A DYNAMIC SYSTEM PERSPECTIVE ON INTERPERSONAL EMOTION
REGULATION

by

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AUTHOR'S NOTE

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ABSTRACT

Contemporary theories frame emotion as an *intra-personal* system comprised of subcomponents such as experience, expressive behaviors, and physiology that interact over time to give rise to emotional episodes. Emotional episodes occur in the context of a social interaction or an ongoing relationship making it important to also conceptualize the *inter-personal* emotion system in which the subcomponents of the emotional response interact not only within the individual but across the partners as well. Emotion theory has been constricted by a dominant linear information processing metaphor and has not yet fully embraced a dynamic systems approach integrating concepts of open, self-organizing systems to interpersonal emotion regulation processes. To address these limitations, this study examined the emergence of structure and patterns in real-time dyadic interactions between pairs of female strangers where one partner is purposefully regulating her emotional responding. One member of each dyad was randomly assigned to suppress, positively reappraise, or act normally during an interaction task. Three subcomponents of emotion were examined (expressive behaviors, experience, and physiology) along with three features of dynamic systems (attractor basins, flexibility/entropy, and physiological linkage). Results indicate differences in the emergence of structure and patterns in real-time dyadic interactions that varies by emotional responding type. Suppression dyads were characterized by a non-emotional response attractor, reduced behavioral flexibility, stronger physiological linkage as compared to control and reappraisal dyads. Reappraisal dyads expressed more positive emotions during the interaction than control or suppression dyads, and reappraisal partners showed evidence of positive physiological

linkage with the reappraiser. In conclusion, structural patterns do differ by emotion regulation condition indicating the importance of intrapersonal phenomena on the emergence of interpersonal system dynamics.

INTRODUCTION

Contemporary theories frame emotion as an intra-personal system of interacting components such as subjective experience, expressive behavior, and physiological reactions that together constitute an emotional episode (Gross, 1999; Lewis, 2005). In addition, emotions are no longer viewed as passions that come and go on their own accord but rather as complex processes that can be regulated by the individual (Gross & John, 2003). Individuals can influence which emotions they have, when they have them, and how they experience and express them (Gross, 1998). These emotional response patterns occur over time within a person, however, what is often portrayed exclusively as an intra-personal system is often occurring in the context of a social interaction or an ongoing relationship. Most of our daily lives involve interaction with others who affect us emotionally, requiring differing levels and types of emotional regulation to fit the situation. Emotional reactions to a supervisor's praise will likely look different than an emotional reaction to a loved one's praise. Unfortunately the social context has been largely ignored by prior work on emotion regulation which has been limited by an almost exclusive focus on individuals in solitary or non-interactive settings, such as controlling emotion while watching a film alone (Gross, 1998; Lazarus & Alfert, 1964) or while being observed or harassed by (but not interacting with) strangers (Friedman & Miller-Herringer, 1991; Harris, 2001; Stemmler, 1997). Furthermore, emotion theory has been constricted by traditional cognitive and behaviorist approaches, where linear information processing (i.e., step by step, incremental) has been the dominant metaphor (Lewis, 2005;

Lewis & Granic, 2000). To address these limitations, the present research adopts a dynamic systems approach that can be used to study emotions and emotion regulation in a relationship context. A dynamic approach is not concerned just with contingencies among proximal events, but also considers the overall temporal organization of the dyadic exchange.

Specifically, this work examines the emergence of structure and patterns in real-time dyadic interactions between pairs of female strangers where one partner is purposefully regulating her emotional responding in one of two ways. The first way is expressive suppression, which entails not showing any behavioral signs of emotion, even though the person is emotionally aroused. The second way is optimistic reappraisal, which involves thinking about the situation in a more positive light. I examine how three subcomponents of emotion (i.e., experience, expressive behaviors, and physiology) within each of the two people develop dynamic structure at the level of the dyadic system during an interaction task. Differences between regulation strategies are examined for each of three features of dynamic interpersonal systems: attractor basins, flexibility/entropy, and physiological linkage.

To test the effect of emotion regulation on the self-organization of dyadic systems, the present research used preexisting data from a study in which unacquainted pairs of females watched an upsetting film together and then discussed their reactions (Butler, Lee, & Gross, 2007; Butler, Lee, & Gross, 2009; Butler, Wilhelm, & Gross, 2006). Only women were chosen to eliminate gender variability, and because women are more emotionally expressive, it was expected that the effects of regulation may be greater

for them (Kring & Gordon, 1998). The pairs were randomly assigned to one of three conditions: suppression, reappraisal, or uninstructed controls. Within the experimental dyads, one woman was instructed to either suppress her emotional responses during the discussion or reappraise her emotional responses in a positive light. Their partners were given no specific instructions for the conversation. Within the control dyads, neither partner was given specific instructions for the conversation.

At the end of the conversation, each participant privately watched the video of her own conversation and rated how she felt during the conversation (*experience*) using a rating dial developed by Levenson and Gottman (1983). The videotapes were coded by experienced raters for positive and negative emotion expressive *behaviors* during the conversation. Coders rated each second of the interaction, rating when participants were speaking positively or negatively "about" the film, or whether the participants were directing positive or negative expressions "at" their partner. The coders rated segments as neutral if there was no emotional behavior present during the interval. During the conversation, participants were also connected to physiological recording equipment measuring heart rate and skin conductance, providing the *physiological* measures. These measures of behavior, experience, and physiology were all time synced for each dyad.

