gottman, 1986). The Cronbach's alpha generalizability coefficients ranged between .651 and .992 and averaged .907 for the entire SPAFF coding of all 130 videotapes. Kappas ranged between .84 and .72 and averaged .80.

The marital interaction assessment consisted of a discussion by the husband and wife of a problem area that was a source of ongoing disagreement in their marriage and two recall sessions in which the couples viewed their marital disagreement discussion. The couples were asked to complete the Couple's Problem Inventory (Gottman, Markman, & Notarius, 1977), an index of marital problems. One of the experimenters then reviewed with the couple those issues they rated as most problematic and helped them to choose several issues to use as the basis for the problem-area discussion. After choosing the topics for the discussion, couples were asked to sit quietly and not to interact with each other during a 2-min baseline. The couples then discussed their chosen topics for 15 min.

When the couple completed their discussion, they were asked to view the videorecording of the interaction. In counterbalanced order, husbands and wives were asked to first view and rate their own affect during the discussion and then to view and rate their spouse's affect. Both husbands and wives used rating dials that provided continuous self-report data. Continuous physiological measures and videorecordings were made during all of the interaction sessions, and data were averaged over 1-s intervals.

Weighting the SPAFF codes. We developed a weighting scheme for using the on-line observational system, the SPAFF (Gottman et al., 1996). The weighting scheme for the SPAFF was based on the differential ability of the specific codes to predict divorce in previous studies in our laboratory. Thus, for example, the codes of criticism, contempt, belligerence, defensiveness, and stonewalling received more negative weights than codes such as anger and sadness because of their greater ability to predict divorce. In the weighting scheme, positive affects such as affection and humor also received highly positive weights. The weighting scheme resulted in a potential range of -24 to $+24$ for the data. The observational coding for the SPAFF was also computer assisted, so that the coding was synchronized with the video time code and the physiological data, as well as later with the couple's subjective recall of their own affects. The computer program that acquired the data scanned the electronic signals from the observational coding station 32 times a second and then determined the dominant code for each second. This code received the appropriate weight, and then these weights were summed over 6-s time blocks. Because 6 s is the average length of a turn at speech during the conflict discussion, we used it as the time block for summing. Interestingly, 6 s is also the unit used in observational coding of classroom interaction (Amidon & Hough, 1967), and it is also the unit used by the Oregon Social Learning Center for analyzing family interactions at home (Patterson, 1982). For the 900 s of the 15-min conversation, this gave us 150 data points for husband and for wife. The weights were as follows: anger, -1; sadness, -1; fear, 0; defensiveness, -2; contempt, -4; belligerence, -2; domineering, -1; stonewalling, -2; disgust, -3; whining, -1; neutral, 0.1; interest, $+2$; affection, $+4$; humor, $+4$; listener backchannels (or any validation), $+4$; and joy, $+4$.

