Complex Dynamics in Intimate Partner Violence: A Time Series Study of 16 Women

David A. Katerndahl, MD; Sandra K. Burge, PhD; Robert L. Ferrer, MD; Johanna Becho, BA; and Robert Wood, PhD

Objective: Three theories attempt to explain the dynamics of intimate partner violence, each representing a different dynamic pattern of violence: periodic, chaotic, and random. But few studies assess violence and its potential predictors in real time or permit assessment of the dynamics of violence. The purpose of this exploratory study was to estimate the degree of complexity in patterns of violence and identify predictors of violent events.

Method: This time series study was conducted between September 2006 and April 2007 among 16 adult women presenting to a university-affiliated family health center who had experienced violence within the past month. Women completed a daily telephone assessment of household environment and marital relationship for 2 months. To assess the degree of complexity, 3 different measures were used. Lyapunov exponents and saturation of correlation dimension were used to approximate dynamic patterns. Vector autoregression identified prior-week predictors of violence. Results were pooled across the 16 subjects who provided daily reports using meta-analytic techniques.

Results: Most relationships exhibited complex dynamics, with all 3 distinct dynamic patterns found. The longer the relationship had lasted, the more predictable and periodic were its dynamics. The more frequent the violence, the more complex and sensitive to change were its dynamics. Comparing dynamic patterns, 3 distinct combinations of significant prior-day and prior-week associations were found.

Conclusions: Although complex dynamics were unrelated to duration of violence, there was a dynamic tension between (1) the duration of the relationship and its periodic temporal patterns and (2) the frequency of violence and its complex dynamics. Identification of dynamic patterns may aid understanding of the phenomena of intimate partner violence and lead to novel targeted screening, monitoring, and intervention/treatment approaches.

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Corresponding author: *David A. Katerndahl, MD, Department of Family & Community Medicine, University of Texas Health Science Center at San Antonio, 7703 Floyd Curl Drive, San Antonio, TX 78229-3900 (katerndahl@uthscsa.edu).*

How does intimate partner violence operate in couples? Most of the work on the dynamics of husband-to-wife abuse is based on surveys or qualitative interviews conducted at one or a few points in time.[1,2] Two studies used daily diaries. Fals-Stewart et al[3] had 15 months of daily diaries kept by couples in which the violent husband was participating in a drug abuse treatment program. They found that the use of alcohol and cocaine was associated with aggression against the wife.[3] Umberson et al[4] asked married men to keep daily diaries over a 14-day period and found that, compared with nonviolent men, violent men are less emotionally reactive to stress and relationship dynamics. Also, after separation, violent men tend to increasingly blame their victims, while victims decreasingly support their husband's accounts of events.[1] Although husbands and wives are believed to affect each others' attitudes toward the violence, there is no evidence that the husband's aversiveness to abuse is shaped by the wife's degree of capitulation.[5]

The search for dynamical patterns has yielded contradictory findings. While the work of Wolf-Smith and LaRossa[1] may support a cyclic pattern of abuse, Ristock's study[2] of abusive lesbian relationships suggests that some relationships display cyclic patterns while others exhibit fluctuating power dynamics. Such power dynamics may reflect the use of differing control strategies by perpetrators.[6] Unfortunately, with the exception of the 2 studies described above,[3,4] none of these studies involved daily assessments of violence. A conceptualization and measurement approach based on women's lived experiences may provide the greatest opportunity to correctly explain dynamics of domestic violence.[7] If we are to understand the day-to-day reality of violence, we must "look inside the black box" and collect unbiased data in real time.

THEORIES ABOUT INTIMATE PARTNER VIOLENCE

Many theories address the cause of intimate partner violence, but only 3 theories address the dynamic patterns seen in intimate partner violence (Figure 1). Each theory represents a different dynamic pattern of violence.

Clinical Points

- Most women in abusive relationships experience violence in unpredictable patterns.
- Someday, dynamics-specific treatment approaches may be advocated.
- Women in abusive relationships who do not wish to leave their partners may benefit from journaling, thereby gaining an understanding about the violent patterns within the relationship and potential triggers of violence.

The Cycle Theory of Violence

On the basis of interviews with self-identified battered women, this theory states that battered women are not constantly abused, nor is their abuse inflicted at totally random times. Instead, battering appears to recur in cycles. The battering cycle has 3 distinct phases, which vary in length and pattern across couples. In the tension-building phase (phase 1), minor battering events may occur, but the woman alters her behavior to keep the peace. Many couples remain in this phase for long periods of time, but eventually, tension builds, leading to the explosion.

