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Change in Relationship Satisfaction among Veterans in Couple Therapy

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Approximately two-thirds of Americans will live with a romantic partner at some point in their lives (Michael, Gagnon, Laumann, & Kolata, 1995), and 75% of individuals marry by age 30 (U.S. Bureau of the Census, 1997). Being in a committed relationship is associated with a number of positive outcomes, including greater individual happiness (Diener, Suh, Lucas, & Smith, 1999). However, relationship problems have been linked with acute emotional distress (Swindle, Heller, Pescosolido, & Kikuzawa, 2000), psychopathology (e.g., Beach, Fincham, & Katz, 1998; Uebelacker & Whisman, 2006; Whisman, Sheldon, & Goering, 2000; Whisman, 2007), and poorer physical health (e.g., Burman & Margolin, 1992; Kiecolt-Glaser & Newton, 2001; Robles & Kiecolt-Glaser, 2003; Schmaling & Sher, 1997; Whisman, Li, Sbarra, & Raison, 2014). Unfortunately, relationship dissatisfaction is a common occurrence, with as many as one-third of couples reporting relationship distress (Whisman, Beach & Snyder, 2008). Furthermore, couple conflict has been linked with poorer parenting (e.g., Krishnakumar & Buehler, 2000), child adjustment (Cummings & Davies, 1994), parent-child attachment (e.g., Owen & Cox, 1997), and family conflict (e.g., Margolin, Christensen, & John, 1996).

Fortunately, extensive research demonstrates that couple therapy is effective for improving relationship satisfaction and reduces the risk of divorce among distressed couples (e.g., Shadish & Baldwin, 2003, 2005; Snyder, Wills, & Grady-Fletcher, 1991). Moreover, couple therapy has beneficial effects for individual psychopathology (see Baucom, Whisman & Paprocki, 2012, for a review), parenting (e.g., Gattis, Simpson, & Christensen, 2008), coping with stress (Bodenmann, 2007), and recovery from medical problems (Baucom, Porter, Kirby, & Hudepohl, 2012). In a review of studies comparing different types of couple therapy to no treatment, Christensen and Heavey (1999) concluded that results demonstrate “unequivocally

that couple therapy increases satisfaction more than does no treatment" (p. 167). In the first meta-analysis of couple therapy outcome studies, Hahlweg and Markman (1988) examined 17 studies of behavioral couple therapy (BCT) and concluded that BCT was more effective than no treatment in improving relationship satisfaction. Later studies have found that many approaches to couple therapy, including BCT, cognitive-behavioral couple therapy (CBCT), integrative behavioral couple therapy (IBCT), emotion-focused therapy (EFT), and insight-oriented marital therapy (IOMT), are more effective than no treatment or than waitlist control conditions (e.g., Dunn & Schwebel, 1995). Mean effect sizes for improvement in relationship satisfaction range from 0.50 (Wilson, 1986) to 1.30 (Johnson, Hunsley, Greenberg, & Schindler, 1999) with an average effect size of .84 (Shadish & Baldwin, 2003).

Despite these promising findings, not every couple benefits from couple therapy, and many couples continue to experience relationship distress after completing therapy (e.g., Hahlweg & Markman, 1988). In fact, only 35% (Jacobson, 1984) to 50% (Snyder, Castellani, & Whisman, 2006) of couples experience significant improvement by the end of treatment, and 30-60% of couples who complete treatment go on to separate, divorce, or experience declines in relationship functioning over time (Christensen, Atkins, Yi, Baucom, & George, 2006; Jacobson, Schmaling, & Holtzworth-Monroe, 1987; Snyder, Wills, & Grady-Fletcher, 1991). Evidence also suggests that couple therapy is less effective for severely distressed couples (e.g., Jacobson & Addis, 1993). Moreover, couple therapy may be contraindicated for some couples, including those experiencing severe intimate partner violence (Holtzworth-Munroe, Meehan, Rehman, & Marshall, 2002), and current alcohol or substance abuse (Epstein & McCrady, 2002).

In addition, although many forms of couple therapy are effective, no one form of couple therapy has clearly been established as superior (e.g., Shadish & Baldwin, 2003, 2005).

Moreover, relatively little is known about how and why couple therapy has its effects, or whether certain types of couple therapy are more effective for specific populations. As a result, there have been a number of calls for research to improve our understanding in these domains. These calls have included recommendations for investigations into when and how change occurs during couple therapy, as well as on the trajectories of change that couples may experience in treatment. Improved understanding of what change may occur, as well as common trajectories of change in couple therapy, would greatly enhance process research on therapy for couple distress.

In this vein, Hayes and colleagues (2007b) observe that although traditional psychotherapy research appears to operate under the assumption that therapeutic change is "gradual and linear" (p. 715), a growing body of research suggests therapeutic change can be discontinuous, nonlinear, or sudden. Far from being anomalies, these patterns have been demonstrated across multiple treatment modalities and for a variety of outcomes, and may reflect some of the changes commonly experienced by individuals and couples undergoing treatment. Within this body of literature, nonlinear change is often categorized into three primary types: rapid early response, sudden gains, and the spike pattern. We will briefly summarize findings on these three pattern types observed in individual therapy before examining evidence for nonlinear change in couple therapy.

In the rapid early response pattern, patients experience improvement in symptoms early in treatment, followed by a leveling off of symptoms. Rapid early response has been observed a number of times in individuals undergoing cognitive-behavioral therapy (CBT) for depression (i.e., Beckham, 1989; Fennell & Teasdale, 1987; Ilardi & Craighead, 1994). However, it is not isolated to CBT or to depressive symptoms, and has also been demonstrated in a number of treatments and for a variety of clinical problems, including binge eating disorder (Hilbert,

Hildebrandt, Agras, Wilfley, & Wilson, 2015; Grilo, Masheb & Wilson, 2006) and major depressive disorder in adolescents (Renaud et al., 1998), as well as generalized anxiety disorder, avoidant personality disorder, and obsessive-compulsive disorder (Crits-Cristoph et al., 2001).

The sudden gains pattern refers to a phenomenon where patients experience sudden large improvements in outcomes between sessions. Tang and DeRubeis (1999) observed that over one-third of patients experienced sudden gains during two manualized clinical trials of CBT for depression. Sudden gains have also been documented in CBT for social anxiety (Hoffman, Schulz, Meuret, Moscovitch, & Suvak, 2006), and individual and couple-based CBT for alcohol use disorders (Drapkin, Epstein, McCrady, & Eddie, 2015). Moreover, they do not occur exclusively within manualized treatments, and have been found in routine clinical practice (Hardy et al., 2005) as well as in outpatients with a variety of disorders receiving treatment with different modalities (Stiles et al., 2003).

The “spike pattern” of therapeutic change describes a temporary period of apparent worsening of symptoms that often co-occurs with increased variability or disturbance in outcome levels. This period is generally followed by linear or curvilinear improvement. Some therapeutic modalities predict this pattern of change: most notably, the theory behind exposure treatment of anxiety disorders, which argues that anxiety must first be activated before the patient can habituate to it and ultimately decrease it (e.g., Foa & Kozak, 1986). Thus, the spike pattern is perhaps best associated with anxiety disorders, and patients in exposure-based treatments for conditions including social anxiety disorder (Heimberg and Becker, 2002) and PTSD (Nishith, Resick, & Griffin, 2002) often show distinct spike and habituation curves. However, the pattern has also been demonstrated in other conditions, including depression (Hayes et al., 2007a) and personality disorders (Strauss et al., 2006).

Nonlinear Change in Couple Therapy

Few studies have examined changes in functioning in couple therapy using methods that can detect nonlinear change. However, limited research suggests that nonlinear and discontinuous change can and does occur in couple therapy. Doss and colleagues (2011) found that 25% of individuals in treatment-as-usual couple therapy experienced a sudden gain (with an average Cohen's *d* of 1.61). In a study using four time points, Christensen and colleagues (2004) showed that couples in traditional behavioral couple therapy (TBCT) improved more rapidly than couples undergoing IBCT, but then leveled off, while IBCT couples continued to make gains throughout therapy. In a third study, latent growth curve analyses showed that a piecewise trajectory was a better fit for changes in weekly measures of relationship satisfaction during multisystemic couple therapy. Both men and women showed a steeper increase in satisfaction during the first half of therapy, followed by slower gains (Knobloch-Fedders, Pinsof, & Haase, 2015). In addition, theories of couple therapy do not necessarily predict a specific pattern of change. Based on this evidence and the literature on nonlinear change in individual and family therapies, it seems reasonable to expect that at least some change in relationship satisfaction in couple therapy will occur in a nonlinear fashion and that not all couples will experience change in the same way.

In assessing for nonlinear change in couple therapy, it is important to take into account individual trajectories of change. Although change may appear to occur in a linear fashion when averaged across couples in a sample, linear change may not reflect the experiences of individual couples. That is, couples in the sample may experience a mix of linear, curvilinear, sudden gains, spikes, or rapid response patterns; analytical methods that estimate average change may obscure important variability from the linear or averaged pattern.

Clarification regarding what changes may unfold during couple therapy, as well as a better understanding of the variability in change across couples, could inform a number of aspects of therapy. For example, therapists may be able to more clearly communicate with couples about what changes to expect (or not expect) in therapy. Therapists may also be better equipped to determine when to terminate therapy. That is, if nonlinear or sudden change is shown to be a common experience, the absence of early or linear change, or even the presence of temporary increases in relationship distress, may not necessarily suggest that a couple is unlikely to benefit from treatment or that a particular modality will be ineffective for that couple. In addition, it will also help guide researchers in investigating moderators and mediators of treatment response, such as predictors of the type of trajectory experience, and outcomes that are differentially associated with patterns of therapeutic change. However, initial investigations on the possibility of nonlinearity in relationship satisfaction is needed before linking nonlinear trajectories to therapy outcomes.

In order to better understand patterns of change in relationship satisfaction that couples may experience, it is first important to explore what changes actually occur, regardless of whether those changes fit a common trajectory (e.g., linear, curvilinear, piecewise, etc.), and to examine the variability in change patterns across couples. Within couples, cross-partner associations in relationship satisfaction should also be explored, as partner levels of and changes in relationship satisfaction are likely to impact one's own. Further, explorations of changes in satisfaction should also take into account the context of couple therapy; that is, couples in therapy may have been experiencing distress for a long time before deciding to engage in therapy, and so any changes that are observed could be conceptualized as occurring in spite of the established factors and circumstances that contributed to the distress.

Dynamic Systems Theory and the Study of Psychotherapy

Dynamic systems theory (DST) may provide both useful guidance for expanding beyond models investigating linear change and a theoretical framework for understanding and explaining phenomena associated with developmental change. DST has been previously applied to patterns of therapeutic change in individuals (e.g., Hayes & Strauss, 1998; Gelo et al., 2016), but it has also been used to examine psychological constructs and processes in couples such as affect co-regulation (Butner et al., 2017), intimacy and disclosure (Boker & Laurenceau, 2006), and couple interaction (Gottman, Swanson & Swanson, 2002), and in other areas such as attitude formation (Simon & Holyoak, 2002), self-regulation (Carver & Schier, 2002), and stereotype processes (Queller, 2002).

Fincham, Stanley and Beach (2007) note that many DST concepts are intuitively appealing to couple and family researchers, in part because they are able to capture and explain processes characterized by mutual influence like those observed in couples and families. DST examines cycles of interaction as they unfold in an iterative process over time, as well as the consequences of those cycles. The authors observe that sometimes the cycles result in discontinuities and shifts to a qualitatively different state, which they refer to as transformative processes (Fincham et al., 2007). Thus, DST is especially well-suited to the study of psychological and related processes, particularly ones that are conceptualized as occurring both within and between individuals, because of its ability to account for not only complex self-regulatory processes contributing to homeostasis, but also change processes that might result in significant, qualitative shifts to a new homeostasis.

In examining psychological phenomena in couples, DST assumes that we can understand the characteristics of a system by measuring constructs of interest in the objects involved in the

system (Butner, Behrends, & Baucom, 2017). When we apply these assumptions to the study of couple therapy, we can conceptualize the relationship as a system containing two romantic partners. We assume that we can understand the characteristics of the relationship by measuring important dyad- and individual-level constructs, such as relationship satisfaction, communication patterns, affection, feelings of connectedness, and conflict. Broader contextual factors, such as living situation, individual well-being, social networks, and stressors occurring at the local, regional, or even global level can also affect the system.

A second key assumption in DST is that systems tend to exhibit patterns of change over time, which implies that the individuals within a system interact and change in predictable ways. Thus, couples are likely to show patterning, not only in terms of their individual behavior, affect, and cognitions, but also in how the partners interact with each other. Couples and individuals are likely to show consistency in how they address conflict, show affection for each other, communicate, or even influence each other's emotions.