The advantages of the SPAFF over the older RCISS observational system are that it codes specific emotional behaviors of husband and wife and that it can code as the couple interacts in the laboratory, essentially in real time. The SPAFF coding scheme was designed to be usable for coding any marital conversation, whereas the RCISS was designed to code only conflict resolution discussions. The SPAFF also specifically discriminates among the positive affects, making fine distinctions between neutral and interest, affection, humor, and validation. Positive affect models have received scant attention in describing marital interaction. An exception is work by Birchler, Weiss, and Vincent (1975), who used a self-report diary measure of "pleases" and "displeases," a precursor of the Spouse Observation Checklist, and a version of the Marital Interaction Coding System (MICS) to code either general conversation when they were supposedly setting up the equipment or the Inventory of Marital Conflict discussion (IMC; Olson & Ryder, 1970). In the summary MICS code, the positives were agreement, approval, humor, assent, laugh, positive physical contact, and smile. According to this scheme, in the interaction distressed couples produced an average of 1.49 positive codes per minute, whereas nondistressed couples produced an average of 1.93 positive codes per minute, a significant difference. In the home environment, distressed partners recorded significantly fewer pleasing and significantly greater displeasing events than was the case for nondistressed partners. The previous RCISS system required a verbatim transcript of the couple's speech, usually taking about 10 hr of a transcriber's time, and then it took 6 hr for an observer to code the conversation from tape and transcript. The unit of analysis for the RCISS was *interact*, which is two "turns" at speech, one for the wife and one for the husband, and the number of interacts at speech varied a great deal from couple to couple; on average, there were 75 interacts per 15-min conflict discussion. The average length of a turn across our studies was approximately 6 s. The "turn" unit was everything one person said until the other began speaking, ignoring what are called "listener tracking backchannels" (Duncan & Fiske, 1977). These backchannels are messages such as brief vocalizations (e.g., "Uh huh," "Yeah," "I see"), eye contact, head nods, and facial movements that tell the speaker that the listener is tracking the conversation. These signals also regulate taking turns at speech. The transformation from RCISS to SPAFF was designed to be a technical breakthrough in our laboratory. First, it made it possible to code on-line in three times real time, instead of waiting 16 hr to obtain the coded data, which was the time for RCISS coding. This streamlined the lab's ability to conduct experiments; we were able to see the effects of an experiment in the math model immediately after doing the experiment with a particular couple. Second, because of SPAFF's design, which applies universal codes suitable for any marital interaction, it now made it possible to code *any* conversation the couple had, such as talking about the events of the day, talking about an enjoyable topic, or everyday conversations such as the 12 hr of time couples spend in our apartment laboratory. Third, we could now obtain a larger number of points per couple, and a uniform number across couples, and this moved us toward more reliable data within each couple, as well as toward the differential equations form of the math model.

Computational Algorithms

As suggested by Cook et al. (1995), we assume that the influence functions are zero at zero values; at the subset of the values for which $H = 0$, using least squares fitting, we fit the reduced linear equation $W_{t+1} = r_1 W_t + a$, and at the subset of values for which $W = 0$, we fit the reduced linear equation $H_{t+1} = r_2 H_t + b$. Then, using these estimates of the parameters r_1, r_2, a, and b, we compute the values of the influence functions, which is $I_{HW} = W_{t+1} - r_1 W_t - a$, and $I_{WH} = H_{t+1} - r_2 H_t - b$. We then fit a functional form, the ogive, to these estimates of the influence functions, finding, by least squares fitting, the husband influence function parameters A_H, B_H, C_H, D_H, E_H, and F_H, and the wife influence function parameters, A_W, B_W, C_W, D_W, E_W, and F_W. The computer program, written by Catherine Swanson, can be supplied on request. All other computations—for example, the wife's uninfluenced steady state, which is $a/(1 - r_1)$, and the husband's uninfluenced steady state, which is $b/(1 - r_2)$—follow from these computations. The influenced steady states are determined graphically, from the intersection of the null clines.

Results

Divorce Prediction

For these analyses, we compared the entire sample of couples who stayed married for whom we had no missing data ($N = 108$) with those 17 couples who eventually divorced.

Uninfluenced steady states. Table 1 shows the predictive validity of the parameters of the mathematical model using our weighting scheme. As can be seen from the table, the wife's uninfluenced steady state, $a/(1 - r_1)$, was much more negative in the first few months of the newlywed phase for couples who eventually divorced. The same was true for the husband's uninfluenced steady state.

Influenced steady states. In the early months of newlywed marriage, for husbands, those who eventually divorced had an average influenced steady state of −1.89, whereas those whose marriages turned out to be stable had an influenced steady state of 0.72. This parameter was thus a significant predictor of divorce. However, the wife's average influenced steady state was −1.95 for the group of wives who eventually divorced and −.65 for the group whose marriages turned out to be stable, and these were not significantly different. Even after the influence process, the husbands were still very different across the two groups.