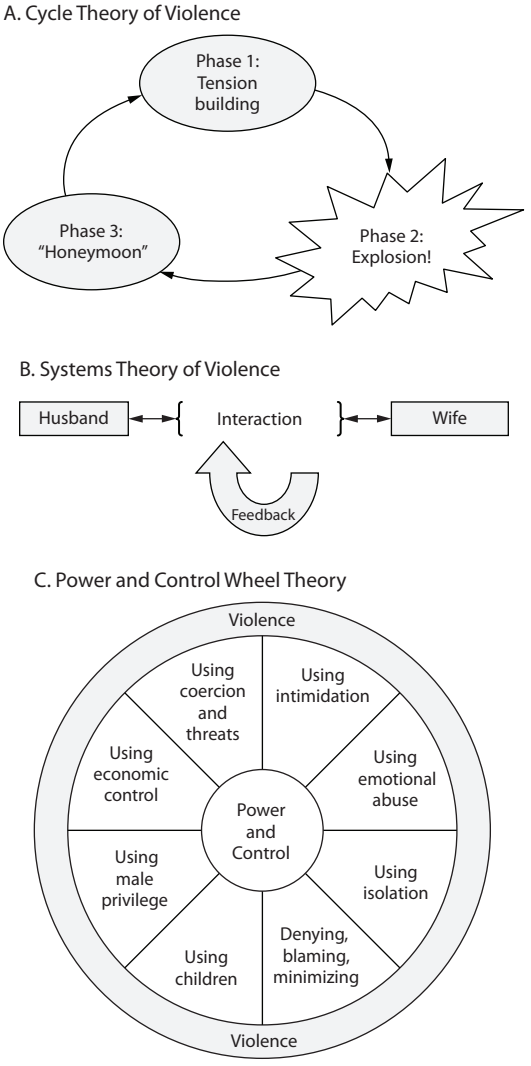
Phase 2 is the acute battering incident (explosion) characterized by high severity and brutality, batterers' lack of control, and brevity (usually a few hours). These episodes are usually triggered by an external event, and the timing may be unpredictable to the victim. Following the explosion is the "honeymoon" (phase 3), wherein the batterer knows he or she has gone too far and tries to reconcile, compensating for the violent behavior with "loving" kindness. This behavior is usually successful at pulling the victim back into the relationship, wherein he or she remains vulnerable to future victimization. Eventually, tension builds, and the couple moves into phase 1 again.[8,9]

The Systems Theory of Violence

Although little research on family systems theory has been conducted as it applies to intimate partner violence, previous work has supported its role in the divorce process[10] as well as in the households of abused and troubled adolescents.[11,12] In this application of family systems theory to intimate partner violence, the systems theory focuses on wife battering as an ongoing interaction pattern resistant to change. The first event of violence in a relationship is generally not severe, and the hitter is usually contrite, so the event does not drive the victim away. When hitting begins, a boundary breaks—the unspoken rule against using violence. The hitter has "stretched" the boundary and the relationship held.[13]

In laboratory experiments, aggressive acts increase the likelihood of the person being aggressive again.[14] At the first act of violence, perpetrators are distressed and contrite about their own behavior. However, with repetition, they become desensitized, and the shock and self-reproof extinguish over time. Being aggressive toward another seems to create a need to justify the violence by degrading the victim. This denigration may then support further violence as victims now seem to deserve the treatment they are receiving. At the same time, victims may acclimate to the punishment and react less dramatically, which leads the aggressor to work

Figure 1. Three Theories Addressing Intimate Partner Violence Dynamics



harder and harder to achieve the same effect. Escalation of aggression is not necessarily tied to the performance of the victim but seems to be more contingent on the abuser's initial aggressive acts. Over time, the physical aggression will squash resistance, while the denigration will batter the victim's self-concept and self-efficacy. The victim becomes trapped in this interaction.[13]

The Power and Control Wheel Theory

Supported by interviews and quantitative cohort studies,[15,16] this theory posits that violence is used to control people's behavior. In contrast to the theory that battering occurs in cycles, authors posit that abuse is a constant force in battered women's lives. Using information from group interviews with more than 200 women, Pence and Paymar[17] developed the power and control wheel, which depicts 8 key nonphysical abusive behaviors exhibited by men who batter: coercion and threats; intimidation; emotional abuse; isolation; denying, blaming, or minimizing the violence; using the children; evoking male privilege; and economic control. It illustrates that violence is part of a pattern of controlling behaviors, not simply isolated incidents of physical violence or cyclical explosions of pent-up anger. A batterer's use of physical assaults may be infrequent, but the assaults reinforce the power of other controlling tactics. These tactics eventually undermine the partner's ability to act autonomously.[17]

UNDERSTANDING RELATIONSHIP DYNAMICS THROUGH COMPLEXITY SCIENCE

Couples can be considered complex systems in which individuals have continued interactions over time; the interactions are affected by learning and feedback. Three general dynamic patterns (periodic, chaotic, and random) are seen in complex systems, and we believe the theories above represent these patterns. Periodic dynamics, in which the system cycles its behavior, result when actions and outcomes are tightly coupled and when current behavior is dependent on previous behavior. Thus, periodic systems have strong tendencies toward constancy, limiting their possible behaviors, and they are insensitive to small changes in their state. Periodic systems are regular and respond predictably to interventions. Because periodic dynamics are so predictable, they are said to be "deterministic" (predictable over the long term).

Chaotic dynamics, in which the overall pattern of behavior recurs but the specific path is unpredictable, result when actions and outcomes are separated in time and when feedback within the system varies in strength and direction. Thus, chaotic systems also tend toward consistency, which limits their behavior but, unlike periodic systems, are sensitive to small changes in the specific path they follow. Chaotic systems are unpredictable over the long term and do not respond predictably to interventions; yet, chaotic systems can be predictable over the immediate short term.

Finally, a type of random dynamics (criticality) is also common in complex systems. This type of random dynamics results from constant stress on a system composed of interdependent components with varying predilections to respond, yielding a random pattern of responses of varying intensity. Random systems do not tend toward consistency, thus their behavior is not limited, and they may or may not be sensitive to changes in their state.[18] Thus, these systems are unpredictable in behavior and in response to intervention. Both chaotic and random dynamics are said to be "nonlinear" because the output of such systems is not proportional to the input and hence is unpredictable.