Further, we are more likely to observe some patterns of change than others. For example, when studying distressed couples, we might expect to measure frequent responses to conflict that are high in hostility, or that are characterized by demand-withdraw. Although the couples could resolve conflicts amicably with constructive communication behaviors and high warmth, we might be less likely to detect these patterns, given the nature of the sample. This assumption is not limited to observable behaviors: for example, two individuals may fluctuate or oscillate about a particular level of relationship satisfaction, and these individual patterns may co-vary or relate to one another over time. If this were an established pattern, it would be unlikely, though not impossible, for the couple's satisfaction to change drastically.

A third central concept is emergence, which suggests that the predictable temporal patterns we observe are a product of lower- and higher-order processes and their interactions (Butner et al., 2017). Lower-order processes might include short-term changes or stability, while higher-order processes refer to longer term or larger patterns. For example, one lower-order process might be the communication patterns that one spouse tends to use in requesting help with the housework from the other partner. However, these individual tendencies could be part of a higher-order process that, when observed on a larger time scale, we might recognize as the demand-withdraw pattern. We could also observe an interaction between lower- and higher-order processes. For example, the couple might only experience demand-withdraw during periods in the marriage when stress is high. Thus, the system and its components can be understood by not only examining relationship patterns while they occur in-the-moment, but also by observing the manner in which these patterns escalate (for example, repeated, increasingly intense episodes of conflict), are maintained, or de-escalate (e.g., when conflicts are resolved or avoided; Butner et al., 2017).

DST assumes that these patterns have varying levels of stability, which can be conceptualized as the degree to which they are likely to persist in the face of external forces. For example, in studying satisfied or non-distressed couples, we might see frequent use of positive communication behaviors, but the consistency of these behaviors over time is likely to depend both on their stability and on the strength of external influences. Many couples may be able to maintain these positive communication skills in the face of minor external forces, such as one partner going on a week-long work trip. In the context of severe stressors, such as sustained absence or military deployment, positive communication patterns with less stability may decrease in quality or frequency, resulting in more frequent or intense conflict. On the other

hand, a couple with very stable communication skills may be able to maintain this pattern even under severe stress. When consistency breaks down over many iterations and under the influence of external factors, this is conceptualized as a transformative process, where couples find themselves in a qualitatively different state from the one they started in (Fincham et al., 2007).

Under this framework, relationship distress can be conceptualized as an equilibrium state, where cognitive, affective, and behavioral patterns of functioning serve to maintain that equilibrium (Hayes & Strauss, 1998; Mahoney, 1991). Even though they may cause distress, the patterns can become well-established and maintained by stabilizing forces (Schiepek, Fricke, & Kaimer, 1992) that cannot be easily disrupted. In order for the system to incorporate sustained change and growth, it must first be destabilized. Destabilization is often experienced as temporarily increased variability and disorder in behavioral, affective, cognitive, and other domains (Hager, 1992; Kelso, 1995; Mahoney, 1991), followed by a qualitative shift to a new state wherein the dysfunctional patterns are, ideally, replaced by healthier ones. With time and consistency, these new healthy patterns represent a new equilibrium state, and are maintained by different stabilizing forces that cannot be easily disrupted; that is, these new patterns persist even under the influence of many external factors (stressors, environmental changes, interpersonal difficulties, ill health). Conversely, if an external force is strong enough, this may be enough to shift the system back to its original equilibrium (or even to a new one).

In DST terms, couple therapy can be conceptualized as an external force designed to interrupt a stable equilibrium of dysfunctional individual- and relationship-level patterns and help couples to shift to an equilibrium marked by healthier, more positive relationship functioning. The goal of couple therapy, then, is to facilitate phase transitions or transformational processes from one stable state to another. These qualitative shifts are preceded by fluctuations

and instability (e.g., Schiepek, Eckert, and Weihrauch, 2003) as old patterns are challenged and the system is destabilized. Couples in therapy are exposed to interventions designed to break down and decrease the frequency of established dysfunctional patterns and to introduce more functional ones that will become more consistent and stable with sufficient practice, reinforcement, or support. The therapeutic relationship, out-of-session practice, and internalization of session content may help ensure the maintenance of new patterns in order to reduce the likelihood of returning to the dysfunctional equilibrium. On the other hand, therapy may fail if the destabilization and transition periods are not sustained, or if stronger external forces serve to maintain dysfunctional patterns. In general, most couple therapies conceptualize the process of clinical change in this way (e.g., Baucom, Epstein, Kirby & LaTaillade, 2015; Christensen, Dimidjian, & Martel, 2015; Gurman, 2015), although the particular approaches and interventions used, as well as the targets for change (such as behavior, affect, and cognitions) may differ across modalities.

Dynamical Systems Analysis

Many current methods used to measure and analyze therapeutic process and change are limited by the assumption of linearity and a focus on final amount of change, sometimes neglecting the processes by which that change is attained. This is important because although research has shown that not all couples benefit from therapy, and that not all couples who do benefit are able to maintain their gains, we have little information on what types of couples are at risk for poorer outcomes. Moreover, the existing data on various couple characteristics associated with therapeutic outcomes are often contradictory, with the exception of initial distress severity (e.g., Jacobson & Addis, 1993). More in-depth examination of processes of change could help researchers predict what couples may need non-traditional therapy (e.g.,

longer therapy, more frequent sessions, greater number of maintenance sessions) in order to benefit and sustain gains. Because of evidence that change in couple therapy may not follow a linear trajectory, researchers investigating the process of couple therapy should utilize theoretical and analytical frameworks capable of detecting and explaining nonlinear change. One promising method of analysis that is particularly compatible with DST and other theories of nonlinear change is dynamical systems analysis (DSA), which has advantages over traditional analytical techniques in its ability to model dynamic and complex change processes (e.g., Hayes et al., 2007b; Salvatore, Tschacher, Gelo, & Koch, 2015).

Traditional multilevel and structural equation modeling approaches may investigate the role of time variables by fitting trajectories to average change over time in the outcome variable and then examining potential moderators and mechanisms of change. In many of these cases, time is included in the model as a separate variable; the time variable can be structured to test linear, quadratic, cubic, piecewise, and other commonly observed kinds of trajectories, and interactions can be included to test whether variables moderate that trajectory. In contrast, DST embeds time within the constructs of interest rather than including it as a separate variable: in the current study, we create models where the outcome variable is a function of the individual and his or her partner's scores at the previous time point, or where the outcome variable explicitly represents change from one time point to the next. DSA creates models of change in which one variable can consistently affect another over time (e.g., Nesselroade & Schmidt McCollam, 2000), and can be used to model constructs that change and interact over time (Deboeck, Nicholson, Kouros, Little, & Garber, 2015; Monpetit, Bergeman, Deboeck, Tiberio, & Boker, 2010). DSA does not necessarily calculate a clear trajectory in the way that multilevel or

structural equation modeling do. Instead, the focus is on the associations between variables from one time point to the next, and on the impact that additional variables have on those associations.

DSA allows for differentiation between first-order change (i.e., processes that serve to organize the system around a stable pattern of functioning) and second-order change, which might reflect the couple shifting to a new pattern or level of behavior. DSA is also able to model processes such as synchrony, where changes in partners may co-occur or reciprocally impact one another, which is especially important for investigations of couples. Synchrony variables can be thought of as similar to time-varying covariates in multilevel modeling. In this case, they would reflect the impact of partner effects (for example, level of partner relationship satisfaction at each time point) on one's own relationship satisfaction at the next time point. Finally, DSA can also be used to examine equilibrium, which might occur as changes stabilize in therapy, or if therapy is ineffective in producing change.

The proposed study is the only known application of DSA and related graphical methods (discussed in greater detail below) to examining processes of change in couple therapy. Using DSA will allow us to flexibly investigate change in relationship satisfaction among couples in therapy. We will be able to build on previous research by investigating these changes from a more flexible perspective that may better approximate the changes and growth experienced by these individuals, also taking into account the context of the marriage or partnership in which these changes occur.

The Current Study

The current study is a secondary analysis of two separate datasets with the primary goal of comparing within-person and cross-partner patterns over time in relationship satisfaction during couple therapy using DST and related analytical techniques. In the current study, we will

investigate the possibility that within-partner therapeutic change in relationship satisfaction may follow a nonlinear or complex trajectory (e.g., Doss et al., 2011; Hayes et al., 2007b). Moreover, as objects in a system are likely to interact, psychological variables in members of a system are also likely to be reciprocal or bidirectional. Thus, we will also investigate how level of or change in one partner's satisfaction may affect the other's, and how the strength of this relation may evolve over time, as the degree of synchrony or interdependence between partners may change over the course of therapy or may be moderated by level of relationship satisfaction.

In light of these considerations and the dearth of previous DSA research on couple therapy, the current study has primarily exploratory goals. We expect to find evidence for pattern formation within the therapeutic process, as well as synchrony between partners. In order to capitalize on advanced analytical approaches in investigating complex within- and cross-partner patterns, and to closely observe changes that may occur over the course of treatment, we assessed these constructs of interest at weekly therapy sessions using DSA. Although we have two samples of couple therapy data, we are unable to combine them because they use different measures of relationship satisfaction that do not contain any overlapping items. Instead, we will use one sample to generate a DSA-based model reflecting within- and cross-partner associations in relationship satisfaction (Study 1) and discuss results from DSA analyses. In Study 2, we will test whether that model generalizes to a second sample.

Study 1

Methods

Procedure

All opposite-sex couples receiving couple therapy through the couple and family therapy clinics of the Veterans' Affairs hospital system in San Diego, California and Charleston, South

Carolina between 2004 and 2008 were invited to participate. There were no official exclusion criteria for treatment in either clinic, although treatment teams at each VA could determine whether couple therapy was clinically indicated; for example, couples might be excluded in cases of severe substance use or intimate partner violence. At the first therapy session, the therapist reviewed the goals and procedures of the research study and asked couples if they would like to participate. If both members of the couple were willing, informed consent was obtained. Participating couples received treatment-as-usual, which could include BCT, IBCT, CBCT, solution-focused therapy, other evidence-based therapies, or a mixture of treatments based on the clinical judgement of therapists and supervisors. At the beginning of each session each partner independently completed a brief questionnaire and returned it to the clinician. Couples participated in the study for as long as their therapy sessions continued, or until they chose to discontinue participation. Couples did not receive payment for their participation in the research study and participation did not affect the type of treatment received or the length of treatment.

Participants

Seventy-two couples in Charleston and 89 couples in San Diego agreed to participate and completed initial questionnaires (described below). Of these, 67 Charleston couples and 74 San Diego couples completed at least two consecutive weekly measures each, for a total sample of 141 couples. Couples who were excluded based on number of weekly measures did not differ from couples who remained in analyses on relationship status, length of relationship, age, whether or not they had children, years of education, personal monthly income, or initial relationship satisfaction. The following information is reported on the subset of couples (n = 141) who completed at least two consecutive weekly measures.

Initial intake questionnaires were missing for 10 couples from the Charleston site; there were no initial intake questionnaires missing for participants from the San Diego site. Because questionnaires were missing for couples rather than individuals, it was not possible to copy data on marital status, length of relationship, and number of children from the partner's initial intake questionnaire. Thus, demographic information is reported on the couples with complete intake questionnaires.

Participants completed 11.1 sessions of therapy on average (range = 2-43 sessions). Couples at the San Diego site attended significantly more therapy sessions (M = 15.2, SD = 7.9) than those at the Charleston site (M = 6.7, SD = 4.1), $t(109.58) = 8.12$, $p < .001$ (equal variances not assumed). This was largely due to site differences in therapy approaches: treatment at the Charleston site was generally more solution-focused, with an emphasis on brief therapy, while treatment at the San Diego clinic integrated techniques from TBCT, CBCT, EFT, and IBCT approaches.

Demographic information. At the initial intake appointment, participants reported on relationship status, length of current relationship, age, race/ethnicity, education, employment, number of children, and monthly personal income. The majority of couples were married (75%) or cohabitating (13%), with a minority who were divorced or separated (3%) or who chose not to respond (11%). Those who were married had been married for 11.9 years on average (SD = 13.4; range = 0-56 years). Participants ranged in age from 20 to 83, with a mean age of 51 for males (SD = 14.1) and 47 for females (SD = 13.5). The sample was predominantly non-Hispanic white (61.5%), African-American (15.3%), and Hispanic (5.7%). Most participants had some college or higher education (66.5%), and approximately 37% of couples reported that they had at least one child.