Negative threshold. The husband's negative threshold was a significant predictor of divorce, $F(1, 123) = 8.25$, $p < .01$, in the predicted direction. In the first few months of marriage, couples who eventually divorced initially had a negativity threshold more negative than couples whose marriages turned out to be stable. A "more negative" negativity threshold means that, for example, a husband has to become more hostile before he gets a response from his wife. The findings mean that it took more negativity on the husband's part to get a response from his wife among couples who eventually divorced than for couples whose marriages turned out to be stable. In other words, the *wife* in a marriage that turned out to be stable at Time 1 was responding to less intense negative affect in her husband than was the case for wives in marriages that ended in divorce. For example, a wife in a marriage that later turned out to be stable had initially reacted to her husband's defensiveness, whereas in a marriage that dissolved, the wife did not react until he became contemptuous, a more negatively weighted behavior. This was a spouse effect rather than a couple effect.

Inertia. Neither the husband's nor the wife's inertia parameter was a significant predictor,

Table 1
Predicting Divorce Using Parameters of the Mathematical Model

Variable	*F* ratio	*df*	*M* Stable	*M* Unstable
Wife				
Inertia	0.20	1, 123	0.39	0.42
Uninfluenced steady state	14.86***	1, 123	0.51	−2.26
Influence functions				
Positive threshold	0.71	1, 123	8.25	7.24
Negative threshold	0.03	1, 123	−6.23	−6.06
Influenced steady state	1.29	1, 106	−0.65	−1.95
Husband				
Inertia	3.07†	1, 123	0.40	0.30
Uninfluenced steady state	18.40***	1, 123	0.72	−1.89
Influence functions				
Positive threshold	2.49	1, 123	8.45	6.65
Negative threshold	8.25**	1, 123	−5.36	−7.71
Influenced steady state	4.36*	1, 106	0.71	−1.49

†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

unlike the results with the RCISS data (Cook et al., 1995).

Results for the Three Criterion Groups

Table 2 summarizes these results. There were only three significant results, two for the husband and wife uninfluenced steady states, and one for the husband's influenced steady state. According to least significant difference tests subsequent to the ANOVA, the husband and wife uninfluenced steady states were able to predictively discriminate all three groups from one another. For both husbands and wives, the divorced group's uninfluenced steady state was significantly lower than the unhappy stable group's uninfluenced steady state, and the unhappy stable group's steady state was significantly lower than the happy stable group's uninfluenced steady state. The husband's influenced steady state also predictively discriminated the three criterion groups from one another. Least significant difference tests subsequent to the ANOVA showed that the husband influenced steady states were able to predictively discriminate all three groups from one another. The happy stable group's mean was significantly different from and greater than the unhappy stable group's mean, which, in turn, was significantly different from and greater than the divorced group's mean. In their influenced steady states, the group means of the wives of all three groups were negative, although that of the happy stable group was near zero. To further investigate this puzzling finding, we conducted ANOVAs on the actual wives' maxima and minima of the data for the three groups. Although the minima were not significantly different, $F(2, 48) = 0.72$; happy group mean = -10.94, unhappy group mean = -12.94, divorced group mean = -12.94, the maxima were marginally significant, $F(2, 48) = 2.94$, $p = .062$, and the least significant difference tests subsequent to the ANOVA showed that the happy stable mean of 20.06 was significantly greater than the divorced group mean of 14.88 (the unhappy stable mean was 17.76). Hence, wives in the stable happy group were being influenced by their husbands to increased ranges of positivity, compared with the divorced group.

Understanding the Uninfluenced Steady State

As noted in our discussion of spillover in the introduction, we wished to assess whether the parameters we have been calling the "uninfluenced" steady states may have actually contained some information about the relationship's prior history and about enduring qualities of the

Table 2
Tests of Significance of the Three Criterion Groups Using Parameters From the Mathematical Model

Variable	*F* ratio	*df*	*M* Happy, stable	*M* Unhappy, stable	*M* Divorced
Wife					
Inertia	0.28	2, 48	0.37	0.41	0.42
Uninfluenced steady state	12.61***	2, 48	1.07	−0.03	−2.26
Influence functions					
Positive threshold	0.73	2, 48	9.12	8.53	7.24
Negative threshold	0.28	2, 48	−5.76	−6.76	−6.06
Influenced steady state	1.60	2, 41	−0.05	−1.88	−1.95
Husband					
Inertia	0.63	2, 48	0.38	0.35	0.30
Uninfluenced steady state	9.10***	2, 48	1.06	−0.41	−1.89
Influence functions					
Positive threshold	0.54	2, 48	7.94	7.94	6.65
Negative threshold	2.22	2, 48	−5.94	−5.29	−7.71
Influenced steady state	1.15	2, 41	−0.33	0.31	−1.49