The 3 theories of intimate partner violence appear to correspond with 3 different dynamic patterns. Under the cycle theory, the 3 phases would yield a cyclic or periodic pattern. Although the period would vary among couples, within each couple, the constellation of constraints and history would keep the periodicity fairly constant. Under the systems theory, the violence would depend on the feedback loops between victim and batterer. Such feedback, variable in strength and direction, should lead to chaotic patterns in violence. Finally, under the power and control wheel, the constant force of abuse would produce constant stress within the relationship, occasionally erupting in violence. The multiple strategies for control may represent interdependent components with varying predilection to respond, typical of critical systems under constant stress. These conditions lead to occasional random violent catastrophes of varying intensity. Hence, we hypothesize that the dynamic pattern of violence observed within abusive relationships can be used as a marker for the process at work within the relationship.

We know little about day-to-day patterns of abuse. Although there are many theories about the causes of intimate partner violence, few address the dynamical patterns in violence. Three generally accepted theories about the dynamics of violence exist, but there is little longitudinal data to support one over another or to explain why different dynamics may be seen in different relationships.[2] In addition, although risk factors for abusive relationships have been noted, we know little prospectively about the day-to-day triggering of abusive events. Holtzworth-Munroe and Meehan[19] have emphasized the need for research on the immediate, situational, and dyadic processes in violent relationships. Urquiza and Timmer[20] have advocated the use of sequential analytic methods to model the interpersonal dynamics of violence.

Thus, the purpose of this exploratory study was to (1) estimate the degree of complexity in daily husband-to-wife violent events over a 2-month period,

(2) identify the dynamic patterns and predictors of violent events within individual time series collected in real time, and (3) combine results across subjects to determine correlates of violent events within the group. Ultimately, we hope this program of study can distinguish among the dynamics-related theories.

METHOD

Overview

This study sought to enroll and follow women from a primary care setting who were in abusive relationships but did not plan to leave their abusive partners. Those who were deemed at low risk for life-threatening abuse completed informed consent. Subjects were asked to report daily via telephone for 2 months about the previous day's violence and home environment. Upon completion, the daily patterns of violence were used to estimate the degree of complexity that violence exhibited and to classify these patterns as periodic, chaotic, or random. In addition, same-day, prior-day, and prior-week correlates of violence were examined using cross-correlations and vector autoregressions (VARs), combining statistics across subjects using meta-analytic techniques.

Sample

Women with a recent history of husband-to-wife physical abuse were recruited from University Family Health Center-Downtown run by the Department of Family and Community Medicine at the University of Texas Health Science Center at San Antonio. Patients visiting the clinic between September 2006 and April 2007 were eligible for inclusion in this study if they met the following criteria:

- Were adult Hispanic or non-Hispanic white women (≥ 18 years old)
- Were not with their husbands at the time of the visit
- Had experienced abuse within the previous month
- Were low risk for victimization by experiencing life-threatening violence during the course of the study.

Procedure

Potentially eligible patients were asked to complete the 6-item brief Conflict Tactic Scale (CTS)[21] in the examination room while they waited to see their physician. The results of the CTS were reviewed by the physician who determined whether the woman had experienced abuse within the previous month. When appropriate, the physician counseled the woman about domestic violence, sharing knowledge about available resources and arranging counseling if desired. Women who had experienced violence within the previous month were then referred by the physician for possible enrollment into the study. Once referred, the bilingual research associate verified the woman's eligibility and conducted a safety assessment to ensure that she was at low risk for experiencing life-threatening violence during the study by asking the following questions:

- Has your husband (partner) ever threatened you with a knife, gun, or other weapon?
- Have you ever broken a bone or been admitted into the hospital because of a fight with your husband (partner)?
- Has your husband ever thrown you from a moving vehicle?
- Is there a gun in your home, or does your husband (partner) have access to a gun?
- Do you feel afraid of your husband (partner)?
- Do you plan to leave your husband (partner) soon, say, within the next 2 months?
- If your husband (partner) discovered that you were participating in a study at the Family Health Center, would he hurt you?
- If your husband (partner) discovered that you received money for participating in a research study at the Family Health Center, would he hurt you?

Only women answering "no" to all of the safety assessment questions were eligible for enrollment and invited to complete informed consent. This study was approved by the Institutional Review Board at the University of Texas Health Science Center at San Antonio. Once enrolled, subjects completed the baseline interview, provided 2 telephone numbers of "safe" contacts, and received information about community resources for victims of domestic violence, if not previously done.

Subjects were offered a cellular telephone (with outgoing numbers restricted to those of the study and 911) to use for reporting daily levels of violence and possible predictors. Subjects were instructed to complete daily surveys by calling into an interactive verbal response telephone system, which can record the subject's responses to the prerecorded survey. This process allowed the subject to report assessments at any time, 24 hours per day, while leaving no written study materials around her home. Callers heard a generic introductory message for the Family Health Center in case the phone number was discovered by the husband (partner). One could only access the survey itself with a 4-digit subject identification number. For 60 days following enrollment, subjects completed the daily assessment by telephone from a "safe" environment, at the same time each day if possible.

Each day, subjects answered the questions about the previous day's experience. Weekly, subjects called the research associate (J.B.) so she could assess their safety, encourage ongoing participation, and answer questions. If no such call was received for 2

weeks, the research associate contacted the subject using the "safe" telephone numbers provided.

Instruments

Baseline and predictor data included variables previously found to be consistent predictors of husband-to-wife abuse.[22] The 13-item baseline interview included data on demographics (including household income, number of children in the household, type of wedding [civil vs church], previous sexual aggression by husband, and witnessing husband-to-wife abuse in household of origin). Basic information about the relationship was also obtained (duration of the relationship, duration of the marriage, duration of the abuse).