There were no site differences in age or employment for men or women, or in years of education or personal monthly income for men. Women at the San Diego site reported significantly greater number of years of education (M = 14.8, SD = 3.18) than women at the Charleston site (M = 13.4, SD = 1.8), $t(93.96) = 2.93$, $p = .004$ (equal variances not assumed). Women at the San Diego site reported significantly greater personal monthly income (M = 2277.9, SD = 2047.0) than women at the Charleston site (M = 1348.5, SD = 1100.7), $t(86.5) = 2.84$, $p = .004$ (equal variances not assumed). At the San Diego site, women were significantly more likely to be Hispanic (12.9% vs. 0%, $\chi^2(1) = 7.48$, $p = .007$) or Asian American (11.3% vs. 0%, $\chi^2(1) = 6.49$, $p = .014$). At the Charleston site, both women (29.6% vs. 6.5%, $\chi^2(1) = 10.87$, $p = .001$) and men (27.3% vs. 11.3%, $\chi^2(1) = 4.88$, $p = .034$) were significantly more likely to be African American. Couples at the Charleston site were more likely to report having at least one child than those at the San Diego site (51.8% vs. 32.7%), $\chi^2(1) = 4.28$, $p = .039$.

Relationship satisfaction. Both partners independently reported on their weekly relationship satisfaction using the six-item Quality of Marriage Index (QMI; Norton, 1983) prior to each therapy session. Items are summed to obtain a total score ranging from 6-45. The QMI is well validated and has high internal consistency; in a previous publication using this dataset, Doss and colleagues (2014) reported coefficient alphas of .94 for men and .95 for women. In addition, the QMI correlated highly with the Dyadic Adjustment Scale (Spanier, 1989) in the subsample we used (rs = .74 for men and .76 for women, $ps < .001$).

There were significant site differences in initial satisfaction scores for both men, $t(118) = 2.39$, $p = .018$, and for women, $t(118) = 2.30$, $p = .023$. Men at the San Diego site (M = 29.1, SD = 9.63) reported significantly higher initial satisfaction than men at the Charleston site (M = 24.9, SD = 9.5). Similarly, women at the San Diego site (M = 25.3, SD = 9.8) reported

significantly higher initial satisfaction than women at the Charleston site (M = 21.1, SD = 9.96). Approximately 35% of men and 52% of women at the San Diego site were below the QMI cutoff for significant distress (24.5; Funk & Rogge, 2007), while 49% of men and 63% of women at the Charleston site were below the cutoff. There were no significant site differences in the percentage of distressed participants for men or women.

Data cleaning and imputation. Nineteen weekly QMI measures were entered as duplicates (i.e., there were multiple entries for the same couple, dated the same week). In 8 of these cases, one of the "duplicate" rows was empty, and was thus excluded from analysis. If the total QMI scores of the duplicated entries were within 4 points, we took the average (8 cases); if the difference was greater than 4 points, we discarded both rows (3 cases). Items from the QMI were only imputed if fewer than three consecutive items were missing. In total, only 31 QMI items were missing under these criteria and subsequently imputed using the SPSS EM multiple imputation procedures (0.02% of all data).

Dynamical Systems Statistical Concepts and Data Exploration

DSA models attempt to flexibly capture patterns of change through differential or difference equations. Topography can be thought of as a way to represent these differential equations in a graphical form (Butner et al., 2015; Butner et al., 2017), sometimes referred to as a state space portrait (Abraham & Shaw, 1992). As an example, Figure 1 is a topographical contour map of the area around a mountain peak. The lines identify the altitude of points on the map, giving a three-dimensional sense of altitude, even though the map has only two dimensions.

Many topographical features correspond to DST concepts. One important idea is that of a set point, which suggests that all of the behavior in the system occurs in relation to that point. One example of a set point would be on the top of the mountain. This particular set point would

be described as a repeller, which generates change in behavior away from that point. Another type of set point is an attractor, which might be found on a contour map as a lake located in a valley. Attractors represent points where no change is likely to occur and can be conceptualized as a point of system equilibrium. A third concept is described in DST as a limit cycle, which might be seen on a topographical map as a looped trail. When combined with an attractor (i.e., a cyclical or swirling attractor), it describes interdependence. That is, each individual does not move independently towards the point, but is influenced or co-regulated by his or her partner. Partner effects can either speed or slow the return to the attractor.

These concepts can easily be applied to romantic relationships. We might think of each couple's typical level of relationship satisfaction as an attractor. A couple with this attractor would be unlikely to change from this "coordinate," and the couple would show stability around that point. That is, during weeks where the partners experience greater stress or conflict, or less quality time together, they may enact coping skills or other compensatory strategies in order to help preserve their relationship quality and satisfaction. However, there may be external influences that are strong enough to disrupt this stability: for example, if the couple experiences a significant stressor that negatively impacts their relationship, they may eventually transition to a new attractor characterized by mutually low relationship satisfaction. Depending on the strength of the attractor, the partners will be unlikely to move from this new attractor in the absence of strong external influences. Couple therapy is hypothesized to act as an external force drawing couples away from an attractor of mutual dissatisfaction and toward an attractor of mutual satisfaction.

When additional predictors are included in dynamical systems models, they are generally referred to as control parameters, which correspond to the traditional statistical concept of

moderators. Control parameters can influence these topological features of psychological phenomena, impacting the likelihood of moving towards an attractor or away from a repeller, or changing the location of the set point. Butner and colleagues (2014) note that it may be possible for a system to shift between having one set point versus multiple set points, depending on the influence of the control parameter. For example, if the control parameter were level of initial distress, more highly distressed couples could show one set point, whereas less distressed couples could demonstrate two or more. Finally, in cases of two or more set points, control parameters can help determine which set point the couple is likely to interact with.

Initial Data Exploration and Hypothesis Generation

Initial spaghetti plots of QMI score over time revealed considerable variability in scores, both within and across participants (see Figure 2). As recommended by Butner et al. (2015), we used a graphical approach to explore the data and to generate hypotheses and testable model equations. First, we generated one-dimensional state space plots separately for partner QMI scores over the course of couple therapy, showing both the raw score (horizontal axis) and the change in score that immediately followed it (vertical axis). This visual guide can be used as a first step to generate hypotheses about the presence of set points, which might be located where the averaged line crosses the horizontal axis, indicating the raw score that was associated with no subsequent change. When the smoothed average line crosses the horizontal axis with a negative slope, this suggests the presence of an attractor; that is, scores below the attractor value would be associated with positive subsequent change, while we would expect that scores greater than the attractor value would be followed by negative change. Conversely, a positively-sloped line crossing the horizontal axis would suggest the presence of a repeller. Scores below the repeller

value would be associated with negative subsequent change, while scores above the repeller value would be followed by positive change (i.e., away from the set point).

We then created a dyadic kernel density plot (KDP), which uses a kernel smoother to simultaneously plot the probability density function of both husband and wife[1] values on the variable of interest. The KDP corresponds directly to the map discussed above, but with one important distinction: where the peak on a map of a geographical feature like a mountain would traditionally represent a repeller (i.e., a point that behavior is directed away from), a KDP is inversely scaled, and the "peak" would instead represent an attractor, where behavior converges over time (Butner et al., 2017). We then added a vector plot to the map, which shows the raw change in scores in the outcome variable *X* as a function of own and partner levels of *X* in the past week. Finally, we overlaid a Loess-smoothed inferred vector plot to the KDP to help in the interpretation of the model. The inferred vector plot can be conceptualized as similar to a smoothed regression line in a scatterplot, as it summarizes the dynamics of the system across the range of outcome values, but does not show raw scores.

Results. The one-dimensional state space plots (Figures 3a and 3b for wives and husbands, respectively), show visual evidence for a fairly linear relationship between raw QMI and change in QMI, with both wife and husband data demonstrating a possible set point where the smoothed slope crosses the horizontal line where change is equal to zero (shown here in blue). For both plots, the set point appears to be an attractor because of the negative slope. The putative attractor appears to be located at QMI scores of approximately 20 for the wives and 22 for the husbands. If supported by the analyses, this would mean that overall, husbands' and

[1] Because all couples were comprised of opposite-sex partners and the majority of couples from both samples were married, we will refer to male and female participants as "husband" and "wife," respectively, for ease of interpretation.

wives' QMI scores tend to move towards the attractor (or towards scores of 22 and 20, respectively) over time. That is, they are attracted toward a point of mild relationship distress.

The initial KDP (see Figure 4a) also showed one primary peak where the QMI data collected over time, occurring at a score range of approximately 19-25 for the wife and 23-26 for the husband. The vector plot (Figure 4b) provides similar visual support for one attractor where husbands' and wives' values are more likely to fall. The Loess-smoothed vectors (Figure 4c) around the attractor demonstrate a swirling pattern, which is consistent with an interpretation of interpersonal dynamics. This pattern indicates that for couples whose scores fall in this attractor basin, one individual's satisfaction is sensitive to his or her partner's satisfaction, and vice versa.

DSA-informed hypotheses. Based on characteristics in the plots of relationship satisfaction, we hypothesize that we will find evidence for one relationship satisfaction attractor, characterized by moderately low husband and wife satisfaction (Hypothesis 1). Because of the swirling pattern, we also expect to find evidence for partner effects, indicating that partners' scores impact one another (Hypothesis 2). We will also include VA site as a control parameter, but with no specific hypotheses as to how site differences may change the topography of relationship satisfaction. Because this is an exploratory question, we will include the term only as a main effect. As described above, we will first generate testable model equations using Sample 1, and then test their generalizability to Sample 2 (Study 2).

Study 1 Results

DSA Models

In order to generate our test model, we estimated two repeated-measures Actor-Partner Interdependence Models (RM-APIMs; Kenny, 1996) for Sample 1. We based the fixed effects of these models on recommendations by Perry and colleagues (2017), who note advantages to using

both models in conjunction with graphic interpretation in examining longitudinal data from a dynamical systems perspective. Although these models are mathematically equivalent (Perry et al., 2017), their dependent variables and centering methods differ, and provide different parameter values that are useful for interpretation.

For both models, we used the dual intercept parameterization (Atkins, 2005), estimated in SAS PROC MIXED using restricted maximum likelihood and a banded Toeplitz variance-covariance structure. Random intercepts were significant for both husbands, $p = .017$, and wives, $p = .005$. In addition, excluding the random intercepts from the models significantly worsened model fit, $-2LL(\sim 2) = 59$, $p < .001$, and so we retained the random intercepts.

Standard RM-APIM. The first model was a standard RM-APIM predicting raw QMI score at time $t + 1$. An important characteristic of standard RM-APIMs is their use of autoregressive parameters. In this case, we included actor effects for husbands and wives (b_{h1} and b_{w1}, respectively) representing QMI scores at time t that directly predict the outcome, QMI scores at time $t + 1$. The actor effects allowed for evaluation of Hypothesis 1, while Hypothesis 2 is reflected in the partner effects (b_{h2} and b_{w2}), where husband's QMI score at time t predicts wife's QMI score at time $t + 1$, and vice versa. We also included site as a control parameter or moderator term, as illustrated below:

$$WifeRS_{it+1} = b_{w0} + b_{w1}WifeRS_{it} + b_{w2}HusbandRS_{it} + b_{w3}Site_i + b_{w4}WifeRS_{it}*Site_i + b_{w5}HusbandRS_{it}*Site_i + e_{wit}$$

$$HusbandRS_{it+1} = b_{h0} + b_{h1}HusbandRS_{it} + b_{h2}WifeRS_{it} + b_{h3}Site_i + b_{h4}HusbandRS_{it}*Site_i + b_{h5}WifeRS_{it}*Site_i + e_{hit}$$

Importantly, actor and partner effects were group mean centered by sex. For example, the husband's actor effect was created by subtracting the mean for all husbands from each husband's

measurement at each time point. By using this method of centering, the intercepts b_{w0} and b_{h0} represent the points at which no change occurs (i.e., where b_{w1} and b_{h1} are equal to zero) and provide coordinates for the putative relationship satisfaction set point (Perry et al., 2017). Moreover, the autoregressive actor slopes represent the relation between each partner's own relationship satisfaction score at time *t* and time *t* + 1. Thus, an actor effect of 1 would indicate no change, or perfect stability, in one's own relationship satisfaction from time 1 to time 2. An actor effect greater than 1 would indicate that relationship satisfaction moves away from one's average score over time (i.e., a repeller), while an actor effect less than 1 suggests that QMI scores move towards one's average over time (an attractor).

Partner paths have a slightly different interpretation than in the Standard RM-APIM. Rather than representing stability, the partner effect predicts change (Perry et al., 2017). The b_{w2} effect reflects the extent to which husband QMI score predicts change in wife QMI, and the b_{h2} effect reflects the association between wife QMI score and change in husband QMI.