***$p < .001$.

individual, as well as how these influences might vary with the eventual fate of the marriage (happy vs. unhappy–stable or divorced). To understand the possible effect of immediate prior relationship history on the uninfluenced steady state parameters, we divided the interaction into two equal halves and investigated the predictors in the first half of the interaction of the second half's uninfluenced steady state parameters. We did this prediction separately for those couples who were eventually either divorced or stable but unhappy, compared with everyone else. There were two parts to answering this question. The first part was to assess whether there was a spillover of uninfluenced steady states from the first to the second half of the interaction (controlling the first half's influence parameters, i.e., influenced steady state and threshold parameters), and the second part was to assess whether the nature of the influence process itself in the first half affected the uninfluenced steady states of the second half (controlling the first half's uninfluenced steady state).

To test these hypotheses, we conducted a regression analysis with group as the main effects variable (group = 2 for the divorced and unhappy couples and group = 1 for every other couple, so that increases in the grouping variable implied the declining health of the marriage) and with Group × Predictors as the interaction. The variables to be predicted were the second half's uninfluenced steady states. The regression had three steps. In the first step, we entered the relevant control variables. In the second step, the main effect variables were then stepped into the equation. In the third step, the interactions were stepped in (assessed by multiplying the group variable by the predictors, after first having stepped in the predictors themselves).

Assessing the influence of enduring qualities of the individual on the uninfluenced steady state, by controlling first-half influence parameters. When the wife's second-half uninfluenced steady state was predicted, controlling the social interaction variables, the F-ratio-for-change was $F(7, 108) = 8.62, p = .0041$. In the next step, the interaction with group was not significant, F-for-change $F(8, 107) = .79$. When the husband's second-half uninfluenced steady state was predicted, controlling the social interaction variables, the F-ratio-for-change was $F(7, 107) = 17.72, p = .0001$. In the next step, the interaction with group was significant, F-for-change $F(8, 106) = 6.87, p < .05$. The interaction partial correlation was $-.25$ ($p < .05$), so that the degree of the stability of the husband's enduring quality was negatively related to marital health. Hence, the analysis showed that the uninfluenced steady state did contain a significant component that reflected the enduring qualities of the individual, and, for the husband, this is related to negative marital outcomes.

The effects of the influence process itself. When the wife's second-half uninfluenced steady state was predicted, the F-ratio-for-change was $F(7, 108) = 3.76, p = .0019$. In the next step, the interaction with group was not significant, F-for-change $F(13, 102) = 0.93$. When the husband's second-half uninfluenced steady state was predicted, the F-ratio-for-change was $F(7, 107) = 5.95, p = .0000$. Hence, the influence process itself made significant contributions. In the next step, the interaction with group was not significant, F-for-change $F(13, 101) = 1.67$.

Discussion

The purpose of the dynamic mathematical modeling proposed in this article was to extend to a newlywed sample the mathematical modeling and the theory that previously sought to explain the ability of the RCISS point graphs to predict the longitudinal course of marriages. We made a number of changes. First, we used the previously recommended ogive sigmoidal influence function. We used this function, in part, because the negative threshold could be used to explain the delay and relapse effects if the results supported this.

A weighting of a new observational coding scheme, the SPAFF, was substituted, which described the couple's affective behavior. The SPAFF system makes it possible to code in real time, on-line, and it will make it possible to code not only conflict-resolution interactions but any couple interactions. Using the weighted SPAFF data taken from a conflict-resolution conversation the couple had in the first few months of marriage, we found that the uninfluenced steady states were enough to accomplish the task of predicting divorce in a sample of newlyweds. This alone was an interesting result because it was a replication of Cook et al.'s (1995) result. In using three criterion groups, we found that these parameters not only predicted divorce but also predictively discriminated happy from unhappy stable marriages.