The 16-item daily assessment included time series predictor data such as daily measures of hassles, argument frequency, estimates of husband's alcohol intake, level of distress, and marital harmony. Hassles are daily irritations such as concerns about home maintenance and routine financial burdens measured using a 10-item scale consisting of the 10 most-frequently experienced hassles from the original 117-item scale.[23] Subjects indicated which hassles occurred and how irritating they were from "0" (none) to "3" (extremely).[24] The item scores were summed to create a total score that could range from 0 to 30. In previous studies with this instrument in Hispanic patients from our clinic population, the 10-item scale had good internal consistency (0.84) and construct validity.[25] The frequency of arguments was rated from "0" (no arguments) to "4" (argued all day).[26] The husband's daily alcohol intake was estimated using a quantity question from the Alcohol Use Disorder Identification Test[27] rated from "0" (no alcohol) to "9" (≥9 drinks). Level of distress focused on the maximal distress experienced by the women during the day, rated from "0" (no stress at all) to "6" (extremely high stress), while level of marital harmony focused on the couple's closeness and communication as experienced by the subject; it was rated from "0" (very distant) to "3" (very close).

Time series outcome data consisted of a daily rating of the level of violence the woman experienced as measured by the 6-item CTS, ranging from none to verbal abuse to moderately severe violence (ie, throw or kick things, push or slap wife) to severe violent events (ie, kick or punch wife, beat wife, threaten wife with gun or knife). The CTS has been used in numerous studies of domestic violence.[21] Internal consistency for the 6-item form in women from our patient population is 0.856. The CTS was used as the measure of violence in the daily assessment, rating the daily level of violence from "none" to "beating or threatening with a gun." Although the CTS has been criticized, these critiques have focused on its context-free nature; in this study, we measured context via daily assessments.

Analysis

Although 20 women enrolled in the study, 4 (20%) withdrew without providing any daily assessments. Women who withdrew were more likely to be Hispanic and high school graduates and reported longer durations for their relationships and violence. Of the women who completed the study, 2 subjects reported on all days, and 4 had response rates above 80%; 3 had response rates over 60%, and 4 more had response rates over 40%. Because complete data of daily violence levels were needed to examine nonlinear characteristics in the time series and to apply VAR analysis, we imputed any missing daily CTS score occurring between the first and last days reported. This required a special approach because imputation techniques assume linear (predictable) relationships in the data. To impute missing data while retaining its complex characteristics, we applied the nstep procedure from the TISEAN nonlinear time series analysis package.[28] The nstep approach to imputation has been shown to least distort nonlinear characteristics of time series when compared to traditional methods.[29] When the initial datapoints in the time series were insufficient to apply nstep (generally ≤ 4), the mode of the time series was inserted until the time series was long enough to impute. On average, incomplete time series required the insertion of a median of 2.0 modes and 7.0 imputed datapoints per person to produce a usable violence time series (< 25% of violence data were imputed).

Assessment of degree of complexity. Three types of complexity measurements are available, and we used one example of each type.[30] First, Lempel-Ziv (LZ) complexity[31] measures of algorithmic complexity (the amount of information needed to describe the data) were assessed; behavior in systems with low LZ complexity can be easily described with simple models, while that of systems with high LZ complexity cannot. Second, approximate entropy, an information-based measure, assesses the regularity (or the lack of it) with which the possible values vary within the time series.[32] Finally, a chaos-based measure of sensitivity to changes in state (speed with which 2 adjacent points diverge over time) was assessed with the largest Lyapunov's exponent.[33] Using the time series of 60 daily assessments of level of violence, we calculated LZ complexity and Lyapunov's exponents using the chaos data analyzer software for each subject's time series. We calculated approximate entropy using the ApEn module in OCTAVE (CERT, Software Engineering Institute, Carnegie Mellon, Pittsburgh, Pennsylvania). Although this is the first study to assess the degree of complexity in the dynamics of husband-to-wife abuse, entropy (disorder related to the number of possible states a system can assume) has been reported for a variety of psychological measures,[34,35] and approximate entropy has been shown to yield stable estimates with as few as 50 datapoints.[36–38]

Identification of predictors within time series data. To assess same-day correlates of violence, we used Spearman correlations due to the ordinal nature of the violence variable. Because of the exploratory nature of this study, we reported a P value of ≤ .10 for all analyses. To assess relationships between level of violence and lagged predictors (ie, hassles, stress, arguments) during the prior week, VAR models were applied to time series data predicting frequency of violent events. VAR models use multiple concurrent predictors' time series to develop models explaining the dependent variable's time series. VARs provide useful descriptions of temporal covariability among variables, good estimates for forecasting, and sensitivity to identification of external "shocks" to the time series. VARs using regression analysis of time series software were run on each subject using the dependent variable (level of violence) and all of the predictor variables. After running an autocorrelation function to ensure that the time series of the dependent variable (level of violence) was stationary (defined as correlations between adjacent datapoints of less than 0.90), we ran sequential VARs with increasing numbers of lags from 1 to 7 days using only predictor variables that showed any day-to-day variation.

