Emotional Well-Being in Recently Bereaved Widows: A Dynamical Systems Approach

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A dynamical systems approach was used to model the intraindividual variability in emotional well-being following conjugal loss. Well-being in a sample of 19 recently bereaved older adult widows was measured every day for 3 months. The pattern of variability of well-being was hypothesized to be an oscillating process that changes across time (i.e., large swings followed by gradual damping). Results indicated there was significant patterned variability in the emotional well-being adjustment that can be modeled by a linear oscillator model (R2 = .77), in addition to an overall positive trend. Applying dynamical systems analyses to capture variability and subsequent well-being trajectories following spousal loss is an important step in delineating the complex adjustment to widowhood.

The death of a spouse in later life is consistently rated as the most stressful normative life event (Bonanno & Kaltman, 2001; Bonanno et al., 2002; Holmes & Rahe, 1967). Furthermore, losing a spouse is three times more likely to occur for women than men, which leads to twice as many women over the age of 65 living alone (U.S. Bureau of the Census, 1997). Conjugal bereavement has been studied extensively; however, there is a gap in our understanding of the process by which new widow(er)s adjust (Blazer, 1990; Lund, Caserta, & Dimond, 1993). According to Wortman and Silver (2001), many researchers have studied bereavement over the past several decades in order to advance our understanding of the field. Traditionally, researchers have examined grief by using cross-sectional studies. More recently, longitudinal studies have been carried out that begin in the first few months after the death and continue for some period of time thereafter. Considering that the adjustment to the death of a spouse is ongoing and contextual, it was important for researchers to make this shift from making comparisons at one or two time points to assessing the change in adjustment across time. The goal of the present study is to complement this work by adding a third style of analysis, which is the examination of the variability in the well-being process after the loss of a spouse.

Many different emotional and psychological states are experienced during the grief process, which can lead to marked fluctuations in mood (Blazer, 1990). Generally speaking, being able to manage one’s expression of emotions has been viewed as an especially important component of well-being (Staudinger, Marsiske, & Baltes, 1993), and not surprisingly, widow(er)hood has been described as inducing states of emotional imbalance (Thomas, DiGiulio, & Sheehan, 1988). One approach to defining successful adjustment or recovery to an event such as conjugal loss is to identify an individual’s ability to keep his or her distress within emotional bounds, or to regulate his or her emotions (Kessler, Price, & Wortman, 1985; Stroebe, Hansson, Stroebe, & Schut, 2001). For example, in a sample of widows, the women who indicated “high distress” 2 years postloss were described as less emotionally stable and more apprehensive and anxious (Vachon et al., 1982). Much of the research in the area of bereavement has used traditional outcome measures, such as depression, anxiety, life satisfaction, and grief resolution. Although researchers have explicitly claimed that patterned emotional fluctuations are associated with the loss of a spouse, this idea has been difficult to test, given the traditional methodologies used in bereavement research. That is, examining specific psychological well-being outcomes as predicted concurrently or even longitudinally does not allow researchers to fully understand the fluctuations in emotional well-being expression after the death of a spouse.

Many researchers and helping professionals view grief resolution as a process that most individuals must go through if they are to master their loss successfully (Stroebe, 1992). According to Stroebe (1992), grief work is defined as an active, ongoing process that centers on memories of the deceased and making an effort to become detached from him or her. However, as Wortman and Silver (2001) pointed out, more recent examinations have shown that there is little evidence that “bereaved individuals who show evidence of ‘working through’ their loss ultimately cope better than those who do not” (p. 412). One way to disentangle these ideas is to examine the daily reports of emotional well-being during the first several months of bereavement. (It should be noted that there is no reason to believe that the fluctuations in emotional well-being are limited to being daily ones. There could be within-daily variability as well. An ideal extension of the study would be to assess emotional well-being multiple times a day; however, given the burdensome task of remembering to complete the questionnaires, we opted to simplify the design by asking our widows to only do it once.)

Support for a more process-oriented approach to understanding loss can be seen in more recent concepts of bereavement. For example, a recent model of coping with bereavement theorizes about the importance of oscillation in the initial months following loss (Stroebe & Schut, 1999). The dual process model of coping includes the stressors related to loss, the cognitive strategies that assist in adjustment to the event, and the “dynamic process of oscillation” (Stroebe & Schut, 1999, p. 212) that distinguishes this conceptualization from more...
traditional models of adjustment. The dynamic process of oscillation refers to the alternation between loss- and restoration-oriented coping. More specifically, at various points in the bereavement process, the widow will confront her loss (i.e., loss orientation), whereas at other times she will actively avoid thinking about it by doing new things or distracting herself from the grief (i.e., restoration orientation). Stroebe and Schut (2001) pointed out the necessity of oscillating between positive and negative affect as a manifestation of loss and restoration. This cognitive process is a self-regulatory mechanism (see e.g., Carver & Scheier, 1998) that is specified as dynamic; oscillation is hypothesized as being necessary for successful adjustment to take place (Stroebe & Schut, 1999).