As noted, we also extended the model in this article to use the ogive form of the influence function because this form of the influence function had a parameter, the negative threshold, that theoretically represented that point at which the husband's negativity has a major impact on the wife's behavior. We hypothesized that if this threshold were more negative in divorcing couples, it would offer one possible explanation for the delay effect that Notarius and Buongiorno (1995) had detected and potentially for the marital therapy relapse effect. Indeed, we found evidence that this was the case.

Using the fact that the new approach produces far more data points than the old RCISS method (which relies on the turn at speech as the unit), we were able to estimate model parameters for both first and second halves of the conversation. This allowed us to attempt to understand more about the uninfluenced steady state. We were able to assess the extent to which the uninfluenced steady state represents enduring qualities of the individual, as opposed to the immediate past history of interactive influence processes in the relationship. The analyses showed that both are the case. There was also evidence that the enduring qualities of the husband were predictive of negative marital outcomes.

The modeling transforms an empirical relationship between the point graphs and eventual marital outcomes into concepts that can explain the prediction. The new language includes parameters of uninfluenced steady state, influenced steady state, and the influence functions. These equations can help suggest a mechanism for the observed effect, as opposed to a statistical model. A statistical model suggests that variables are related, but it does not propose a mechanism for understanding this relationship. For example, we may find that socioeconomic status is related to divorce prediction, but we will have no idea from this fact how this effect may operate as a mechanism to *explain* marital dissolution. The nonlinear difference equation model approach suggests a theoretical and mathematical language for such a theory of mechanism. The mathematical model differs from the statistical model in presenting an equation linking a particular husband and wife over time, instead of a representation of husbands and wives, aggregated across couples as well as time.

By varying parameters, we can make predictions of what would happen to this couple if we could change specific aspects of their interaction, which is a quantitative thought experiment of what is possible for this particular couple. We are currently using this approach in a series of specific intervention experiments designed to change a couple's second interaction about a particular issue. The model is to be derived from the couple's first interaction in the laboratory; the intervention is designed to change a model parameter (whether it does or not is assessed). Thus, the model can be tested and expanded by an interplay of modeling and experimentation.

The qualitative assumptions that form the underpinnings of this effort are also laid bare by the process. For example, the choice of the shape of the influence functions can be modified with considerable effect on the model. In accordance with this qualitative approach, subsequent correlational data can quantitatively test the theory. We might use a bilinear form of the influence function, in which there are two different slopes, one for positive and one for negative ranges. This bilinear form of the influence function proposes that every marriage has a negative and a positive stable steady state. In effect, this mathematical form of the influence function is positing that every marriage potentially has a "dark side attractor," and a "bright side attractor." How the marriage proceeds then depends only on the starting values (uninfluenced steady states) and the relative strength of the two attractors. This is an appealing theoretical formulation for any balance theory.

There are several approaches we can take to developing these equations further. One is to explore whether the parameters are functions of other theoretical variables, such as the couple's physiology or the couple's perception of the interaction (derived from our video recall procedure). We expect that physiological arousal may be related to greater emotional inertia and that a negative perception of the interaction would relate to feeling flooded by one's partner's negative affect (see Gottman, 1993) and negative attributions (see Fincham, Bradbury, & Scott, 1991). A second approach is to modify the model. The model is, in some ways, rather grim. Depending on the parameters, the initial conditions determine the eventual slope of the cumulated curves. Unfortunately, this is essentially true of most of our data. However, some couples began their interaction by starting negatively but then changed the nature of their interaction to a positively sloping cumulative point graph; their cumulative graph looked somewhat like a check mark. This was quite rare (characterizing only 3.6% of the sample), but it did characterize about 14.0% of the couples at least for part of their interaction. Also, most curves have local ups following downs. This more optimistic type of curve suggests adding to the model the possibility of *repair* of the interaction once it has passed some threshold of negativity. This could be incorporated by changing the influence function so that its basic sigmoidal shape had the possibility of a repair function in the very negative parts of the x-axis of Figure 1. The size of the repair jolts and the threshold at which the jolt took effect would add other parameters to the model, each of which would have to be estimated from the data.