All of the likelihood ratios (assessing whether additional variance was accounted for by increasing the number of lags) were always significant ($P \leq .10$) and could not be used to determine which model was best. Instead, we used the VAR model with the most numbers of possible lags as long as the sum of the squared residuals was minimal and the Durbin-Watson statistic exceeded 0.32, indicating no cointegration (variable time series parallel each other). Although adjusted R^2 may not be accurate, these VARs yielded measures of Granger causality (the extent to which the predictors across the prior week account for the current dependent variable) to assess prior-week correlates and b coefficients (and their significance) for each predictor of level of violence[39]; lag-1 b coefficients were used to assess prior-day correlates. Spearman correlations were used to assess associations between the degree of complexity and characteristics and predictors of abuse.

Identification of dynamic patterns. To assess whether groups of subjects reported similar behaviors, subjects were assigned to 1 of 3 groups based on dynamic patterns. Two measures were used to classify dynamic patterns: the Lyapunov exponents and the presence of a saturated correlation dimension (indicating the tendency toward consistency). A negative Lyapunov exponent with correlation dimension saturation suggested periodic dynamics, while a positive Lyapunov exponent with correlation dimension saturation suggested chaotic dynamics; a positive Lyapunov exponent without correlation dimension saturation suggested random dynamics.[40] Kruskal-Wallis analysis of variance was used to compare predictor coefficients and complexity measures across groups.

Combining measures. Initially, predictors of abuse were analyzed individually by subject. To combine results across subjects, we applied methods traditionally reserved for meta-analyses in which individual study statistics are combined across studies to estimate overall statistics; thus, statistics are combined rather than the raw data. Same-day correlations were combined by squaring each r_s term, calculating the mean r_s^2 overall, and then taking the square root to obtain an overall r_s term, while maintaining the sign throughout. This method yields accurate summaries even if the component correlations differ by more than 0.50.[41] Significance of combined r_s term was based upon whether confidence intervals included zero. To combine the measures of causality (in P values), it is recommended that more than 1 approach be used.[42] Hence, we used the Stouffer technique, which converts P values to Z statistics prior to combining,[43] and the method advocated by Jones and Fiske,[44] which combines the logarithmic transformation of P values. When the 2 approaches were compared, both yielded similar results; however, the Stouffer method yielded slightly higher P values and was determined to be the more conservative approach in this study and thus was selected for use here. Finally, coefficients for the prior-day predictors were combined using Greenland's method,[42] in which weighted coefficients (weighted by standard error) are combined to derive an overall coefficient across subjects.

RESULTS

Table 1 summarizes the demographic, marital relationship, and abuse history information for the women enrolled in the study. This predominantly low-income, Hispanic group of women reported long-term marital relationships. Most women had observed violence during childhood against their mothers and reported experiencing significant violence during the prior month. For most, abuse had started years after their relationship began. The 16 participants who did not withdraw provided 586 daily assessments for a mean of 36.6 assessments per subject.

Home Environment and Violence Among Subjects

Table 2 presents the summary data on relationships, abuse history, and daily assessments of the home environment and abuse for the total sample. Women reported considerable amounts of abuse during their 2 months of recording. Of the 586 reports, subjects reported abuse on 225 (38%) days. Although many of these incidents involved insults or threats (183 incidents), on 104 days women reported husbands throwing things and on 43 occasions reported

Table 1. Demographic, Marital Relationship, and Abuse History Information for the Women Enrolled in the Study (N = 20)

Variable	Participants (n = 16)	Withdrawals (n = 4)
Demographics		
Race/ethnicity, n (%)		
White	4 (25)	0 (0)
Hispanic	12 (75)	4 (100)
Age, mean ± SD, y	36.9 ± 11.8	42.3 ± 16.1
Employment, n (%)		
Part-time	1 (6)	1 (25)
Full-time	7 (44)	2 (50)
Education, n (%)		
< High school graduate	9 (56)	0 (0)
High school graduate	3 (19)	4 (100)
Some college	4 (25)	0 (0)
Income (< $20,000), n (%)[a]	4 (50)	2 (50)
Socioeconomic class, n (%)		
III	1 (6)	1 (25)
IV	6 (38)	0 (0)
V	9 (56)	3 (75)
Marital relationship		
Type of marriage, n (%)		
Church	4 (25)	1 (25)
Civil	7 (44)	3 (75)
Common law	5 (31)	0 (0)
No. of children, mean ± SD	1.44 ± 1.37	1.25 ± 0.96
Duration of relationship, mean ± SD, y	14.7 ± 9.4	22.5 ± 14.8
Duration of marriage, mean ± SD, y	14.0 ± 9.6	19.0 ± 13.1
Onset lag (marriage-relationship), mean ± SD, y	0.7 ± 1.1	3.5 ± 1.7
Abuse history		
Witnessed abuse as child (frequency), mean ± SD[b]	2.6 ± 1.7	1.5 ± 1.3
Abuse onset from start of relationship, mean ± SD, y	29.3 ± 11.0	24.5 ± 13.7
Abuse duration, mean ± SD, y	8.7 ± 7.0	17.8 ± 18.0
Onset lag (abuse-marriage), mean ± SD, y	5.3 ± 9.0	1.3 ± 7.9
Onset lag (abuse-relationship), mean ± SD, y	6.1 ± 9.1	4.8 ± 7.1
Abuse severity prior month (level), mean ± SD[c]	2.4 ± 1.3	1.3 ± 0.6
Husband forced her into sex, n (%)	4 (25)	1 (25)

[a]Data incomplete.
[b]Frequency range, 0–4.
[c]Severity range, 1–6.

being pushed or slapped. Six women reported being kicked or hit on 21 occasions, and 3 women were beaten on 5 different days. One woman reported being threatened with a weapon on 31 days.