Change-as-outcome RM-APIM. Second, we used a change-as-outcome RM-APIM (Perry et al., 2017). As illustrated in the equations below, the change score outcomes are calculated by subtracting each partner's QMI score at time *t* from time *t* + 1. In this model, both actor and partner effects are included as raw scores and are not centered. Again, we included site as a moderating term.

$$\Delta WifeRS_{it} = b_{w0} + b_{w1}WifeRS_{it} + b_{w2}HusbandRS_{it} + b_{w3}Site_i + b_{w4}WifeRS_{it}*Site_i + b_{w5}HusbandRS_{it}*Site_i + e_{wit}$$

$$\Delta HusbandRS_{it} = b_{h0} + b_{h1}HusbandRS_{it} + b_{h2}WifeRS_{it} + b_{h3}Site_i + b_{h4}HusbandRS_{it}*Site_i + b_{h5}WifeRS_{it}*Site_i + e_{hit}$$

Actor paths in the change-as-outcome model have a similar method of interpretation as actor effects in the standard RM-APIM, but with different parameter values. In the change-as-outcome model, an actor effect of 0 would represent perfect stability in QMI scores from time *t* to time *t* + 1. In comparison, we would expect an actor effect reflecting perfect stability in the standard RM-APIM to have a value of 1; thus, actor paths in the two models will always differ by 1 (Perry et al., 2017). In the change-as-outcome model, an actor effect of less than 0 suggests the presence of an attractor, as scores return to the individual's mean over time, while an actor effect over 1 would suggest a repeller, where scores move away from the mean. Partner paths have the same interpretation as in the standard RM-APIM, and in fact have identical parameter values because they represent the same effects (Perry et al., 2017). In both models, partner paths describe the extent to which one partner's QMI score predicts change in the spouse's QMI score.

Model results. Site did not moderate any intercepts or actor or partner effects in either the standard RM-APIM or the change-as-outcome RM-APIM, and so we dropped it from the models. The results reported are from the subsequent analyses. Results from both models supported our hypotheses (see Table 3). The standard RM-APIM actor effects for were significant for both husbands ($b = .75$, $SE = .02$, $p < .0001$) and wives ($b = .74$, $SE = .02$, $p < .0001$). Because the magnitude of the effects were less than 1, this supports our hypothesis that an attractor exists for both husbands and wives in that scores return to the overall mean over time. Notably, the magnitude of actor effects in the standard RM-APIM are exactly 1 point higher than those in the change-as-outcome RM-APIM, as discussed above. The standard RM-APIM intercepts indicated that the attractor was located at QMI scores of 23.45 for husbands and 21.41 for wives, consistent with our previous graphic interpretations of the one- and two-

dimensional state space plots (Figures 2 and 3). These scores are below the cutoff for marital distress (24.5; Funk & Rogge, 2007).

In addition, the partner effects (identical in both models, as discussed above) were significant for both husbands (b = .05, SE = .02, p = .033) and wives (b = .08, SE = .03, p = .003). It is important to note that the partner effects were in the opposite direction of the actor effects. Because the actor effects were negative, indicating return to the attractor, and partner effects were positive, indicating that partner scores predicted positive actor change over time, we interpret that spouses' QMI scores tended to slow their partner's return to the attractor over time (Perry et al., 2017).

Discussion. Overall, the results from the initial model generation suggest that in Sample 1, there is evidence for a single attractor that husbands' and wives' scores move towards over time (Hypothesis 1). The significant partner effects demonstrate that there is significant interdependence in scores (Hypothesis 2), such that husbands and wives tend to slow each other down as they move towards the attractor (e.g., husbands and wives tend to inhibit each other as their QMI scores move towards their points of equilibrium). These findings could suggest that couples in therapy experience a single point of homeostasis characterized by moderate distress, rather than multiple states reflecting differential levels of relationship satisfaction.

Study 2

Procedure

All opposite-sex couples receiving couple therapy through the couple and family therapy clinics of the Veterans' Affairs system in San Diego, California and Charleston, South Carolina were invited to participate. Study 2 followed the same general procedures as Study 1. Data was collected between 2008 and 2011.

Participants

Fifteen couples in Charleston and 43 couples in San Diego agreed to participate and completed initial questionnaires (described below) for the study; of these, 12 Charleston couples and 33 San Diego couples completed at least two weekly measures each, for a total sample of 45 couples. Couples who were excluded based on number of weekly measures did not differ from couples who remained in analyses on relationship status, length of time living together, age, education level, race, personal monthly income, or initial relationship satisfaction. Couples who were excluded were more likely to have children (100% vs. 71%), $\chi^2(1) = 4.84$, $p = .028$. The following information is reported on the subset of couples ($N = 45$) who completed at least two consecutive weekly measures.

Initial intake questionnaires were missing for approximately 10 male (23%) and 9 female (21%) participants from the San Diego site; there were no initial intake questionnaires missing for participants from the Charleston site. Where available, data on marital status, length of relationship, and number of children was copied from the partner's initial intake questionnaire. Demographic information is reported on the participants with complete intake questionnaires, or whose information could be copied from the partner's questionnaire. The majority of couples were married (70%) or cohabitating (26%), with a minority who were separated or living apart (2.2%). Those who were married had been married for 12.6 years on average ($SD = 10$; range = 1-37 years). Participants ranged in age from 21 to 74, with a mean age of 44 for males ($SD = 13.1$) and 43 for females ($SD = 12.6$). The sample was predominantly non-Hispanic white (53.3%), Hispanic (8.9%), and African-American (10%). Most participants had some college or higher education (63.3%).

Participants completed 10.6 sessions of therapy on average (range = 3-24 sessions). Couples at the San Diego site attended significantly more therapy sessions (M = 12.6, SD = 5.4) than those at the Charleston site (M = 5.3, SD = 2.8), $t(37.21) = -4.44$, $p < .001$ (equal variances not assumed). Again, this was largely due to site differences in therapy approaches, as discussed above.

Relationship satisfaction. Couples reported on their current relationship satisfaction using the Couple Satisfaction Index (CSI; Funk & Rogge, 2007) at the beginning of therapy (the 32-item version) and prior to each subsequent session of therapy (the 4-item version). The CSI was developed using item response theory and is a well-validated measure, with high internal consistency ($\alpha = .98$; Funk & Rogge, 2007). In the current sample, the shortened version showed excellent internal consistency for the first weekly questionnaire ($\alpha = .91$ for men and .96 for women), and the full 32-item form showed acceptable internal consistency at baseline ($\alpha = .81$ for men and .88 for women). There were no site differences in initial relationship satisfaction (CSI-32) for men, $t(33) = -1.74$, $p = .091$, or for women, $t(35) = -.45$, $p = .654$. Approximately 83% of men and 42% of women at the Charleston site were below the cutoff for couple distress (104.5 on the CSI-32), while 91% of men and 64% of women at the San Diego site were below the cutoff. There were no significant site differences in the percentage of distressed participants for men, $\chi^2(1) = .495$, $p = .482$, or for women, $\chi^2(1) = .111$, $p = .739$.

Demographic information. At the initial intake appointment, participants reported on relationship status, length of current relationship, age, race/ethnicity, education, employment, number of children, and monthly personal income. Couples at the Charleston site were more likely to be married (100% vs. 58%, $\chi^2(1) = 6.9$, $p = .009$), but were not married for significantly longer (M = 16.5 years, SD = 12.44) than married couples at the San Diego site (M = 9.1, SD =

7.21), $t(21) = 1.77$, $p = .09$. Unmarried couples at the San Diego site reported living together for 6.31 years on average ($SD = 6.65$). At the Charleston site, men (26% vs. 7%, $\chi^2(1) = 4.06$, $p = .044$) and women (26% vs. 2%, $\chi^2(1) = 8.39$, $p = .004$) were significantly more likely to be African American. There were no site differences in age, personal monthly income, education level, or employment for men or women, and no site difference in the number of couples who reported having one or more children.

Data imputation. Data that appeared to be missing at random (i.e., fewer than three consecutive questions in a multi-item questionnaire) were imputed using the SPSS EM multiple imputation procedures. Missing data were not imputed if the item was a categorical or string variable (e.g., level of education), occurred in the questionnaire battery as a single item (e.g., age), or if three or more consecutive items in a questionnaire were missing. For the weekly questionnaires, only items from the CSI-4 were imputed if they met the above criteria (i.e., if fewer than three consecutive items were missing). In total, only 43 CSI items were missing under these criteria and subsequently imputed (1.2% of all data).

Differences from Sample 2

The two samples did not differ on average number of therapy sessions completed. Participants did not differ on education level, personal monthly income, proportion of couples who were married, or proportion of participants who identified as Hispanic, African-American, Asian, or Native American. Samples did not differ on women's age or on proportion of female participants who identified as White. Participants in Sample 2 were significantly more likely to have at least one child than those in Sample 1 (71% vs. 42%, $\chi^2(1) = 11.16$, $p = .001$). Male participants in Sample 1 were significantly more likely to identify as White than those in Sample

2 (72% vs. 47%, $\chi^2(1) = 8.99$, $p = .003$). Men in Sample 1 ($M = 50.62$, $SD = 14.1$) were significantly older than those in Sample 2 ($M = 44.49$, $SD = 13.1$), $t(140) = 2.268$, $p = .025$.

Study 2 Results

We applied the DSA model generated from Sample 1 using the same standard and change-as-outcome RM-APIM models described above. Both models were estimated in SAS PROC MIXED using restricted maximum likelihood and a banded Toeplitz variance-covariance structure. For Sample 2, random intercepts were not significant for husbands or wives; in addition, excluding the random intercepts from the models did not significantly worsen model fit, -2LL(~2) = 2.5, $p = .287$, and so we dropped the random intercepts from the model.

Hypotheses were fully supported after applying the generated DSA model to Sample 2 (see Table 4). As expected, results from the standard RM-APIM demonstrated significant actor effects for both husbands ($b = .93$, $SE = .02$, $p < .0001$) and wives ($b = .93$, $SE = .02$, $p < .0001$); again, because the magnitude of the effects were less than 1, this suggests that this sample also contains an attractor (Hypothesis 1). The intercepts suggest that the attractor is located at CSI-4 scores of 17.67 for husbands and 16.11 for wives, which is above the cutoff score of 13.5 indicating marital distress. Partner effects were also significant for both husbands ($b = .04$, $SE = .02$, $p = .047$) and wives ($b = .05$, $SE = .02$, $p = .041$; Hypothesis 2). As in the model for Sample 1, the partner effects were in the opposite direction of the actor effects in the change-as-outcome model. Because the actor effects were negative, indicating a return to the attractor, and partner effects were positive, these results suggest that spouses' CSI scores tended to slow their partner's return to the attractor over time.

Data Exploration

After applying the generated DSA model to Sample 2, we visually inspected the data using the DSA data exploration procedures described above in order to determine whether the model appeared to be a good fit based on data characteristics. As in Sample 1, spaghetti plots of CSI score over time showed within- and between-person variability in scores (see Figure 5).The one-dimensional state space plots (Figures 6a and 6b for wives and husbands, respectively), show a possible cubic relationship between raw CSI score and change in CSI, with both wife and husband data demonstrating two potential set points where the smoothed slope (shown in blue) approaches or crosses the horizontal line where change is equal to zero. For both plots, the set points appear to be attractors because of the negative slope. The lower putative attractor (where the blue line approaches the *x*-axis) appears to be located at approximate CSI scores of 15 for wives and 17 for husbands, and the higher putative attractor (where the blue line crosses the *x*-axis at 0) appears to be located at CSI scores of approximately 22 for wives and 22 for husbands. Butner et al. (2017) notes that two attractors must have a repeller in between them (and vice versa) to delineate the different attractor basins. In these plots, the putative repeller appears to peak at approximate CSI scores of 18 for wives and 18 for husbands.

The initial KDP (see Figure 7a) showed three possible peaks where the CSI data collected over time, with one pronounced peak occurring at a score of approximately 13 for the wife and 16 for the husband, and two less pronounced peaks occurring at a score range of approximately 20-25 for both the husband and wife. The vector plot (Figure 7b) provides visual support for two attractors (low-low and high-high) where husbands' and wives' values are more likely to fall; the two less pronounced peaks appear to function as a single attractor. There is also a ridge in

between the putative attractors where vectors are less dense, suggesting that scores are less likely to fall in that area (e.g., the repeller).

The Loess-smoothed inferred vectors (Figure 7c) demonstrate a swirling pattern around the low attractor, which is consistent with an interpretation of interpersonal dynamics or score coupling as before. The high attractor shows less prominent swirling patterns, suggesting that couples whose scores fall in this basin of attraction are less sensitive to each other's satisfaction. Finally, the area between the two attractors demonstrates a ridge, such that scores in this area are likely to be pulled to one attractor or the other (e.g., the repeller).

Taken together, this visual evidence suggests that Sample 2 may have two attractors in relationship satisfaction (one characterized by moderately low husband and wife satisfaction, the other characterized by moderately high husband and wife satisfaction), with a repeller in between. Thus, we decided to conduct post hoc analyses to investigate this alternative model and the possibility of multiple set points. As before, we expect to find significant mutual partner effects because of the swirling patterns.