Our primary purpose in the present study was to assess the initial process of grief resolution. Specifically, our focus was on how individuals regulate emotional well-being between 1 month and 4 months following conjugal loss. We used a dynamical systems approach to identify the intraindividual variability in emotional well-being following the loss of a spouse. This type of methodology allows the parameters (i.e., the variability in emotional well-being, the frequency of well-being shifts, and the rate at which these shifts occur) of the system to be estimated. More specifically, this allows us to make an explicit test of the oscillation of emotional well-being.

Although much research on bereavement has focused on outcomes, some work has assessed the trend associated with psychological well-being postloss. In one study, researchers assessed measurements of psychological well-being at four time points, including 4, 7, 10, and 13 months postloss (Beem, Maes, Cleiren, Schut, & Garssen, 2000). They found that psychological dysfunction decreases across time and that the nature of this decrease was linear. Additionally, widows had higher levels of psychological dysfunction than a comparison group of nonwidows. In a second study examining the trend of adjustment to conjugal loss, researchers examined depression levels at four different occasions postloss (ranging from 6–20 weeks to 18 months). They found five different types of curves, including (a) low depression, stable; (b) high depression, stable; (c) high or moderate depression, descending; (d) ascending depression; and (e) moderate depression, stable (Levy, Martinowski, & Derby, 1994).

As already delineated, previous examinations of widowhood have been designed in one of two ways: Either they assess group differences in outcomes (interindividual differences), or they use multiple points in time to assess the change in well-being (intraindividual change). According to Baltes, Reese, and Nesselroade (1988), interindividual differences refer to differences between individuals on a given behavior or characteristic at one point in time. Conversely, intraindividual change refers to within-person differences in the same behavior across time and is characterized as relatively slow changes that occur as a result of precursors, consequences, and correlates (Baltes, 1987). Both of these types of designs are important and necessary in understanding the effects of conjugal loss on an individual’s psychological well-being; however, one of the existing gaps in the bereavement literature is the inability of current designs to examine the variability in psychological functioning. Intraindividual variability refers to relatively short-term changes that occur rapidly (Nesselroade, 1990a). This type of variability is often viewed as random noise and is not part of the conceptualization of change. Nesselroade (1990b) claimed, however, that this variability may not be noise; rather it may be indicative of changes in attributes, such as states (as opposed to traits) in the organism. The variability in emotional well-being after a significant life event is by nature a measure of intraindividual variability, in that an individual experiences marked fluctuations in states that are more or less reversible. Because emotions “manifest as rapid, fleeting, and organized response systems” (Bonanno & Kaltman, 1999, p. 765), using methodologies that assess interindividual differences or intraindividual change ignore any patterned variability in emotions that may be present.

To understand the expression of emotional well-being after a significant life event, we need a methodology that allows for the possibility of oscillation across time (Larsen, 1987). One such approach is dynamical systems, which gives researchers a unique investigative opportunity in the study of bereavement in later life. A basic assumption of dynamical systems is that all systems change and evolve in time (Boker, 2002). The knowledge of a system’s current state contributes to the prediction of the future state of the system (Nowak & Lewenstein, 1994). Dynamic systems are made up of dynamic variables, which are numbers that change in time and that characterize the relevant properties of the state of the system. Nowak and Lewenstein (1994) made the distinction between order parameters, which are macroscopic global parameters internal to the system, and control parameters, which represent conditions or influences external to the system itself but that determine to a great extent the character of the dynamics observed.

According to Smith and Thelen (1993), there is a geometric way of understanding a dynamical system. The set of numbers \( x_1(t), x_2(t), \ldots, x_n(t) \) may be considered coordinates of a point in an \( n \)-dimensional space, called a phase space. The actual state of the system, described by the dynamical variables, is represented as a point in this space. This motion draws a curve, or a sequence of points, in the phase space that is often referred to as a trajectory. In other words, a trajectory is a set of points “visited” by the system during its time evolution (Nowak & Lewenstein, 1994). A phase space portrays all the potential states of a system and the transitions between them (Smith & Thelen, 1993). Generally, the trajectory settles into a subset of the phase space, which is called the system’s attractor (Nowak & Lewenstein, 1994). Whatever its initial conditions and whatever path the system takes to reach equilibrium, the attractor is the ultimate region in which the system settles.