Table 2 also summarizes the correlates of abuse. Same-day correlations suggest that, on the day of abuse, the level of arguments and stress correlate significantly with the level of abuse ($r_s = 0.54$ and 0.36, respectively), while closeness was inversely related ($r_s = -0.37$). When seeking predictors in the week prior to abuse (based on Z statistics for Granger causality), the levels of violence, hassles, arguments, and closeness were significantly related to subsequent abuse. However, only 1 predictor (arguments) was significantly associated (using VAR) with the following day's abuse, suggesting that frequent arguments 1 day were associated with level of violence the next day.

Measures of Degree of Complexity and Their Relationships With Abuse

Most subjects demonstrated complex dynamics of abuse, as assessed by 3 different metrics. First, LZ complexity (is the pattern simple to describe?) was high with a mean of 0.977 (± SD = 0.360; values > 0.25 suggest complex dynamics). Second, the mean approximate entropy (are values regular over time?) across all subjects was 0.535 (± SD = 0.212; values > 0.40 suggest unpredictable dynamics). Most approximate entropies were within the range of chaotic dynamics. Third, the overall mean for Lyapunov's exponent (are the data sensitive to change in state?) was 0.054 (± SD = 0.282); most subjects had Lyapunov exponents within the range of chaotic dynamics. However, several subjects had negative exponents, suggesting periodic dynamics.

Significant correlations between measures of degree of complexity and abuse characteristics were found. Higher LZ complexity was related to shorter relationship ($r_s = -0.490$, $P \leq .10$) and marriage ($r_s = -5.06$, $P \leq .10$) durations. However, degree of complexity was not correlated to baseline characteristics or levels of daily predictors. Concerning measures of daily abuse and their predictors, LZ complexity was only associated with the coefficient of prior-day arguments ($r_s = -0.495$, $P \leq .10$). Approximate entropy was related to same-day correlation with hassles ($r_s = 0.511$, $P \leq .10$) and proportion of days with any abuse ($r_s = 0.550$, $P \leq .05$). Lyapunov's exponent correlated with proportions of days with any abuse ($r_s = 0.698$, $P \leq .01$) or insults/threats ($r_s = 0.637$, $P \leq .05$) as well as prior-day arguments ($r_s = 0.664$, $P \leq .05$). Excluding LZ complexity, these results suggest that the more frequent the abuse, the more complex (and unpredictable) the violence dynamics.

Dynamic Patterns and Differences in Outcomes

By combining Lyapunov's exponent (positive versus negative) and correlation dimension saturation (present versus absent), 12 (75%) subjects could be classified as periodic (n = 3), chaotic (n = 4), or random (n = 5) in their dynamic patterns. Table 2 compares the relationship and abuse characteristics across dynamic patterns. Dynamic patterns did not differ in their relationship, baseline abuse, or daily home environment variables. However, the dynamic patterns did differ in the proportions of days with any abuse, insults/threats, and pushing/slapping. The chaotic group reported the highest frequencies of violence, while the periodic group reported the lowest frequencies.

While the dynamic patterns demonstrated no statistical differences in same-day correlations, they did differ in prior-week and prior-day predictors. The group with periodic dynamics had significant prior-week associations for abuse, hassles, and stress. The group with chaotic dynamics reported prior-week associations for abuse, hassles, arguments, and closeness. Finally, the

Table 2. Summary Data on Relationships, Abuse History, and Daily Assessments of the Home Environment for the Final Sample (n = 16)

Variable	Dynamic Patterns[a]				Statistics (Kruskal-Wallis χ^2)[b]
	Total (n = 16)	Periodic (n = 3)	Chaotic (n = 4)	Random (n = 5)	
Baseline relationship, mean					
Relationship duration, y	16.4	16.7	17.5	8.8	NS
Marriage duration, y	15.1	16.3	16.5	7.8	NS
Marriage-relationship lag, y	1.3	0.3	1.0	1.0	NS
Witnessed abuse as a child, frequency (rank)	2.4	5.8	6.4	7.0	NS
Baseline abuse					
Abuse onset age, mean, y	28.3	25.3	30.0	29.0	NS
Abuse duration, mean, y	10.6	7.7	10.3	7.8	NS
Abuse-marriage lag, mean, y	4.5	8.7	6.3	0.0	NS
Abuse-relationship lag, mean, y	5.8	9.0	7.3	1.0	NS
Abuse severity prior month (range, 1–6)	2.2	3.5	2.0	2.0	NS
Forced into sex, n (%)	5 (25)	1 (33)	1 (25)	2 (40)	NS
Daily environment, mean[c]					
Violence (maximum)	3.1	3.3	3.3	3.6	NS
Hassles (minimum)	12.4	8.2	20.1	11.1	NS
Arguments (median)	0.8	0.2	1.6	0.7	NS
Alcohol (median)	7.8	8.8	8.0	6.2	NS
Stress (median)	3.6	3.0	4.3	4.2	NS
Closeness (median)	1.0	1.7	1.1	0.5	NS
Proportions of abuse, mean					
Any abuse	0.38	0.12	0.66	0.35	6.79*
Insults/threats	0.27	0.06	0.53	0.28	4.81#
Throwing things	0.17	0.06	0.38	0.15	NS
Pushing	0.07	0.01	0.14	0.07	4.63#
Kicking	0.04	0.01	0.03	0.05	NS
Beating	0.01	0.01	0.02	0.00	NS
Weapons	0.05	0.00	0.18	0.00	NS
Correlates of violence[d]					
Same-day correlations, r_s					
Hassles	0.22**	0.21#	0.31***	0.14	NS
Arguments	0.54****	0.36****	0.48**	0.65****	NS
Alcohol	−0.22	−0.15	0.19	−0.30	NS
Stress	0.36****	0.23****	0.40	0.41**	NS
Closeness	−0.37***	−0.39	−0.47***	−0.22	NS
Prior-week predictors, causality *Z*					
Violence	5.94****	2.22*	4.56****	2.59**	NS
Hassles	4.14****	2.94***	1.81#	1.57	NS
Arguments	4.60****	1.27	2.82***	2.81**	NS
Alcohol	0.48	1.44	−0.87	0.36	NS
Stress	1.55	2.23*	0.10	−0.78	NS
Closeness	3.18****	0.48	2.08*	1.48	NS
Prior-day predictors, b					
Violence	0.058	0.081	0.168	−0.024	NS
Hassles	0.018	0.038	0.009	−0.010	NS
Arguments	0.179****	0.099	0.718****	0.194*	6.11*
Alcohol	−0.009	−0.023	0.605****	0.001	NS
Stress	0.001	0.021	0.062	0.008	NS
Closeness	−0.040	−0.078	0.006	0.017	NS