Post Hoc Analyses

Sample 2

We again estimated standard and change-as-outcome RM-APIMs, using the dual intercept parameterization as before. Models were estimated in SAS PROC MIXED using restricted maximum likelihood and the same banded Toeplitz variance-covariance structure. Following the recommendations of Butner and colleagues (2017), we added quadratic and cubic actor and partner effects to the models in order to test for three set points (two attractors, with a repeller in between, and partner effects for each set point):

Standard RM-APIM:

$$WifeRS_{it+1} = b_{w0} + b_{w1}WifeRS_{it} + b_{w2}WifeRS^2_{it} + b_{w3}WifeRS^3_{it} + b_{w4}HusbandRS_{it} + b_{w5}HusbandRS^2_{it} + b_{w6}HusbandRS^3_{it}$$

$$HusbandRS_{it+1} = b_{h0} + b_{h1}HusbandRS_{it} + b_{h2}HusbandRS^2_{it} + b_{h3}HusbandRS^3_{it} + b_{h4}WifeRS_{it} + b_{h5}WifeRS^2_{it} + b_{h6}WifeRS^3_{it}$$

Change-as-outcome RM-APIM:

$$\Delta WifeRS_{it} = b_{w0} + b_{w1}WifeRS_{it} + b_{w2}WifeRS^2_{it} + b_{w3}WifeRS_{it} + b_{w4}HusbandRS_{it} + b_{w5}HusbandRS^2_{it} + b_{w6}HusbandRS^3_{it}$$

$$\Delta HusbandRS_{it} = b_{h0} + b_{h1}HusbandRS_{it} + b_{h2}HusbandRS^2_{it} + b_{h3}HusbandRS_{it} + b_{h4}WifeRS_{it} + b_{h5}WifeRS^2_{it} + b_{h6}WifeRS^3_{it}$$

The post hoc cubic model (see Table 5 for model results) provided insufficient evidence for more than one attractor or set point. In the standard RM-APIM, the linear actor effects (b_{h1} and b_{w1}) were significant for both husbands (b = 1.01, SE = .05, p < .0001) and wives (b = .95, SE = .04, p < .0001). Wives showed evidence for a single attractor because the linear effect was less than 1, and their quadratic and cubic actor effects were nonsignificant. Husbands showed significant linear and cubic actor effects, but their quadratic effect was nonsignificant. However, the estimate for husbands' linear effect was above 1, indicating that scores moved away from this point over time, while the cubic effect was negative (b = -.002, SE = .01, p = .028), which could be indicative of an attractor. None of the partner effects were significant for either husbands or wives.

Based on this model, husbands' results are inconsistent with a repeller followed by an attractor because of the nonsignificant quadratic term that occurs in between the linear and cubic terms, which appear to show the repeller and attractor, respectively. In order to better explicate husbands' results, we dropped the cubic actor and partner terms from the model (see Table 6). If

husbands' relationship satisfaction did form a repeller followed by an attractor, these should be reflected in the subsequent linear and quadratic terms, respectively. Husbands' linear actor effect remained significant, but was below 1 (b = .92, SE = .03, p < .0001), indicating that scores return to the set point over time. The quadratic effect was nonsignificant.

Finally, we used an online resource (Wolfram Alpha, 2009) to graph the change-as-outcome equation for husbands to solve for the values of the actor effects when change was 0, as suggested by Butner and colleagues (2014). The cubic equation only crossed the horizontal axis once (where change was equal to 0); moreover, the equation solver supplied only one real value, and the remaining two values contained imaginary numbers. If husbands' relationship satisfaction had in fact contained three set points (two attractors with a repeller in between), the graph generated by the change-as-outcome equation would have crossed the horizontal axis three times, indicating three separate points where no change was observed, resulting in three real values of x (i.e., the set point locations). Thus, we concluded that we had insufficient evidence that husbands had more than the single attractor found in the original model. Taken together, these results indicate that both husbands and wives in Sample 2 showed only a single attractor in the CSI data.

Sample 1

Because the linear attractor model generated in Study 1 is only capable of detecting a single set point, we also applied the cubic actor and partner model to Sample 1 in order to investigate the possibility that it shows multiple set points. We estimated the same standard and change-as-outcome RM-APIMs, using the dual intercept parameterization and linear, quadratic, and cubic actor and partner effects. As in the model generation phase, models were estimated in SAS PROC MIXED using restricted maximum likelihood and the same banded Toeplitz

variance-covariance structure; as before, we also included random effects for husbands and wives.

As with Sample 2, the post hoc cubic model for Sample 1 (see Table 7 for model results) provided insufficient evidence for more than one attractor or set point. In the standard RM-APIM, husbands' linear effect was significant and below 1 (b = .69, SE = .04, p < .0001), and their quadratic and cubic effects were nonsignificant. Wives showed significant linear (b = .80, SE = .04, p < .0001) and quadratic (b = .01, SE = .002, p < .0001) effects, both of which were below 1, as well as a nonsignificant cubic effect. When we dropped the cubic actor and partner effects from the model (see Table 8), these effects remained similar for wives.

Because Butner and colleagues (2015) note that two attractors would need to be separated by a repeller and vice versa, in a standard RM-APIM we would expect to see significant linear and cubic effects below 1, as well as a significant quadratic effect above 1, if the data did actually show two attractors with a repeller in between. Because wives do not show evidence of a repeller, and the two effects below 1 are linear and quadratic (i.e., not separated by another term), these results do not provide strong evidence for more than one set point. Instead, results may indicate that the cubic and quadratic models are actually parceling out the effects from a single attractor. Taken together, our post hoc results do not provide sufficient evidence that wives or husbands in either sample show more set points than a single attractor in relationship satisfaction. Thus, we concluded that our original single attractor model best captured patterns of relationship satisfaction over time for both of these samples.

Discussion

Despite evidence that therapeutic change in both individuals and couples may occur in a sudden, disjointed or nonlinear fashion (e.g., Christensen et al., 2004; Doss et al., 2001;

Heimberg & Becker, 2002; Hoffman et al., 2006; Ilardi & Craighead, 1994; Knobloch-Fedders et al., 2015), the majority of research examining patterns of change in relationship satisfaction in couple therapy has utilized more traditional analytical methods that may not be optimized to detect nonlinear patterns of change. Furthermore, no known studies to date have examined patterns of change in couple therapy using a theoretical framework like dynamical systems theory, which can explain both processes of change and qualitative shifts as well as self-stabilizing processes that might occur as a system reaches an equilibrium state.

In order to investigate the possibility of nonlinear or complex patterns of change in couple therapy, we used DST and related analytical methods to generate and test a model of patterns of relationship satisfaction over the course of couple therapy for two samples of veterans and their opposite-sex spouses. We chose to use DST in order to capitalize on its ability to model and account for nonlinear patterns within partners as well as interdependence between partner scores. Specifically, we examined whether there was evidence for nonlinear change in weekly measures of relationship satisfaction for these couples.

We ultimately concluded that the single attractor model generated in Sample 1 appeared to be the best fit for both samples. This interpretation was supported by post hoc data exploration and analyses that investigated the alternative possibility that relationship satisfaction might demonstrate up to three set points; these post hoc models provided insufficient evidence that the samples demonstrated more than one set point. Importantly, we found consistent evidence across both samples for a single relationship satisfaction attractor for husbands and wives, as well as significant score interdependence where individuals slow their partner's return to the attractor.

Overall, these findings support our general hypothesis that relationship satisfaction does not necessarily follow a linear trajectory over the course of couple therapy. Instead, we found

evidence that couples in therapy experience an equilibrium point that relationship satisfaction fluctuates around and is drawn to over time. In our samples, the equilibrium points reflected moderate relationship dissatisfaction (Sample 1) and non-distress (Sample 2). This pattern can be conceptualized as a nonlinear or complex trajectory, in comparison to a linear trajectory, where scores might either remain the same over time or exhibit linear change across the course of therapy. If couples' satisfaction scores did follow a linear trajectory and demonstrated consistent change, we would not have found evidence for an attractor, as there would be no point for couples' scores to return to; that is, there would be no single score on the measures of relationship satisfaction where we would expect no change to occur. On the other hand, if couples' scores did not change at all over therapy, the actor effects would have been 1 in the standard RM-APIM or 0 in the change-as-outcome RM-APIM, indicating perfect stability in satisfaction from one week to the next.

These findings are consistent with some previous literature on couple therapy that suggests that linear change should not always be expected. Two of those such studies found evidence for piecewise trajectories (Christensen et al., 2004; Knobloch-Fedders et al., 2015), while a third demonstrated sudden gains (Doss et al., 2011). Although we did not specifically test for these trajectories in the current study, we might expect to see evidence for two separate attractors (with a repeller in between) in both cases. For a piecewise trajectory, the location of the knot or "turning" point might reflect a moderator of attractor location. For example, we might find evidence for a lower attractor where scores cluster for the first segment of therapy, and for a higher attractor for the second segment as scores shift to and remain in a different level reflecting higher functioning.

We might find similar results for the sudden gains pattern, where the sudden change experienced during a clinically meaningful session or between two successive sessions might function as a repeller or tipping point. In that case, we might see that the couple's scores move quickly away from that point as the partners experience an important shift in critical cognitions, affect, or behavior (e.g., Tang & DeRubeis, 1999). In addition, the equilibrium states before and after sudden gains might function as separate attractors. A tipping point pattern combined with interdependence of scores could be consistent with previous findings of sudden gains in couple therapy observed in one of our datasets (Doss et al., 2011), where sudden gains in one partner significantly predicted sudden gains in the other, again underscoring the importance of analyzing cross-partner effects.

Overall, our results indicate that couples in therapy experience homeostatic processes in their relationship satisfaction that serve to maintain either moderate relationship distress (Sample 1) or non-distress (Sample 2). Given that we found evidence for only one attractor, rather than multiple set points, these results may be indicative of how difficult it is for couples to destabilize and ultimately shift from well-established dysfunctional patterns to more satisfying ones, even when engaged in therapy. While therapy may primarily focus on changing targets within the couple and the relationship, such as communication and conflict behaviors, acceptance of partner differences, and positive relationship-related cognitions and affect, therapy may neglect other important embedded contextual factors that act as maintaining forces of the dissatisfied attractor, such as stress, unemployment or marginalization (Fincham et al., 2007). By the time couples decide to engage in therapy for relationship difficulties, maladaptive patterns may have become well-established and ingrained in the couple's day-to-day life, maintained by significant

contextual influences, and difficult to destabilize or shift, particularly with the short-term interventions that are often emphasized.

In addition, we found significant partner effects that showed partners' dependency in relationship satisfaction scores. Overall, this suggests that for couples in therapy, the idea of a collaborative set (e.g., Dimidjian, Martell, & Christensen, 2002; Jacobson & Margolin, 1979) may be crucial to therapeutic change, such that partners are able to view the relationship distress as something that they can resolve by working together, rather than viewing the issue as a problem generated by one partner (i.e., blame). Consistent with this idea, the partner effects that we found suggest that the couple is unlikely to improve if only one partner experiences increased satisfaction; it may be that both partners will need to experience changes in the relationship (for example, using new communication strategies or efforts to stop problematic conflict) before satisfaction is able to be increased and then sustained. Because partner effects were in the opposite direction of actor effects, we conclude that partner satisfaction may act as a mild destabilizer, as it slows individuals' return to the attractor. For example, if both partners experience higher satisfaction than usual, the partner effects may help both individuals' scores to stay elevated longer than they typically would if there were no partner effects. However, this pattern occurs in the opposite direction as well: when both partners experience levels of satisfaction below the attractor (i.e., less satisfaction than usual), they will stay in that state for longer than might otherwise be expected given the strength of the attractor.

Importantly, however, our results do not necessarily suggest that couple therapy is ineffective in improving relationship satisfaction for couples in distress. In the absence of additional variables, it is difficult to determine whether the equilibrium state we detected is the same one that couples might have started out with (i.e., a state of distress and dysfunction) or

perhaps one reflecting some mid-point in therapeutic change (for example, marked by hope and initial steps toward change in the absence of increased relationship satisfaction). It is also possible that even in successful couple therapy, we may detect only one attractor representing the distressed equilibrium experienced in the beginning of therapy. Over the course of therapy, the couple may experience destabilization as they work on implementing new skills and gaining new insight, but they may not experience stabilization and a shift to a new equilibrium until after therapy has concluded and participation in the study has stopped.

What is clear from previous research is that not all couples benefit from therapy; what is not yet clear is who does not benefit, and why. In this vein, it is important to note that our data captures a wide range of couples and couple therapy experiences. Approximately half of each sample was characterized as experiencing significant distress, with a wide range of scores on measures of relationship satisfaction (see also Figures 2 and 5). Many couples terminated treatment prematurely or completed fewer than 8 sessions. There was also variability across couples in contextual factors such as education level, number of children, and income that could contribute to maintaining forces such as stress. Thus, while our overall results suggest the presence of a single equilibrium point, it is likely that moderating variables may show different attractors or patterns of change for different types of couples.