We used a dynamical system modeling perspective in the present study. Lund and colleagues (1993) hold that there are many ups and downs during conjugal loss. Furthermore, one theory of adaptation holds that people will eventually adapt to even the most extreme positive and negative life events (Brickman & Campbell, 1971). More specifically, Lucas, Clark, Georgellis, and Diener (2003) overview that, according to the crisis explanation for the association between marital status and subjective well-being, marital transitions are disruptive and cause short-term changes in well-being, which ultimately return to previous levels through adaptation. Therefore, on the basis of specific research on bereavement as well as more general research on adaptation, we tested a model in the present study that reflected a “pendulum with friction” that is hypothesized...
to reflect the pattern in intraindividual variability that may result from conjugal loss. We refer to this model as a damped linear oscillator (see Figure 1). According to a recent model of coping, oscillation between positive and negative affect is necessary in order to adjust to one’s loss successfully (Stroebe & Schut, 2001). A linear oscillator model examines the parameters of the oscillations in order to determine if, after a period of time, these oscillations damp, remain stable, or magnify.

The equation for the damped linear oscillator can be expressed as a linear regression formula in which the acceleration is the outcome variable and the position and velocity are the predictor variables (Boker, 2001). More specific to a developmental perspective, velocity refers to the linear change in the system (e.g., change in emotional well-being), and acceleration pertains to the curvature. Differential equation models express effects within a system in terms of their derivatives (i.e., the instantaneous rates of change of the variables) as well as in terms of the values of the variables themselves (Boker & Graham, 1998). For example, a differential equation model of the variability in emotional well-being after conjugal loss might relate daily well-being to its slope, or first derivative (i.e., how rapidly the widow’s emotional well-being was changing), whereas a more complete model might include effects related to its curvature, or second derivative (i.e., how rapidly emotional well-being was accelerating and decelerating in its change). These three parameters, initial position (emotional well-being), velocity (change), and acceleration (speed of change), are related as a dynamical system in which the relationships between them define a central tendency of a family of trajectories that any one individual might have (Boker & Bisconti, in press).

Differential equations models are only one method for testing patterned variability in longitudinal data. These models constitute a continuous time extension of other time series methods such as Auto Regressive Moving Average (ARMA) or Auto Regressive Integrated Moving Average (ARIMA) models and offer a number of advantages. There are three primary advantages to state-space continuous time differential equations techniques such as the local linear approximation method (Boker & Graham, 1998) used here or the stochastic differential equations method (e.g., Oud & Jansen, 2000). First, the derived parameters are independent of the interval between occasions of measurement. Second, the distribution of the residuals is independent of the interval between occasions of measurement and length of the time series. Third, the estimated parameters from such models have appealing interpretations, such as a frequency of oscillation or amount of damping, that can be communicated in a meaningful way to substantive researchers (see Boker, Neal, & Rausch, in press, for a more complete discussion).

In sum, opportunities for growth and development coexist with the losses associated from the death of one’s spouse in later life. Previous investigators have described the bereavement process as a roller coaster, with many ups and downs, although to our knowledge few if any investigations to date have actually examined this idea. The current study is designed first to empirically examine whether there are patterned oscillations within the first months following the death of a spouse, and second to determine if these oscillations damp across a 3-month period.

**Methods**

**Participants**

Forty Caucasian widows from the Northern Indiana–Southwest Michigan area met the inclusion criteria of the present study, which was having a spouse at least 60 years of age at the time of his death and not being involved in a subsequent romantic relationship (we used the age of the deceased rather than that of the widow as a criterion because that was available by means of death notices). Participants ranged in age from 57 to 82 years ($M = 72.23$; $SD = 6.13$); all women graduated from high school and 18 of them received some education or training after high school. Income levels were difficult to assess immediately following the loss because of the financial fluctuations that occur immediately following conjugal loss; however, at the follow-up interview (i.e., approximately 4 months postloss), 12 participants reported having a yearly income between $7,500 and $15,000, 19 participants reported an annual income between $15,000 and $25,000, 3 participants reported an annual income between $25,000 and $40,000, and 6 of the participants reported making more than $40,000 per year. Of the participants, 34 were in their first marriage, and 6 were in their second marriage. The length of marriage ranged from 14 to 63 years ($M = 49.93$; $SD = 10.97$).

At the onset of the project, we identified 288 recent widows on the basis of information obtained through newspaper death notices from a midsize Northern Indiana city and surrounding areas. Approximately 7 days after the death, we sent a letter describing the purpose of the study to the 197 widows that had full address information available; we followed up this letter with a phone call. Of the 197 women, we had correspondence with 163 of them, including 13 widows or family members who declined before the follow-up phone call could be made; 94 individuals who declined or had a family member decline for them during the phone call (with the vast majority stating that they “just weren’t interested”); and 56 women who expressed interest. Of the 56 widows who initially accepted, 7 canceled before the initial interview took place, resulting in a sample of 49 widows who participated in the initial interview (approximately 25% of the invited sample of 197), which was conducted between 18 and 42 days after their spouse’s death ($M = 28.76$, $SD = 7.00$; $Mdn = 24$; mode = 24). Nine of the 49 women who were officially enrolled in the study discontinued...
EMOTIONAL WELL-BEING IN RECENTLY BEREAVED WIDOWS

some portion of the project after the first interview; therefore, the data set being used for the present study includes the 40 widows who met the inclusion criteria and who provided sufficient data for the analytical techniques. It should be noted that for 4 of the 9 dropouts, no questionnaires were obtained, but 5 of the women completed the initial packet of questionnaires and are used as a dropout comparison group.