[a]4 subjects not classifiable.
[b]Differences in measures across patterns.
[c]Because each subject had up to 60 daily reports, a summary statistic for each variable was used for each subject (ie, maximum violence level), and the mean for each statistic across all subjects was reported.
[d]Correlates of abuse for same-day r_s statistics, prior-day b coefficients from vector autoregression analyses, and prior-week Granger causality *Z* statistics.
#$P \leq .10$.
*$P \leq .05$.
**$P \leq .01$.
***$P \leq .005$.
****$P \leq .001$.
Abbreviation: NS = not significant.

group with random dynamics had significant prior-week associations for only abuse and arguments. The dynamic patterns had 3 distinct patterns of prior-day predictors. No prior-day predictors were significant for the periodic group, while arguments were significant for the random group, and arguments and alcohol were significant for the chaotic group (see Table 2).

DISCUSSION

Most subjects reported complex dynamics of abuse. Although we measured degree of complexity with 3 different metrics, and their overlap was imperfect, there was strong evidence of complex dynamics in nearly all the relationships. Three dynamic patterns were identified, corresponding with 3 theories of the day-to-day dynamics of intimate partner violence. The chaotic pattern (systems theory) was the most violent, reporting violence on 66% of days, with the highest severity. In these relationships, violence recurs at regular yet unpredictable intervals. In contrast, the periodic pattern (cycle of violence) had violence on only 12% of days, with the lowest severity; violence in these relationships is predictable and occurs at regular intervals. The random pattern (power and control wheel) fell in the middle, with violence on 35% of days, with a midlevel severity of violence; violence in these relationships shows no pattern except unpredictability.

The degree of complexity in these relationships may be driven by varying phenomena. First, men's motivations and behaviors related to violence shift over time. Violent men can be categorized in predictable typologies; however, a man's typology does not remain stable over time.[19] Second, violent men use different standards when judging their own and their wives' behavior against the tapestry of past memories that trigger violence. Violent men tend to use rigid criteria when judging their wives, suggesting a linear (predictable) component, but use flexible criteria when judging their own behavior, suggesting a nonlinear (unpredictable) component.[45] This use of different and inconsistent standards may be reflected in the dyadic splitting observed by Seigel.[46] She examined batterers and battered women who return to their husbands and found that the battered women held views that their partners' views and behaviors concerning their relationship are often either extremely favorable or extremely unfavorable and could quickly shift between these extremes. Sudden shifts in perspective could contribute to complex dynamics in their interactions.[46] Third, aggressive behavior within the marriage is not just the product of the relationship and its household environment. External sources of demand and support interact constantly with the marital system leading to unstable, unpredictable dynamics.[47] The combination of unstable typologies among violent men, disparate criteria applied by these men to their own and their wives' behaviors, and marital systems in a constant state of flux due to external supports and stresses may produce the complex dynamics we observe in most of these violent relationships.

Predictors of Violence

We evaluated a range of same-day, prior-day, and prior-week associations of violence. In line with expectations, arguments were consistently associated with violence across all 3 time frames. Husbands' alcohol use was not associated, because most drank at the highest level of measurement with little variability. Heavy drinking by batterers is consistent with previous studies.[3,48]

Contrary to expectations, we did not find consistently high levels of stress. Nor did prior-day or prior-week stress predict violence. Only same-day stress seemed consistently associated with violence. Frye and Karney[47] also found evidence that acute stress in violent husbands triggered abuse, although their sample also reported chronic stress, unlike ours. Schumacher et al[48] found that stress and negative life experiences were consistent factors, but that home and occupational stress did not predict physical abuse. This lack of a consistent link between stress and violence may reflect a complex relationship, in which stress is important because of its role as a moderating factor. A previously unstudied association, hassles, proved to be a same-day and prior-week predictor of violence.

Sense of closeness was inversely related to same-day violence as well as being a prior-week predictor. Low sense of intimacy was associated with abuse in previous studies,[49] as was poor attachment,[48,50] poor marital satisfaction,[48] poor marital adjustment,[50] and poor communication skills.[50] Thus, the relationship between violence and sense of closeness that we found agrees with prior work. However, the relationship between closeness and violence is complex. First, emotional commitment may motivate a woman to remain in a relationship with a violent man. Second, a lack of intimacy may trigger violence,[51] or, conversely, violence may cause emotional distance.