Another way that the model could be developed is by inquiring about what we might call "strength of the attractors in phase space." Each influenced steady state is like a gravitational force point, and it has a mass or a strength of attraction. This strength is the speed of return of a point perturbed away from the steady state. This notion could have some theoretical appeal. For example, one consequence of our brief interventions could be that they increase the strength of attraction of the positive stable steady state and decrease the strength of attraction of the negative stable steady state. This might be an adequate therapeutic outcome. To operationalize this measure, we are planning to use a standard mathematical parameter called the eigenvalue obtained from linearizing the model using Taylor series in the region near an attractor (see Murray, 1989, Appendix 1 and pp. 65–68). We will have to see if this measure has validity.

We may ask the question, How permanent would these changes be that might be suggested by the models? For example, is changing only a husband's positive affect enough to completely change a dysfunctional marriage? Potentially, according to this model, this is adequate, *assuming that the* influence functions and the other parameters were such that there was indeed a positive influenced steady state for the couple. The model suggests that as long as this state exists, starting on the right side of the separatrix (i.e., husband and wife starting positively), they will inevitably drift toward this positive attractor. The model also suggests a kind of "second-order" change in which the influence functions themselves change. In this case, the marriage can provide a buffer against negativity. The concepts of "first-order" and "second-order" change were appealing to the original systems theorists, and they wrote about them, but they had little notion of how to operationalize them.

The mathematical model made it possible to separate the influence of enduring qualities of the individual on the uninfluenced steady state, by controlling first-half influence parameters, and then to estimate the effects of the influence process itself. The analysis showed that the uninfluenced steady state does contain a significant component that reflects the enduring qualities of the individual, and, for the husband, this is related to negative marital outcomes. Hence, both the history of the individual and the prior history of the relationship affect the "starting" places of the marital interaction. Analyses also showed that the first-half influence process itself makes a significant contribution to the second half's uninfluenced steady state.

In clinical recommendations, a number of writers have suggested the proposition that for healthy marriages, people ought to lower their expectations (Lederer & Jackson, 1968). In a similar vein, Jacobson and Christensen (1996), in their recent book on couple's therapy, suggested moderating the demand for change with acceptance of the partner and also recommended that people should learn how to take better care of themselves and meet their own needs. Although these are extreme views of very balanced positions, the implications for maintenance of change in our results is generally quite the opposite of these recommendations, namely, our results suggest that couples fix problems soon and detect even small issues. Our recommendation, based on the negativity threshold results, would be: "Don't let things ride and have a chance to build up." Baucom's systematic research on expectations and standards in marriage (e.g., Baucom et al., 1996) was intended as a direct test of Lederer and Jackson's proposition. His findings were quite clear that the people with the highest expectations have the best marital outcomes. His findings support our recommendations. Despite the predictive nature of the relationship, it is unclear in the findings about the relationship between the negative threshold parameter and marital outcomes which is cause and which is effect. However, the negative threshold parameter is something that a couple may establish in courtship as they progress toward commitment. We hypothesize that it seems logical that a lowered threshold for negativity implies that negativity does not become escalated, because lower intensity negativity is responded to and dealt with before it escalates. In courtship, a couple may first establish a lower negativity threshold to deal with problems before they become too escalated. This would act to minimize the degree of reciprocity of negativity that leads to escalated conflicts and could be beneficial in the long-term stability and happiness of the relationship. Some support for this notion comes from a 5-year longitudinal study by Filsinger and Thoma (1988) with premarital couples. Dissolution of the relationship and relationship satisfaction were predicted by negative reciprocity, assessed from sequential analysis of observational data.

References

Amidon, E., & Hough, J. B. (Eds.). (1967). *Interaction analysis: Theory, research, and application.* New York: Addison-Wesley.

Arnold, V. I. (1986). *Catastrophe theory.* Berlin, Germany: Springer-Verlag.

Bakeman, R., & Gottman, J. (1986). *Observing interaction: An introduction to sequential analysis.* New York: Cambridge University Press.