Procedure

We alternately assigned participants to a target group or a control group. The target group (n = 19) participated in the full battery of assessments (described in the paragraphs that follow), and the control group (n = 21) participated only in the initial and follow-up interviews (i.e., no daily assessments). Because it has been shown that writing is associated with an increase in psychological well-being (for a more detailed review of writing as a therapeutic process, see Pennebaker, 1997), our purpose with the second group was to assess the potential treatment effects of filling out the daily surveys. Although reporting one’s daily well-being is not synonymous with freestyle writing, we thought that a similar treatment effect could occur (see Results section for our analyses of group differences).

All interviews took place in the participant’s home. The average time of the initial interview was 90 min and ranged from 60 to 120 min. Interviewers asked each individual several questions to prompt her “story” about the death of her spouse. At the conclusion of the interview, interviewers explained the expectations for the remainder of the study, one of which included filling out the Center for Epidemiologic Studies—Depression (CES-D) scale on the widow’s own within the first few days after the interview. In addition to the interview and the questionnaires, interviewers asked the target group to answer a series of questions each day, which included components of emotional well-being. We gave this daily questionnaire to the participants in bimonthly increments for a total of 12 weeks. We dated each questionnaire, and participants were asked to fill it out in the evening. It was reported that the procedure took 5–10 min per day. If a person missed a day, she was instructed to leave that day’s response sheet blank. Interviewers gave the first set to the participants at the initial interview and included a self-addressed, postage-paid envelope for the participants to use to return the surveys. Every 2 weeks, we mailed a new set of questionnaires (all including a self-addressed postage-paid envelopes) to the widows.

After the 12-week period of data collection was completed, we asked all widows to participate in a follow-up interview, which ranged from 30 to 90 min (average = 45 min). Debriefing also took place, in which participants had a chance to ask any questions and comment on the structure of the study. Again, we asked the participants to fill out the CES-D scale on their own and mail it back. Incentive for participating in the target-widowed group was $50.00 in cash, $30.00 after the first interview and $20.00 after the postinterview. The control group received $30.00 for participation, $20.00 after the initial interview and $10.00 after the postinterview.

To remind the widows in the target group to mail the packet of daily assessments as they finished them, we made phone calls every 3 weeks on average. These conversations were also a way to keep in touch with the widows over the 3-month duration of the project. We also called widows in the control group approximately every 3 weeks to keep the procedure standard across the groups. Although information was not coded for these conversations, the typical conversation lasted between 5 and 15 min and usually involved an informal conversation about how the widows were adjusting to their loss.

Materials

Measures included standard assessments of depression (to assess group differences at both time points) and emotional well-being (daily assessment). In addition, there was a semistructured interview outline that was followed during both interviews.

Emotional well-being.—The Mental Health Inventory (MHI; Veit & Ware, 1983) is a 36-item measure designed to assess aspects of emotional and psychological functioning (in the Results section, we refer to emotional well-being as MHI). Items assess several dimensions, including anxiety (e.g., “Today I felt anxious, worried”), depressive affect (e.g., “Today I felt downhill and blue”), emotional ties (e.g., “Today I felt loved and wanted”), positive affect (e.g., “Today I felt cheerful, light-hearted”), and behavioral or emotional control (e.g., “Today I felt emotionally stable”). Each item is followed by a response format ranging from 1 (completely true) to 4 (not at all true). A higher score indicates a more positive emotional state. In college samples, the reliability (internal consistency) ranged from .92 to .96 (Veit & Ware, 1983). Because there was a small number of participants in the target group, we could not establish internal consistency reliability in the current sample.

Depression.—The CES-D scale was designed to assess depression, emotional distress, or both (Radloff, 1977). This scale consists of 20 items that represent a depressive symptom for which participants rate the frequency of occurrence during the past week; 16 items measure cognitive, affective, behavioral, and somatic symptoms associated with depression, whereas 4 items assess positive affect. Both reliability and validity have been well established (Devins & Orme, 1984). Responses are made on a 4-point scale that ranges from 1 (rarely or none of the time) to 4 (all or most of the time), with a higher score on the scale indicating an increased amount of distress. In the present study, Cronbach’s alpha is $\alpha = .82$. In a larger aging study (N = 232) from the same geographical region, Cronbach’s alpha was $\alpha = .88$ (Bisconti & Bergeman, 1999).