Because of these limitations, future dynamic systems research on couple therapy should build on the current study by investigating salient variables that could act as control parameters or moderators of trajectories of relationship satisfaction, or that could impact the location and/or strength of attractors or repellers. For example, analyses could take into account whether couples who dropped out of therapy show different patterns than those who completed therapy. Based on previous research that suggests that couple therapy is less effective for highly distressed couples

(Jacobson & Addis, 1993), we might also expect that patterns of change and topological features may differ based on level of marital distress at intake, or on whether the couple met criterion cutoffs for relationship distress. Features might also differ based on the number of total therapy sessions attended, or on whether the couple attended enough sessions to be characterized as having received a full course of therapy. It would also be particularly important to include larger sample sizes.

Future research could also incorporate variables reflecting therapist- or setting-related constructs in investigations of couple therapy. For example, therapeutic modality or therapist theoretical orientation, as well as therapeutic interventions used in session, could impact the topography of relationship satisfaction. Investigating change associated with different theoretical approaches could provide important insight into potential mechanisms of couple therapy, particularly if different modalities are associated with distinct (or similar) patterns of change. Relatedly, these analyses could be repeated in other samples in order to better reflect couples who seek therapy from the general population; in particular, it would be important to utilize non-veteran samples, as well as less affluent and highly educated samples, and to collect data from other areas of the country. Further, DSA-based research on relationship processes should include other outcome measures in order to investigate other changes that may occur during couple therapy, as relationship satisfaction is not the only construct we might expect to change. Therefore, it would be helpful to include other measures, including ones assessing skills or behavior, partner- and relationship-related cognitions and attributions, relationship commitment, security, acceptance of partner differences, and feelings of connectedness, affection, warmth, or understanding.

Finally, the analyses presented here represent trajectories of lower-order change (i.e., change from week to week). Additional investigations could include DST models to test higher-order change patterns that may occur, including ones that unfold over multiple sessions (such as a significant relationship injury and the subsequent repair process), as well as their interactions with lower-order change or levels of relationship satisfaction. Higher-order patterns may also shift as a result of couple therapy: for example, a couple whose interactions are often characterized by the demand/withdraw pattern may become less polarized over time, and this cyclical pattern may weaken in stability over the course of therapy. Patterns like oscillation and acceleration or deceleration in behavior frequency would involve more computationally complex models to capture (Butner et al., 2014) and are beyond the scope of the current paper, but are likely to provide additional insight into constructs of interest.

The current study is the first known application of DST and related analytical methods to the study of relationship processes during couple therapy. It represents an important first step in the application of DSA to couples research, not only in demonstrating that these methods are an appropriate and useful way to examine time-related processes in couples, but also in providing a number of directions for research that could help inform future implementations of couple therapy. Based on our findings, we have evidence across two separate samples of veterans and their opposite-sex romantic partners that couples in therapy experience an equilibrium state that may be difficult to shift from. In examining moderators of the topology of relationship satisfaction as well as predictors of specific therapeutic outcomes from a DSA perspective, we may be able to glean information about the impact that therapists have in treatment and about what couples do outside of treatment that creates a new attractor marked by higher satisfaction,

shifts couples from the low to the high attractor (i.e., allows couples to benefit from treatment), and keeps them at the high attractor, enabling couples to maintain benefits over time.

The results from the current study also give way to a number of broader questions about the field of couple research relating to the concept of transformative change (Fincham et al., 2007). Couples in distress likely did not begin their relationships in that state of discord, suggesting that some couples start out with high satisfaction and, through an initial perturbation and subsequent iterative processes, come to experience distress and dissatisfaction. Transformative change can also move in a positive direction: preliminary evidence suggests that couples in distress can experience remission in the absence of couple therapy or other formal intervention (Waite & Luo, 2002). Given that not all couples benefit from therapy, and that some couples are able to make changes without therapy, we can use dynamical systems theory and analyses to examine whether couples in distress need therapy or similar interventions in order to shift to a more satisfied equilibrium state. We can examine what types of couples experience these transformative processes leading to spontaneous remission, as well as the circumstances under which remission is observed, in order to better understand who is at risk for needing external help. Finally, for couples that do need therapy, DSA can enhance investigations of how self-repair and other naturally-occurring self-regulatory processes can be utilized to improve the efficacy and long-term benefits of couple therapy.

Limitations and Considerations

Limitations

The findings from the studies reported above should be interpreted within the context of a number of methodological limitations. First, sample 2 was limited by a small sample size (n = 45 couples); unfortunately, the studies used different measures of relationship satisfaction that were

unsuitable for comparison using Item Response Theory methodology, and so we could not combine the samples. Because these studies focused on the novel application of flexible analytical methods to couple therapy, we took a primarily exploratory approach, with the goal of better understanding the evolution of relationship satisfaction during couple therapy. As a result, we did not account for variables that could have acted as moderators (i.e., control parameters) of changes in relationship satisfaction over time, or of set point number, strength and location.

The sample was comprised of veterans and their romantic partners, who may systematically differ from civilians in ways that may impact couple therapy or relationship satisfaction, and results may not necessarily generalize to non-veterans. Further, the studies took place within the VA healthcare system. Therapy conducted by VA-employed psychologists may not be representative of how private practitioners or therapists in other institutions conduct or are trained in couple therapy. Further, couple therapy at the VA may differ in the types or frequency of interventions used in session from couple therapy in other practice settings. The sample was limited to veterans and their partners in the catchment areas of the Charleston and San Diego VA Medical Centers, and so is somewhat limited geographically; results may not generalize to veterans and romantic partners who live in more rural areas or in other geographical areas of the country, such as the Pacific Northwest, Midwest or Northeast.

Finally, couples in both samples completed a wide range of number of therapy sessions, and we did not incorporate data on drop out versus treatment completion in our analyses. It is possible that couples may experience different patterns of relationship satisfaction depending on overall length of therapy, or depending on whether they prematurely end treatment or are considered treatment “completers.” Even within couples who completed treatment, length of therapy may be tied to other important third variables, such as level of marital distress, scope of

relationship difficulties, communication skills, commitment to the relationship, belief in treatment efficacy, etc.

Ethical Considerations

A major ethical consideration in the current study is the presence of intimate partner violence (IPV) in couples who were screened for eligibility to participate in the study. Because they were not eligible and thus did not complete intake questionnaires, we do not have data on the percentage of couples who were excluded because of IPV. Because most of the participants were not members of a protected population (e.g., minors, the elderly, or the disabled), study staff were prohibited from reporting IPV to protective services for those participants. In cases of significant IPV or significant drug or alcohol abuse, participants were given referrals to resources; however, staff members were not necessarily able to follow up with participants who were ruled ineligible because to ensure that they had accessed appropriate treatment or resources.

Due to the nature of the study and participating clinics, couples completed therapy-as-usual and may not have had choices in the type of therapy they chose because of clinic or therapist limitations. They may have preferred a different type of therapy (or therapist) that might have resulted in more positive outcomes but were unable to participate in the preferred therapy because of site limitations. Participants may also have dropped out or been less engaged in therapy because of these limitations.

Cultural Considerations

It is important to note that both studies took place in VA hospitals, and so all participating couples were comprised of at least one veteran and their civilian partner (in rare cases, both partners were veterans). Veterans and their partners may deal with different relationship and individual issues than couples where both members are civilians, and so results

may not generalize to a civilian population. Results of the study may also not generalize to veterans and partners who chose to receive health care services outside the VA system; this may include those who are more affluent, who are very impoverished, or who live in more rural areas.

Other demographic aspects of the sample should also be taken into consideration. Because the sample was comprised of male-female pairs, results may not generalize to same-sex relationships, even among veterans and same-sex partners. In addition, most participants were Caucasian or African American, so results may not generalize to participants who identify as Hispanic, Asian, Native American, or as members of multiple races/ethnicities, or to interracial couples. Couples reported relatively high monthly personal income (over $9000) and high educational attainment, with 74% attending some college or higher, and 30% completing college or higher. As a result, our findings may not reflect couple therapy experiences in less affluent samples, or in samples with fewer years of formal education. The studies were only conducted with couples in the catchment areas of the VAs in San Diego and Charleston, and so was fairly limited geographically. San Diego and Charleston are relatively affluent, primarily urban/suburban areas, and so results may not generalize to couples who live in rural areas or less affluent urban areas.

Conclusion

We examined changes in relationship satisfaction during couple therapy in two samples of veterans and their opposite-sex romantic partners using a novel application of dynamical systems theory and related analytical methods. We not only demonstrated the feasibility of examining couple therapy processes using DST, but also consistently found evidence that both samples contained a single attractor that relationship satisfaction scores were drawn to over time. These preliminary findings suggest that couples in therapy experience homeostasis in satisfaction

that may be difficult to disrupt or shift, even when the couples are in distress. Future inquiries into potential moderators of this homeostasis may provide insight into therapeutic, individual- and couple-level factors that may enable these couples to disrupt patterns that maintain distress in order to shift to a state of more adaptive and sustained functioning.

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Table 1

Sample 1 means, standard deviations, and percentages for demographic and model variables by gender and site.

	Charleston		San Diego	
	Men	Women	Men	Women
Age	49.0 (13.3)	45.02 (11.6)	51.8 (14.7)	48.6 (14.6)
Ethnicity				
White, non-Hispanic	36 (63.2%)	38 (66.7%)	45 (60.8%)	42 (56.8%)
Hispanic	3 (5.3%)	0	4 (5.4%)	8 (10.8%)
African American	15 (26.3%)	15 (26.3%)	6 (8.1%)	4 (5.4%)
Other	1 (1.8%)	1 (1.8%)	6 (8.1%)	8 (10.8%)
Did not respond	2 (3.5%)	3 (5.3%)	13 (17.6%)	12 (16.2%)
Education				
High school	17 (29.8%)	16 (28.1%)	18 (24.3%)	10 (13.5%)
Some college or Associate's	22 (41.5%)	22 (42.3%)	20 (33.3%)	18 (30.5%)
BA/BS or higher	11 (20.7%)	9 (17.3%)	21 (35.0%)	26 (44.0%)
Monthly income	2395.7 (1884.3)	1348.5 (1100.7)	3245.1 (2704.0)	2277.9 (2047.0)
QMI	24.9 (9.50)	21.1 (9.96)	29.1 (9.63)	25.3 (9.79)

Table 2

Sample 2 means, standard deviations, and percentages for demographic and model variables by gender and site.

	Charleston		San Diego	
	Men	Women	Men	Women
Age	45.8 (10.7)	43.2 (9.9)	43.8 (14.4)	42.9 (14.0)
Ethnicity				
White, non-Hispanic	8 (66.7%)	9 (75%)	13 (39.4%)	18 (54.5%)
Hispanic	0	0	5 (15.2%)	3 (9.1%)
African American	3 (25.0%)	3 (25%)	2 (6.1%)	1 (3.0%)
Other	1 (8.3%)	0	3 (9%)	3 (9.1%)
Did not respond	0	0	10 (30.3%)	8 (24.2%)
Education				
High school	4 (33.3%)	2 (16.7%)	4 (12.1%)	3 (9.1%)
Some college or Associate's	5 (41.7%)	9 (66.7%)	14 (42.4%)	13 (39.4%)
BA/BS or higher	3 (25.0%)	2 (16.7)	4 (12.1%)	8 (24.2%)
Monthly income	3167.8 (1244.9)	1500.5 (824.8)	3479.2 (2093.5)	2113.7 (2328.8)
CSI	116.5 (12.7)	108.1 (22.6)	125.2 (14.6)	111.4 (20.1)

Table 3

Results from the standard and change-as-outcome RM-APIMs for QMI score.

		Standard RM-APIM			Change-as-outcome RM-APIM		
		B	SE B	p-value	B	SE B	p-value
Husband	Intercept	23.45	.18	< .001	5.31	.52	< .001
	Actor effect	.75	.02	< .001	-.25	.02	< .001
	Partner effect	.05	.02	.033	.05	.02	.033
Wife	Intercept	21.41	.20	< .001	4.25	.53	< .001
	Actor effect	.74	.02	< .001	-.26	.02	< .001
	Partner effect	.08	.03	.003	.08	.03	.003

Table 4

Standard and change-as-outcome RM-APIM results from applying the test model to Sample 2.

		Standard RM-APIM			Change-as-outcome RM-APIM		
		B	SE B	p-value	B	SE B	p-value
Husband	Intercept	17.67	.08	< .001	.68	.32	.036
	Actor effect	.93	.02	< .001	-.07	.02	.005
	Partner effect	.04	.02	.047	.04	.02	.047
Wife	Intercept	16.11	.08	< .001	.35	.32	.275
	Actor effect	.93	.02	< .001	-.07	.02	.001
	Partner effect	.05	.02	.041	.05	.02	.041

Table 5

Standard and change-as-outcome RM-APIM results from the post hoc cubic model for CSI.