Baker, G. L., & Gollub, J. P. (1996). *Chaotic dynamics: An introduction.* New York: Cambridge University Press.

Bateson, G., Jackson, D. D., Haley, J., & Weakland, J. (1956). Toward a theory of schizophrenia. *Behavioral Science, 1,* 251–264.

Baucom, D. H., Epstein, N., Rankin, L. A., & Burnett, C. K. (1996). Assessing relationship standards: The inventory of specific standards. *Journal of Family Psychology, 10,* 72–88.

Beltrami, E. (1993). *Mathematical models in the social and biological sciences.* Boston: Jones and Bartlett.

Berge, P., Pomeau, Y., & Vidal, C. (1984). *Order within chaos: Toward a deterministic approach to turbulence.* New York: Wiley Interscience.

Birchler, G. R., Weiss, R. L., & Vincent, J. P. (1975). Multimethod analysis of social reinforcement exchange between maritally distressed and nondistressed spouse and stranger dyads. *Journal of Personality and Social Psychology, 31,* 349–360.

Castrigiano, D. P. L., & Hayes, S. A. (1993). *Catastrophe theory.* New York: Addison-Wesley.

Cherlin, A. (1981). *Marriage, divorce, remarriage.* Cambridge, MA: Harvard University Press.

Cook, J., Tyson, R., White, J., Rushe, R., Gottman, J., & Murray, J. (1995). The mathematics of marital conflict: Qualitative dynamic mathematical modeling of marital interaction. *Journal of Family Psychology, 9,* 110–130.

Duncan, S. D., Jr., & Fiske, D. W. (1977). *Face-to-face interaction: Research, methods, and theory.* Hillsdale, NJ: Erlbaum.

Ekman, P., & Friesen, W. V. (1978). *Facial Action Coding System.* Palo Alto, CA: Consulting Psychologists Press.

Filsinger, E. E., & Thoma, S. J. (1988). Behavioral antecedents of relationship stability and adjustment: A five-year longitudinal study. *Journal of Marriage and the Family, 50,* 785–795.

Fincham, F. D., Bradbury, T. N., & Scott, C. K. (1990). Cognition in marriage. In F. D. Fincham & T. N. Bradbury (Eds.), *The psychology of marriage* (pp. 118–149). New York: Guilford Press.

Gilmore, R. (1981). *Catastrophe theory for scientists and engineers.* New York: Dover.

Glass, L., & Mackey, M. C. (1988). *From clocks to chaos: The rhythms of life.* Princeton, NJ: Princeton University Press.

Gleick, J. (1987). *Chaos: Making a new science.* New York: Viking Press.

Gottman, J., Markman, J., & Notarius, C. (1977). The topography of marital conflict: A sequential analysis of verbal and nonverbal behavior. *Journal of Marriage and the Family, 39,* 461–477.

Gottman, J. M. (1993). The roles of conflict engagement, escalation, or avoidance in marital interaction: A longitudinal view of five types of couples. *Journal of Consulting and Clinical Psychology, 61,* 6–15.

Gottman, J. M. (1994). *What predicts divorce?* Hillsdale, NJ: Erlbaum.

Gottman, J. M., & Levenson, R. W. (1992). Marital processes predictive of later dissolution: Behavior, physiology, and health. *Journal of Personality and Social Psychology, 63,* 221–233.

Gottman, J. M., McCoy, K., Coan, J., & Collier, H. (1996). The Specific Affect Coding System (SPAFF). In J. M. Gottman (Ed.), *What predicts divorce? The measures* (pp. 1–169). Hillsdale, NJ: Erlbaum.

Guerney, B. (1977). *Relationship enhancement.* San Francisco: Jossey-Bass.

Hendrix, H. (1988). *Getting the love you want.* New York: Holt Rinehart, & Winston.

Jacobson, N. S., & Addis, M. E. (1993). Research on couples and couple therapy: What do we know? Where are we going? *Journal of Consulting and Clinical Psychology, 61,* 85–93.

Jacobson, N. S., & Christensen, A. (1996). *Integrative couples therapy.* New York: Norton.