Interview.—The purpose of the interview was twofold: first, to build rapport with the participant, and second, to get some understanding of the impact of the events surrounding the death. The interview was semistructured and audiotaped. At the onset of the study, there was an informal introduction and a brief explanation of the study. Two investigators were present at each interview. Following a small introduction to the interview, each interview was individualized depending on the participant. Some of the specific information that was collected during the interview included the events surrounding the death, whether or not the death was expected, and whether the individual was a caretaker to her dying spouse prior to the death. Although use of this detailed information is beyond the scope of the present study, one way we used it was to determine the comparability of the groups. In addition, there was a second interview for all participants in which the investigator distributed the follow-up
Analyses

Group Comparisons

We conducted analyses to determine whether there were any differences between the individuals who stayed in the project for the full duration and those who dropped out. Results from a series of *t*-test and chi-square analyses on age, depression, how many days since the death, how long the couple was married, whether the marriage was the widow’s first or second, the expectedness of the death, and educational status suggest that individuals who dropped out of the project were younger and more highly educated ($\chi^2 = 11.18, p < .05$) than those who remained in the project. More specifically, widows who dropped out of the project ranged in age from 61 to 68 years ($M = 64.80; t = -2.65, p < .01$), and four of the five went back to work after their husband’s death, which may have contributed to these particular participants’ dropping out. We found no other differences.

To estimate differences between the target group and the control group, we conducted *t*-test and chi-square analyses. There were no significant differences at the initial interview between the two groups on any of the aforementioned variables. In addition, there were no significant differences at the follow-up interviews in levels of depression ($M_{\text{Target}} = 37.44, SD_{\text{Target}} = 6.97, M_{\text{Control}} = 37.19, SD_{\text{Control}} = 9.98$; $t = -0.01, n.s$), suggesting that completing the daily assessments did not have a differential effect on depression outcomes across the 3-month study.

Analyses

**Descriptive statistics.**—Scores ranged from 62 to 144 ($M = 117.44, SD = 13.13$) on the MHl, which was filled out by the 19 individuals in the target group. For individual means, standard deviations, and number of missed days, see Table 1. (Participants 1, 15, and 16 have more than 50% of their data missing; however, unbalanced data are handled well by mixed effects models. In addition, we ran analyses with and without these individuals, and we found no differences.)

**Surrogate data test.**—Our first step in identifying the underlying dynamics of the variability in emotional well-being was to perform a surrogate data test. A surrogate data test manipulates the sample data in such a way as to ensure that a specific null hypothesis is true. Many of these surrogate data sets are created so that an empirical estimate of the distribution of the null hypothesis can be obtained. Then the actual sample data are compared to the distribution of the null in order to determine how unlikely the data are given a distribution of the null. This method is powerful because it uses the sample data to create the surrogate data, so that it is equally representative of the population.

In the current case, the null hypothesis is that the residual variability in emotional well-being is measurement error, an independent identically distributed random variable. If this null hypothesis is true, then the ordering of these residuals carries no information. Thus, by reordering the sample data, we obtain a data set with the same distribution of scores but in which the null hypothesis is true. The only difference between the data set of interest and the surrogate data sets is that the surrogates are ordered by chance rather than chronology. Twenty random permutations of the residual MHI scores were created, and the autocorrelation function (ACF) of each of these surrogates and the true ordered sample data was created for each individual.

The autocorrelation in the real data set was greater than all 20 surrogate data sets for every individual, indicating that the real relationships within the data were greater than would be expected by a chance ordering. One individual’s sample data ACF and 20 surrogate data ACFs are plotted in Figure 2. Thus the data were unlikely to be time independent ($p < .05$) because the true ACF was greater than that found in any of the 20 surrogate tests.

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**Table 1. Individual Characteristics for Daily Assessments of Emotional Well-Being**

<table>
<thead>
<tr>
<th>Subject</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>No. of Missing Days</th>
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Note: Emotional well-being is assessed with the Mental Health Inventory.

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**Figure 2. Autocorrelation function (ACF) plots for a single subject.** The line on the top plots the ACF of the true ordering of the data, and the lines toward the bottom plot the ACFs of the 20 surrogate data sets. Because no line in any surrogate data set is higher than the ACF of the real data, the null hypothesis of no time dependence of residuals is rejected.
Linear trend and initial variability.—To examine the linear trend of the system, which is the traditional measure of the intrindividual change typically assessed in longitudinal bereavement studies, we estimated a regression equation,

$$X_i = I_i + S_i t + e_i,$$

where $X_i$ represents the value of daily emotional well-being at $t$ (days since death of spouse), $I_i$ represents the intercept for each individual, $S_i$ represents the slope of the overall trend (for the $i$th widow), $t$ represents time (day), and $e_i$ represents the error of measurement on the daily assessment of emotional well-being. Consistent with previous research, and as we hypothesized, the overall trend is significantly positive ($t = 2.94$, $p < .01$), indicating that the intrindividual change in emotional well-being is positive. More specifically, widows’ levels of emotional well-being significantly improved across the 3-month duration of the study. The estimates for these parameters are located in Table 2, including values, standard errors, degrees of freedom, $t$ values, and $p$ values.