		Standard RM-APIM			Change-as-outcome RM-APIM		
		B	SE B	p-value	B	SE B	p-value
Husband	Intercept	17.76	.15	< .001	8.23	3.25	.013
	Actor effect	1.01	.05	< .001	-1.65	.70	.019
	Quadratic actor effect	-.01	.01	.362	.10	.04	.026
	Cubic actor effect	-.002	< .01	.028	-.002	< .01	.028
	Partner effect	.04	.04	.311	.11	.32	.740
	Quadratic partner effect	< .001	< .01	.921	-.004	.02	.842
	Cubic partner effect	< .001	< .01	.833	< .001	< .01	.833
Wife	Intercept	16.14	.15	< .001	2.42	3.24	.457
	Actor effect	.95	.04	< .001	-.30	.32	.356
	Quadratic actor effect	< -.001	< .01	.557	.02	.02	.429
	Cubic actor effect	< -.001	< .01	.389	< -.001	< .01	.389
	Partner effect	.06	.05	.212	-.16	.70	.825
	Quadratic partner effect	.002	< .01	.773	.01	.04	.809
	Cubic partner effect	< -.001	< .01	.847	< -.001	< .01	.847

Table 6

Standard and change-as-outcome RM-APIM results from the post hoc quadratic model for CSI.

		Standard RM-APIM			Change-as-outcome RM-APIM		
		B	SE B	p-value	B	SE B	p-value
Husband	Intercept	17.63	.13	< .001	1.27	1.17	.282
	Actor effect	.92	.03	< .001	-.14	.16	.399
	Quadratic actor effect	.002	< .01	.714	.002	< .01	.714
	Partner effect	.04	.02	.045	304	.10	.675
	Quadratic partner effect	< .001	< .01	.970	< .001	< .01	.970
Wife	Intercept	16.10	.13	< .001	.69	1.16	.551
	Actor effect	.93	.02	< .001	-.03	.10	.730
	Quadratic actor effect	-.001	< .01	.662	-.001	< .01	.662
	Partner effect	.05	.03	.037	-.02	.16	.889
	Quadratic partner effect	.002	< .01	.634	-.001	< .01	.662

Table 7

Standard and change-as-outcome RM-APIM results from the post hoc cubic model for QMI.

		Standard RM-APIM			Change-as-outcome RM-APIM		
		B	SE B	p-value	B	SE B	p-value
Husband	Intercept	22.97	.27	< .001	6.96	1.26	< .001
	Actor effect	.69	.04	< .001	< .001	.22	.999
	Quadratic actor effect	.003	< .01	.192	-.02	.01	.150
	Cubic actor effect	< .001	< .01	.121	< .001	< .01	.121
	Partner effect	.10	.04	.008	-.38	.19	.051
	Quadratic partner effect	.003	< .01	.076	.02	.01	.066
	Cubic partner effect	< -.001	< .01	.144	< -.001	< .01	.144
Wife	Intercept	21.07	.26	< .001	4.85	1.24	< .001
	Actor effect	.80	.04	< .001	-.84	.19	< .001
	Quadratic actor effect	.01	< .01	< .001	.02	.01	.028
	Cubic actor effect	< -.001	< .01	.167	< -.001	< .01	.167
	Partner effect	.04	.04	.375	.50	.22	.020
	Quadratic partner effect	-.004	< .01	.098	-.02	.01	.161
	Cubic partner effect	< .001	< .01	.353	< .001	< .01	.353

Table 8

Standard and change-as-outcome RM-APIM results from the post hoc quadratic model for QMI.

		Standard RM-APIM			Change-as-outcome RM-APIM		
		B	SE B	p-value	B	SE B	p-value
Husband	Intercept	23.02	.25	< .001	7.23	.91	< .001
	Actor effect	.74	.03	< .001	-.32	.09	< .001
	Quadratic actor effect	.001	< .01	.523	.001	< .01	.523
	Partner effect	.06	.02	.012	-.12	.08	.141
	Quadratic partner effect	.004	<.01	.027	.004	<.01	.027
Wife	Intercept	21.06	.24	< .001	4.72	.89	< .001
	Actor effect	.77	.02	< .001	-.59	.08	< .001
	Quadratic actor effect	.01	< .01	< .001	.01	< .01	< .001
	Partner effect	.06	.03	.017	.30	.09	< .001
	Quadratic partner effect	-.01	< .01	.010	-.01	< .01	.010

Figure 1

Topographical map with vector overlay.

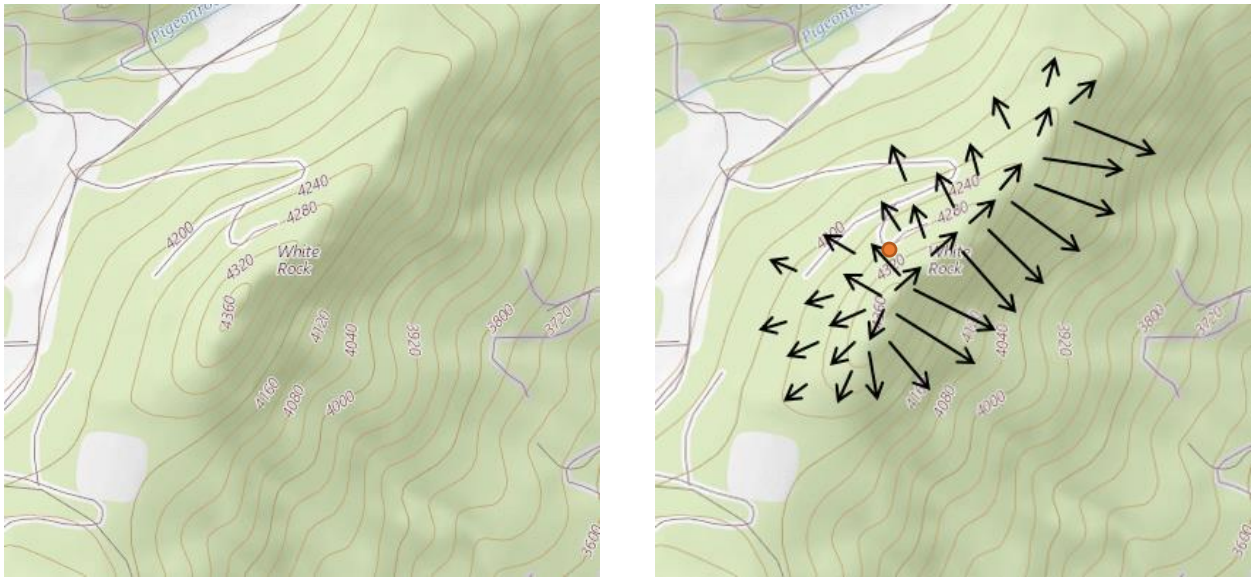


Figure 1. On the left, a topographical map of White Rock Mountain (U.S. Geological Survey map generated with NationalMap.gov, https://viewer.nationalmap.gov/basic/?basemap=b1&category=ustopo&q=&zoom=15&bbox=-81.83896065,36.15561783,-81.79119587,36.18593125&preview=&avail=&refpoly. On the right, the same map with an overlaid vector field showing the possible progression and rate of descent from a path originating at the top of the ridge.

Figure 2

Spaghetti plot for QMI scores over the course of therapy for Sample 1.

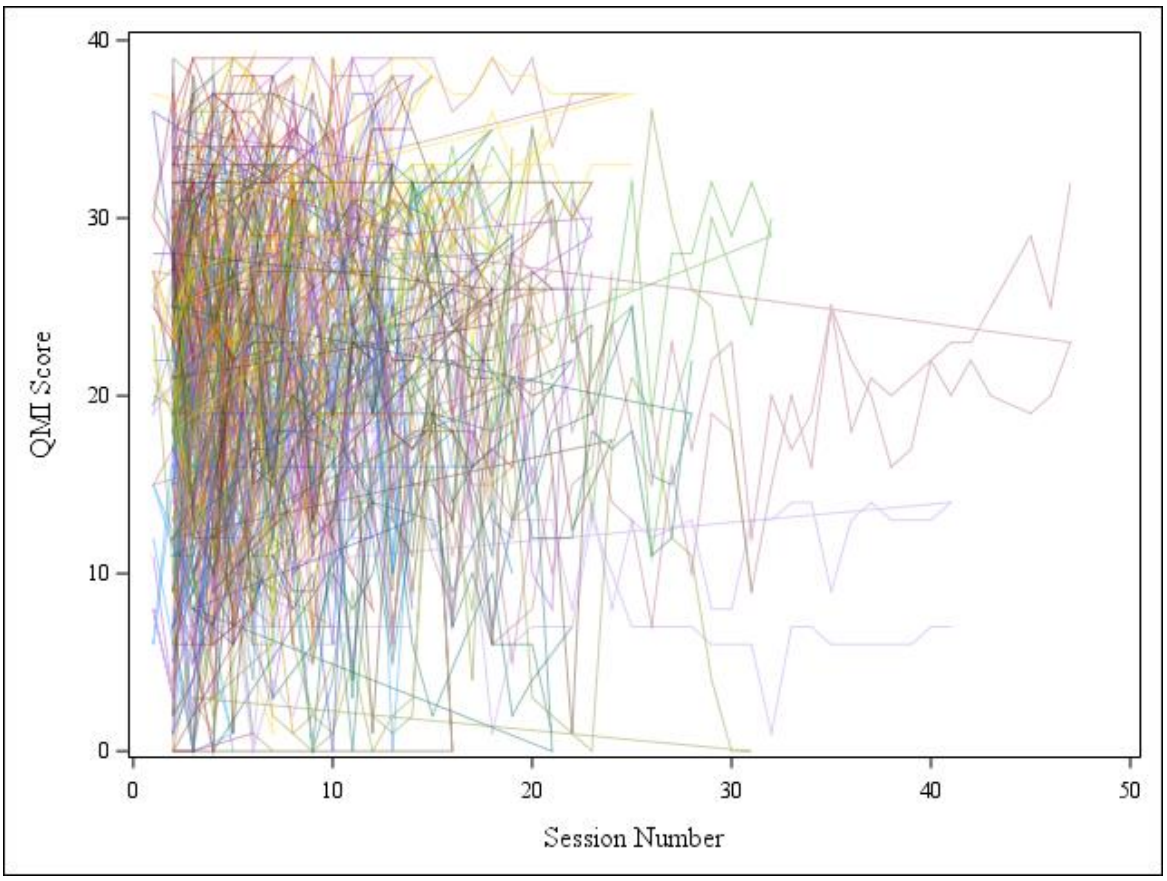


Figure 3

One-dimensional state space plots for husband and wife QMI scores.

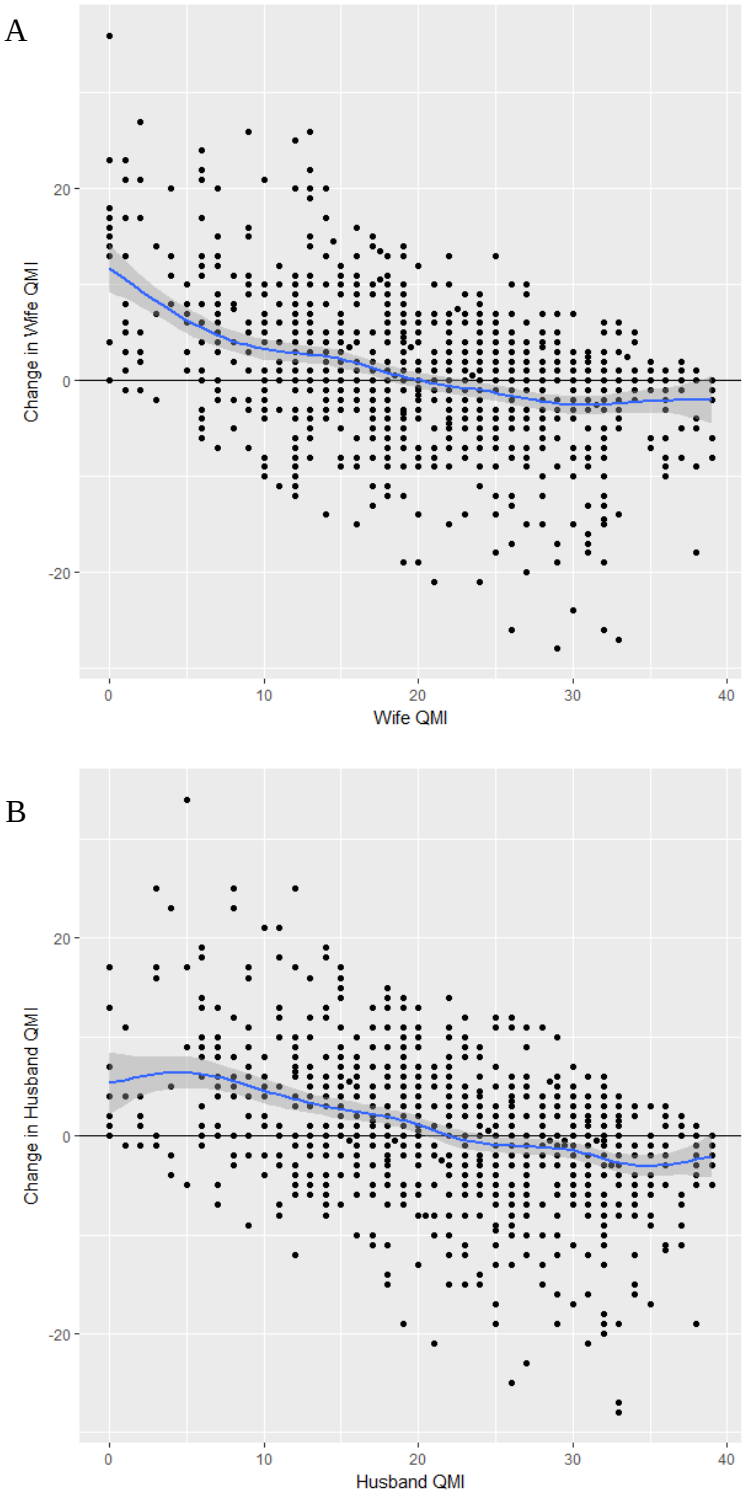


Figure 4

Two-dimensional kernel density plot, vector overlay, and Loess-smoothed inferred vector overlay plots for QMI scores.