Karney, B. R., & Bradbury, T. N. (1995). The longitudinal course of marital quality and stability: A review of theory, method, and research. *Psychological Bulletin, 118,* 3–34.

Kelly, E. L., & Conley, J. J. (1987). Personality and compatibility: A prospective analysis of marital stability and marital satisfaction. *Journal of Personality and Social Psychology, 52,* 27–40.

Krokoff, L. J. (1987). Anatomy of negative affect in working class marriages. *Dissertation Abstracts International, 45,* 7A. (University Microfilms No. 84-22, 109)

Krokoff, L. J., Gottman, J. M., & Haas, S. D. (1989). Validation of a global Rapid Couples Interaction Scoring System. *Behavioral Assessment, 11,* 65–79.

Kurdek, L. A. (1991a). Marital instability and changes in marital quality of newlywed couples: A test of the contextual model. *Journal of Social and Personal Relationships, 8,* 27–48.

Kurdek, L. A. (1991b). Predictors of increases in marital distress in newlywed couples: A three-year longitudinal study. *Developmental Psychology, 27,* 627–636.

Kurdek, L. A. (1993). Predicting marital dissolution: A five-year prospective longitudinal study of newlywed couples. *Journal of Personality and Social Psychology, 64,* 221–242.

Lederer, W. J., & Jackson, D. D. (1968). *The mirages of marriage.* New York: Norton.

Locke, H. J., & Wallace, K. M. (1959). Short marital adjustment and prediction tests: Their reliability and validity. *Marriage and Family Living, 21,* 251–255.

Lorenz, E. (1993). *The essence of chaos.* Seattle: University of Washington Press.

Morrison, F. (1991). *The art of modeling dynamical systems: Forecasting for chaos, randomness, & determinism.* New York: Wiley Interscience.

Murray, J. D. (1989). *Mathematical biology.* Berlin, Germany: Springer-Verlag.

Notarius, C., & Buongiorno, J. (1995). *Wait times for marital therapy.* Unpublished paper, Catholic University of America, Washington, DC.

Olson, D. H., & Ryder, R. G. (1970). Inventory of Marital Conflicts (IMC): An experimental interaction procedure. *Journal of Marriage and the Family, 32,* 443–448.

Patterson, G. R. (1982). *Coercive family process.* Eugene, OR: Castalia Press.

Peters, E. E. (1991). *Chaos and order in the capital markets.* New York: Wiley.

Rapoport, A. (1972). The uses of mathematical isomorphism in general systems theory. In G. J. Klir (Ed.), *Trends in general systems theory* (pp. 42–77). New York: Wiley Interscience.

Rosenblatt, P. C. (1994). *Metaphors of family systems theory.* New York: Guilford Press.

Saunders, P. T. (1990). *An introduction to catastrophe theory.* Cambridge, England: Cambridge University Press.

Shannon, C., & Weaver, W. (1949). *The mathematical theory of communication.* Urbana: University of Illinois Press.

U.S. National Center for Health Statistics (1986, September 25). Percent distribution of divorces and annulments by duration of marriage to decree, and median and mean duration of marriage to decree: Divorce-registration area 1984 (Table 11). *Monthly Vital Statistics Report* (Vol. 35, No. 6, p. 14). Hyattsville, MD: Author.

U.S. National Center for Health Statistics (1988). *Percent of all divorces by duration of marriage.* Washington, DC: U. S. Government Printing Office.

Vallacher, R. R., & Nowack, A. (1994). *Dynamical systems in social psychology.* New York: Academic Press.

von Bertalanffy, L. (1968). *General system theory.* New York: Braziller.

VonNeumann, J., & Morgenstern, O. (1947). *Theory of games and economic behavior.* Princeton, NJ: University of Princeton Press.

Wiener, N. (1948). *Cybernetics.* New York: Wiley.

Wiggins, J. (1977). *Personality and prediction.* New York: Addison-Wesley.

Wile, D. B. (1993). *Couples therapy: A nontraditional approach.* New York: Wiley Interscience.

Winfree, A. T. (1990). *The geometry of biological time.* Berlin, Germany: Springer-Verlag.

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