We used a second linear model to measure the predictability of the initial variability on the overall MHI score by calculating the standard deviation for the first 20 scores per person,

$$X_i = b_0 + b_1 t + e_i,$$

where $b_0$ represents the initial standard deviation of the intrindividual variability (for the $i$th widow) and $e_i$ represents the error of measurement on the daily assessment of emotional well-being. We found that the initial variability in emotion regulation does not show a relationship with mean level of well-being ($t = -1.61$, $ns$). The estimates for these parameters are also located in Table 2, including values, standard errors, degrees of freedom, $t$ values, and $p$ values.

Intraindividual variability.—Our next step was to examine the predictability of the residual of each person’s daily assessment of emotional well-being score ($e_i$). As shown in Equations 1 and 2, the traditional linear modeling uses the variability in each individual’s score as an error term that is conceptualized as noise. The crux of the present study was to test Nesselroade’s (1990a) ideas that for some state-like constructs, such as daily emotional well-being, ignoring intrindividual variability results in an incomplete understanding of an individual’s change trajectory.

Testing a linear oscillator model required that differential equation models be fit to the data. To do this, we used general linear mixed-effects modeling to estimate the relationship between the total score on the MHI and its derivatives. In the current study, this process involves three steps based on the work of Boker (2001): (a) the overall linear trend for each individual is estimated as discussed herein, and the residuals from that trend are used as intraindividual variability scores; (b) local linear approximations to the first and second derivatives (i.e., change in emotional well-being and speed of change, respectively) of emotional well-being are calculated for each appropriate occasion of measurement; (c) the relationship between emotional well-being and its derivatives is estimated within subjects.

To fit a differential equation model to the data, we put the data in the form of approximations to the instantaneous first and second derivatives of emotional well-being at each occasion. For example, we would use three consecutive measurements of MHI scores (i.e., $A_1$, $A_2$, and $A_3$) to approximate the first derivative of $A$ (i.e., slope, or how rapidly the widow’s emotional well-being was changing) at the second occasion of measurement. We calculate the slope of these three consecutive scores by the average of the two slopes between $A_1$ and $A_2$ and between $A_2$ and $A_3$ (Equation 3), setting the necessary criteria for calculating derivatives at three consecutive data points.

$$\frac{dA_{i+1}}{dt} = \frac{(A_{i+2} - A_i)}{2\tau \Delta t},$$

where in this case $\tau = 1$ because $A_1$, $A_2$, and $A_3$ are successive occasions of measurement and $\Delta t$ is the interval of time between measurements.

Similarly, we can calculate the local linear approximation for the second derivative of $A$ (i.e., curvature, or the acceleration or deceleration with which a widow’s emotional well-being changes) at the second occasion of measurement from the same triplet of scores $A_1$, $A_2$, and $A_3$ as the change in the slopes shown here:

$$\frac{d^2 A_{i+1}}{dt^2} = \frac{(A_{i+2} - 2A_{i+1} + A_i)}{\tau^2 \Delta t^2}.$$  

We fit a multilevel differential equation model for a damped linear oscillator of the MHI (refer again to Figure 1) to the sample of widows (see Boker & Ohsletta, 2001 for implementation details of this type of model). This model allows each widow to have a unique frequency (i.e., rate of emotional well-being ups and downs) and damping (i.e., regulation of emotional well-being) parameter as shown in Equations 5, 6, and 7. We make an assumption that these widows’ parameters are a sample from a normal distribution of frequency and damping parameters in the population.
tau (τ or time parameter). For the model to be acceptable, the $R^2$ (indicating how well the first and second derivatives predict the score) must reach a level, and subsequently asymptote, at a minimum of .76 (Boker & Nesselroade, 2002). Furthermore, a damped linear oscillator requires that the damping parameter, ζ, is negative. If this parameter is positive, then the oscillations are amplifying across time rather than damping. If it cannot be differentiated from zero, then the system is not decaying or amplifying, but remaining stable (Boker, 2001). The frequency parameter, η, can be interpreted based on its magnitude, with larger values (e.g., -0.40) indicating more rapid oscillations and smaller values (e.g., -0.05) indicating much slower oscillations.

To calculate derivatives by using local linear approximation, we must specify tau (time parameter). According to previous stimulations, the most appropriate tau is the one at which the $R^2$ for a linear oscillator model first reaches asymptote (Boker & Nesselroade, 2002). According to Boker and Nesselroade, calculating tau based on this method introduces the least amount of bias into estimates of the frequency and damping parameters. In the present analyses (using τ = 12), the overall $R^2$ for the linear oscillator model was .77, suggesting that the residual intraindividual variability in emotional well-being can be predicted by a damped oscillatory model. More specifically, there is intraindividual variability in emotional well-being following the loss of a spouse that is unlikely to be due to error of measurement ($p < .05$). In examining the levels of the fixed effects parameters, we found a significant frequency parameter ($\eta = -.018, p < .001$). A frequency parameter of this magnitude (i.e., close to zero) indicates that the speed of the oscillations in emotional well-being is relatively slow, with a single cycle lasting on average approximately 47 days. The damping parameter was also significant and negative ($\zeta = -.015, p < .001$), suggesting that the oscillation in well-being following the death of a spouse significantly damps across a 98-day period (for group and individual values of etas, zetas, and $R^2$'s, see Tables 2 and 3, respectively). The significant frequency and damping parameter indicate that the intraindividual variability in emotions following conjugal loss is patterned and can be modeled by a linear oscillator model.