Finally, violence itself predicts violence. This study found that prior violence predicted subsequent episodes. This finding is consistent with laboratory experiments, wherein aggressive acts increase the likelihood of the person being aggressive again.[14] Aggression is not necessarily tied to the performance of the victim but seems to be more contingent on the abusers having begun aggressive acts in the first place.[13] In this study, prior-week but not prior-day violence predicted subsequent violence; next-day violence was unusual. This may reflect the woman distancing herself from her spouse or contrition on the part of the abuser.

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In summary, despite considerable individual-level variation, there are common patterns seen both on the day of abuse and on preceding days.

Dynamic patterns revealed varying combinations of predictors. Patterns differed in same-day hassles, stress and closeness, prior-day arguments and alcohol intake, and the prior-week levels of hassles, arguments, stress, and closeness. The group with periodic dynamics (reflecting the cyclic theory of violence) had no significant prior-day predictors, but stress was an important prior-week factor. The group with random dynamics (reflecting the power and control wheel) differed from the entire sample in the following way: same-day and prior-week hassles and closeness were not significantly related to violence. The group with chaotic dynamics (reflecting the systems theory of violence) differed from others in the following way: prior-day alcohol use was associated with violence, but same-day stress was not correlated.

Implications of Violence Dynamics

This study has several implications for theories about intimate partner violence. We hypothesized that different theories would be associated with different dynamics and found evidence for all 3 dynamic patterns. Potential interpretations include the following. First, each theory may describe a different subpopulation of battering relationships. Johnson[52] suggests that different research methods using different sampling strategies (population versus shelter samples) capture different subsets of violent couples. For example, shelter samples display more severe, escalating violence, while population samples report less severe, sporadic conflicts. Holtzworth-Munroe and Meehan[19] described varying batterer typologies, and these may be reflected in different dynamic patterns.

Second, the theories may be describing a developmental transition over time, as suggested by Heath.[53] Longer relationships were more linear in their dynamics, with a possible transition from chaos to randomness to periodicity. As the dynamics move from chaos to periodicity, the importance of stress increases, while that of closeness decreases; prior-day predictors steadily lose their importance. This suggests that over time, the system becomes less responsive to environmental stimuli and more hard-wired. Heath[53] suggests that linearity in dynamics is often a mark of severe pathology in the system.

Third, it is possible that none of the 3 theories can accurately describe the dynamics of intimate partner violence. Can a single theory capture such a complex phenomenon? We observed that each woman reported a unique pattern of violence, triggers, and predictors. These theories naturally represent an oversimplification of each relationship's unique environment and stressors; thus, our results may reflect this limitation when applying models to complex systems.

This line of inquiry may lead to treatment implications. Phenomena with complex dynamics yield unpredictable responses to treatment; complex dynamics were found in most of the couples in this study. Recognizing dynamic patterns may assist in the development of pattern-specific approaches. Thus, women displaying periodic dynamics may respond to a simple targeted intervention, while those with chaotic dynamics may need control or anticontrol techniques that target the dynamics themselves rather than the pathology.[53] Random dynamics may need multifaceted treatment approaches. Finally, the strategies used in this study to retain women and gather information may themselves have clinical applications. Women's daily reports (such as journaling) could provide personal feedback to help them identify when a situation is ripe for violence so they could act to avoid the violence or reduce the risk of escalation.

Limitations

This study is subject to several important limitations. First, we excluded women who were at high risk for life-threatening violence. The frequency and intensity of violence reported here is therefore likely to underestimate the abuse in more violent relationships. Those who did not withdraw from the study had been in their relationships and experienced violence for a shorter period of time. Second, the sample size is small. Even accepting a liberal *P* value for significance, this study is still underpowered. Third, because the sample consisted of predominantly low-income, Hispanic women, results should be extrapolated cautiously to other groups. Fourth, missing and imputed data may have biased the dynamics assessment. While the 3 measures of degree of complexity were not associated with day-of-week reporting differences, each measure was associated with a different source of datapoints. LZ complexity was inversely related to the number of daily assessments made, the Lyapunov exponent correlated with the number of modes inserted, and approximate entropy was correlated with the number of imputed datapoints. Kreindler and Lumsden[54] found that Lyapunov exponents were resistant to the effects of missing data if nonlinearly imputed data were used in datasets with underlying periodic or chaotic dynamics; however, the amount of imputed data in this study exceeded the 15% studied by Kreindler and Lumsden.[54]

Finally, the validity of the dynamic-theory patterns may be questioned. We may have overreached in mapping the theories of intimate partner violence into specific dynamic patterns. The autoregressive moving average models generally agreed with the patterns expected: autoregressive moving average models in periodic dynamics and 0,0,0 models in random dynamics. As predicted, approximate entropy and LZ complexity are maximal in the random group, and the maximal significant lag is highest in the periodic group. From the

theoretical model standpoint, the significant predictors found matched what was expected. The cyclic theory was associated with hassles and stress, the systems theory was associated with closeness, and the power wheel group had the fewest significant predictors.

CONCLUSION

Although each woman reported unique patterns of abuse, some commonality was identified. In addition, violent relationships often demonstrated complex dynamics, but all 3 dynamic patterns were observed, supporting all 3 theories. Three potential interpretations follow: all 3 theories could be correct, with each operating in a subset of violent relationships; 3 theories may represent developmental stages in violent relationships; or none could be correct, with more coherent and comprehensive understanding of intimate partner violence awaiting a new theory. Further exploration of the dynamics of intimate partner violence may lead to new understanding and eventually to unique and targeted interventions as well as novel screening and monitoring approaches.

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