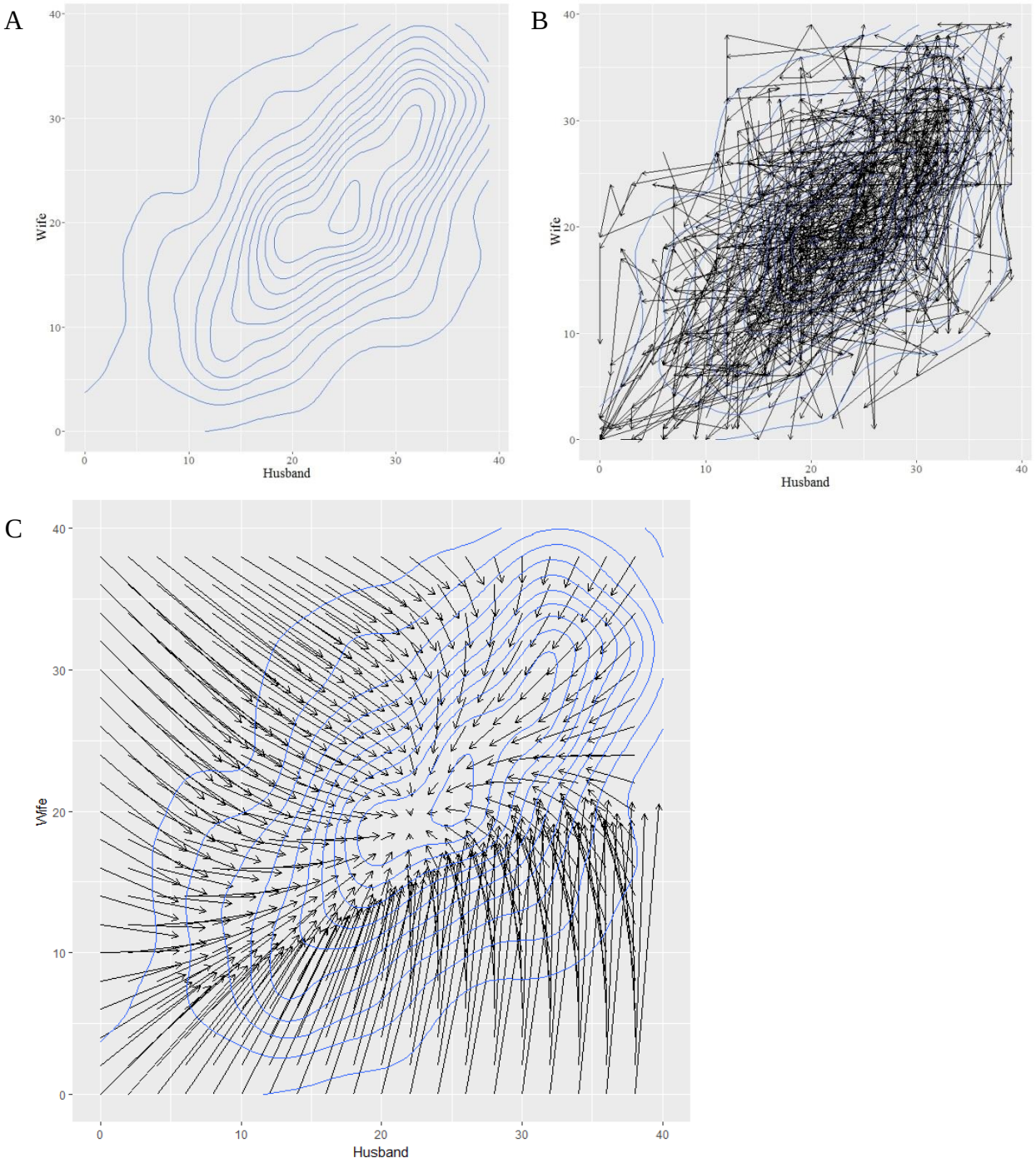


Figure 5

Spaghetti plot for CSI-4 scores over the course of therapy for Sample 2.

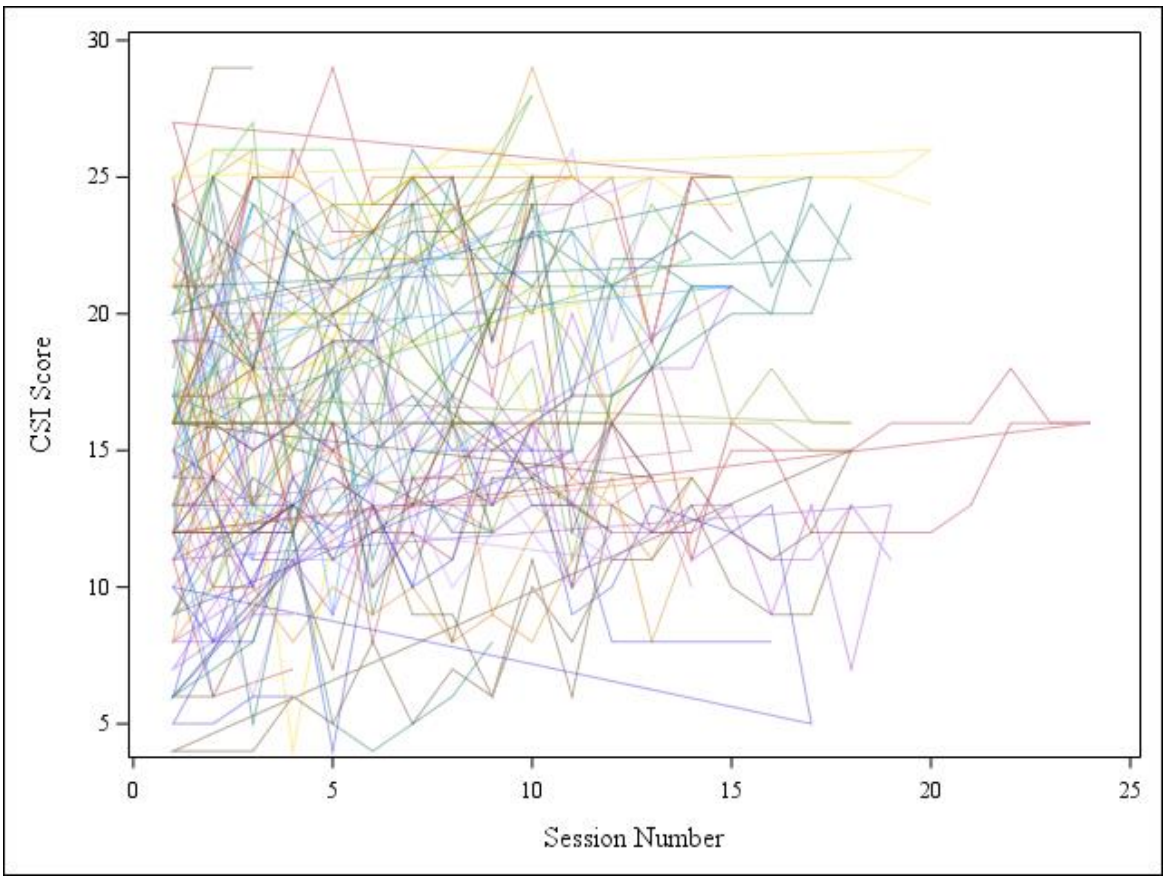
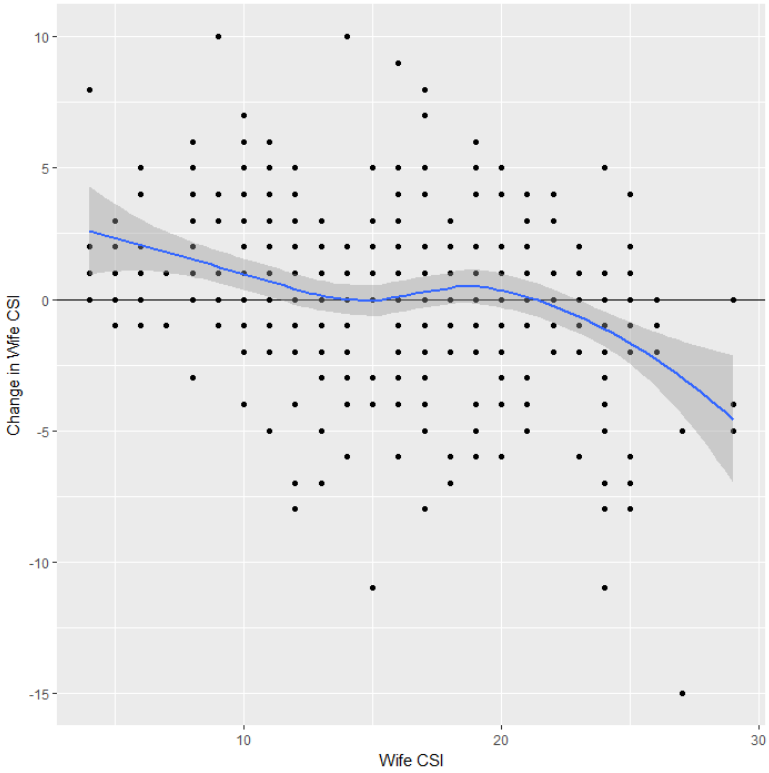


Figure 6

One-dimensional state space plots for husband and wife CSI-4 scores.

A



B

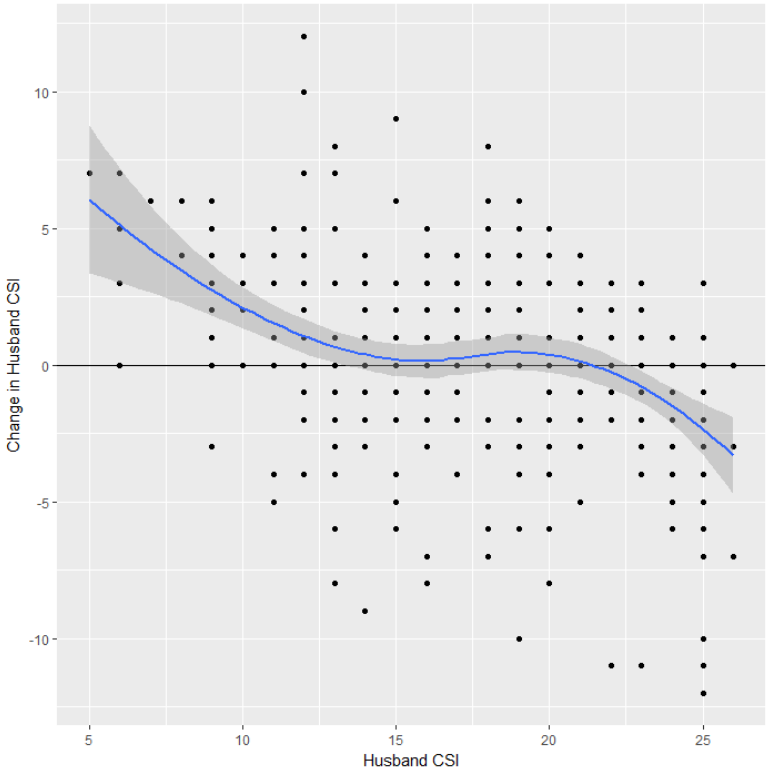


Figure 7

Two-dimensional kernel density plot, vector overlay, and Loess-smoothed inferred vector overlay plots for CSI-4 scores.