**DISCUSSION**

In the present study we assessed the process of initial expression of emotional well-being after conjugal loss. We hypothesized that, in normal older adults, the day-to-day change in a person’s emotional well-being has an equilibrium point that lies somewhere between being emotionally stable and unstable. A stressful life event, such as the death of a spouse, perturbs the emotional well-being state of the individual away from equilibrium, contributing to emotional shifts that vacillate between negative and positive affect (Larsen, 1987). That is, widows are displaced from their previous equilibrium point (prior to the loss), resulting in emotional lability. Findings of the present study suggest that, over a period of time, the widow regulates her emotional state and achieves equilibrium in a manner that is successfully predicted by a linear oscillator model. Using a dynamical systems approach to identify the intraindividual variability in emotional well-being following the loss of a spouse allowed us to estimate the parameters (i.e., the variability in well-being, the frequency of shifts in the expression of well-being, and the rate at which the shifts in well-being decay) of this system. As we hypothesized, results indicate that the intraindividual variability of emotional well-being following conjugal loss exhibits a frequency, a damping in variability, and an overall positive trend.

Intraindividual variability, or rapid within-person change, has been theorized to be an important determinant of successful adaptation to loss, but it has been neglected in the bereavement literature. Appreciating short-term changes in widows is a critical extension in understanding the development, functioning, and adaptation of individuals to a constantly changing environment (Nesselroade, 1988). One application of the current findings is to better our understanding of the psychology of loss, which focuses on people’s novel conceptualizations of personal loss as well as loss in a broader sense (Harvey & Miller, 1998). It has been suggested that there are both commonalities across different kinds of losses (e.g., reduction in resources or experiences of certain emotions); however, there may also be individual differences in grieving patterns (Harvey & Miller, 1998). For example, it may be that a major loss, such as the loss of a spouse, leads to a longer adjustment period and more deregulation than a minor loss, such as the loss of a favorite sweater. Most previous research on the adjustment to widowhood has focused on longer term change, neglecting the day-to-day variations and attributing them to measurement error; however, “if the covariations among the fluctuations reveal an organized structure . . . then the idea that the fluctuations are simply errors can legitimately be disregarded” (Eizenman, Nesselroade, Featherman, & Rowe, 1997, p. 490). In the present study there was a predictable pattern of emotional well-being, lending support to the idea that the period immediately following conjugal loss is one of disequilibrium. Over time equilibrium is reestablished, providing support to one general consensus of some researchers that there is a usual adjustment to conjugal loss that occurs across time, including less distress, intrusion, and avoidance related to the loss (Stroebe, Stroebe, Schut, Zech, & van den Bout, 2002). The unique contribution of the present study is that we have more

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**Table 3. Individual Estimates of Frequency and Damping Parameters and $R^2$'s**

<table>
<thead>
<tr>
<th>Subject</th>
<th>$\zeta$</th>
<th>$\eta$</th>
<th>$R^2$</th>
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<tr>
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One major limitation is that individuals who agree to participate in a study of this type may not be representative of the larger population. Although the selection bias of the present study is great given the relative small percentage of participants in the project from the overall sample, traditional participation rates in bereavement research are often less than 50% (see Stroebe & Stroebe, 1989, for a review). Furthermore, widow(er)s who have been contacted by researchers without the assistance of a hospital or other health care facility often report participation rates of less than 30% (Stroebe & Stroebe, 1989). Research designed to examine potential effects of bias in the project from the overall sample, traditional participation rate) to examine long-term adjustment. With the design of the present study and dynamical systems analyses, a hypothesis about the variability parameters (i.e., frequency, amplitude, and decay rate) to examine long-term adjustment. The results from many studies on bereavement suggesting that there are long-term detrimental effects of losing one’s spouse, one would expect the loss-orientation and restoration-orientation fluctuations to last longer than the first 4 months postloss. In the present study, a slow but patterned oscillation was found in the first 4 months postloss, which may suggest that the shift between components of loss orientation and components of restoration orientation occur more rapidly than what one would expect. Similarly, “habituation” can be conceived as the damping parameter that was exhibited by the widows. Although not an explicit test of the dual process model of coping with bereavement, the overall findings of the present study are not inconsistent with this theory. That is, the current findings indicate that, on average, recent widows show increased oscillation immediately following their loss, which decreases over time. A piece of the puzzle remains unstudied is whether or not those individuals who damp more quickly also better adjust to their loss. More specifically, one extension of the present study that would be a more direct investigation of the dual process model is to use the variability parameters (i.e., frequency, amplitude, and decay rate) to examine long-term adjustment. With the design of the present study and dynamical systems analyses, a hypothesis such as this can be tested, allowing a better understanding of the process and predictors behind the adjustment to widowhood.

An important expansion of the present study of patterned variability is to examine the individual differences in those patterns. More specifically, each widow might have her own unique frequency and damping parameters that could be predicted on the basis of certain internal or external resilience factors. Researchers are beginning to differentiate various trajectories of the adjustment to widowhood on the basis of the general population of widows. The goal of the present study was to first be able to model intra-individual variability in a select sample of recently bereaved widows. Subsequent studies will expand on these findings by using multiple recruitment methods to increase the size and broaden the demographics of our sample.

Another form of sample bias in the present study is the exclusion of widowers. Generalizing the findings of the present study to widowers may be inappropriate given the differential effects of conjugal loss between men and women. In a national survey (N = 3,614), men experienced conjugal loss as a more emotionally distressing event than women (Umberson et al., 1992). These researchers have suggested that this may be due to the fact that social integration is facilitated by women, which leads men to depend on their wives for social participation and support. Therefore, social and emotional isolation may be more debilitating for men than for women, leading to more vulnerability to postloss depression in men. Our next step will be to generalize these findings by replicating the study in different populations.

Our present examination of the adjustment to widowhood lends an important empirical addition to the recent conceptualization of the dual model process of bereavement. According to Stroebe and Schut (1999), adjustment consists of the unwilled and unexpected ups and downs of emotions. Their model is not a phasal model, but rather a “waxing and waning,” or oscillation, across time. There are no real time-line markers that have been set forth by Stroebe and Schut in terms of the process model; however, given the findings from many studies on bereavement suggesting that there are long-term detrimental effects of losing one’s spouse, one would expect the loss-orientation and restoration-orientation fluctuations to last longer than the first 4 months postloss. In the present study, a slow but patterned oscillation was found in the first 4 months postloss, which may suggest that the shift between components of loss orientation and components of restoration orientation occur more rapidly than what one would expect. Similarly, “habituation” can be conceived as the damping parameter that was exhibited by the widows. Although not an explicit test of the dual process model of coping with bereavement, the overall findings of the present study are not inconsistent with this theory. That is, the current findings indicate that, on average, recent widows show increased oscillation immediately following their loss, which decreases over time. A piece of the puzzle that remains unstudied is whether or not those individuals who damp more quickly also better adjust to their loss. More specifically, one extension of the present study that would be a more direct investigation of the dual process model is to use the variability parameters (i.e., frequency, amplitude, and decay rate) to examine long-term adjustment. With the design of the present study and dynamical systems analyses, a hypothesis such as this can be tested, allowing a better understanding of the process and predictors behind the adjustment to widowhood.

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particular protective mechanisms. For example, in order to identify the psychosocial dimensions that might account for the differences between the curves in a study by Levy and colleagues (1994), who examined widowhood at four occasions across 18 months, a discriminant function analysis was performed and then correlated with potential mitigating variables. Several factors were linked to these differential adaptation patterns in bereavement, including anticipatory grief, concurrent stressors, spirituality, and social support. Similarly, one can study the individual differences in the patterned variability expressed after conjugal loss, exploring, for example, whether individuals who have a strong support network have a quicker damping rate, or, in other words, return more quickly to equilibrium.

For many different kinds of psychological attributes, including measures of emotional well-being, there exist coherent and systematic fluctuations over relatively short intervals of time (Nesselroade, 1990b). From a dynamical systems perspective, the death of a spouse is an event that perturbs the emotional well-being system from its normal equilibrium state. Understanding the variability within individuals who experience conjugal loss allows researchers and helping professionals to better understand the lack of uniformity in coping with such a loss. It is increasingly important to recognize intraindividual variability and change and to incorporate it into theory and research on the mastery of bereavement in later life. A study of this type moves beyond the outcome effects of conjugal loss to understand the process by which widow(er)s eventually adjust to this stressful life event. To date, no research-validated “guideposts” have been available to describe the normal bereavement process. The current study is a strong first step.

ACKNOWLEDGMENTS

This study was supported in part by grants from the National Institute on Aging (Grant 1 RO3 AG18570-01), the American Psychological Association Division 20—Retirement Research Foundation Student Awards Program of 1999, and the William Kirby Endowment for Research, University of Notre Dame.

In addition, this project would not have been possible without the extraordinary generosity of the widows who shared their stories with us. They have displayed tremendous courage and grace in their ability to recapture the joy of loving their husbands and the pain of losing them.

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Received February 21, 2003
Accepted March 1, 2004
Decision Editor: Margie E. Lachman, PhD