The present study examined how these three subcomponents of emotion (i.e., experience, expressive behaviors, and physiology) within each of the two people developed dynamic structure at the level of the dyadic system during the interaction task. Differences between regulation strategies were examined with a focus on three features of dynamic systems: attractor basins, flexibility/entropy, and physiological linkage. First,

I will introduce dynamic systems theory and how it provides a useful framework for investigating interpersonal systems. I will then describe different strategies of emotion regulation and how they may differ in a dynamic, interpersonal context. Following that, I present the three features of dynamic structure that are predicted to be affected by interpersonal emotion regulation.

CHAPTER I. REVIEW OF LITERATURE

Dynamic Systems

Dynamic systems (DS) principles provide a framework for describing how novel forms emerge and stabilize through a system's own internal feedback mechanisms (Prigogine & Stengers, 1984; von Bertalanffy, 1968). This process is known as self-organization and refers to the spontaneously generated order in complex, adaptive systems. A definition of a whole system is a complex of elements in mutual interaction (von Bertalanffy, 1968) and a dynamical system is a set of elements that interact and continually evolve over time (Hayes, Laurenceau, Feldman, Strauss, & Cardaciotto, 2007). DS principles have been applied in different disciplines (e.g., physics, chemistry, biology) and to various phenomena (e.g., lasers, brain dynamics) at vastly different scales (from cells to economic trends). In general, higher-order patterns (macroscopic processes) set the conditions for lower-order processes on a microscopic level, and in turn these microscopic processes contribute to the form of the macroscopic processes (Granic, 2000). For decades, DS principles have been successfully applied by theorists to explain underlying processes in normative human development (Fogel, 1993; Thelen & Smith, 1994).

Self-organizing systems become more complex over time by adding interacting parts and processes as they evolve. As the system gains complexity, it also becomes increasingly ordered, with macro and micro-level components expanding and contracting, allowing the system to maintain the intricate arrangement of interacting parts and processes (Lewis, 2000). Both increasing order and increasing complexity depend on the

coordination or coupling of interacting system elements. This coupling can be described as an ongoing "conversation" within the system that allows different elements to form ensembles, and ensembles of ensembles, providing an overarching orderliness that supports the complex structure. The specific characteristics that emerge in self-organization influence the path of subsequent self-organization, such that the growth process constrains the conditions for further growth (Lewis, 2000).   Although early relationship formation in the context of first-time encounters has no constraints on the form it can take, subsequent conversations and interactions would be affected by the outcome of the first encounter. If you did not like a person you met briefly during a university psychological experiment, it is unlikely that you would behave in the same manner upon the next encounter as you would if you had liked them. When growth and change of systems are being discussed, two time components are relevant to interpersonal processes: 1) the real-time moment to moment interactions, and 2) the slower paced development and maintenance of the relationship. The present study focuses on the moment to moment time frame, but this has implications for the longer time frame because the two are mutually constraining.

As open, self-organizing systems are growing in complexity and order, there are periods where stability is achieved for a time. When new information becomes available for integration, the system will shift for a period, evolving its structure and complexity until a new stable state is achieved. The multi-stability of open systems is very different from the concept of thermodynamic equilibrium which implies that all components of the system organize and transfer energy until a stable state is achieved and the system can no

longer *spontaneously* change its state (Haken, 1984; Pincus, 2001). For example, water cannot spontaneously revert back to its component hydrogen and oxygen ions. In the current view of open, self-organizing systems, people within an interpersonal system will fluctuate around a particular state of interaction, such as a cycle of coercion between two married people. As the system comes close to stasis where there are no longer opportunities for fluctuation (termed the edge of chaos), it will spontaneously erupt into a new state instead of dissolving or staying in the current state. For example, the coerced partner may become discontented and decide to seek a counselor, or divorce the partner, which will inevitably shift the dynamics within the marriage. After the shift in dynamics, the system will eventually re-stabilize with newly formed complexity and order.

The edge of chaos, the point where the system is coming close to stasis, is thought to be the most adaptive region for the evolution of system dynamics (Pincus, 2001). Systems poised at this edge are between a frozen/static region where information makes no impact and a gaseous/chaotic region where the effects of information will have a functional impact (Pincus, 2001). Closeness to the edge of chaos is thought to be an indication of complexity, and there is a positive relationship between systemic complexity and functional adaptability (Pincus, 2001). In a newly forming relationship, as is the case in this study, the system will be in a highly chaotic state because it has no previous structure to build upon and new information is integrated at a rapid pace as the system attempts to order itself. Order will occur spontaneously and its structure will be unique to the information exchanged between the two people during the conversation.

The present research focuses on three DS principles that can be used to understand how system complexity and order emerges in newly forming relationships: attractor basins, flexibility/entropy, and physiological linkage. I will briefly introduce these here, but will expand upon them in a later section. As two strangers begin to interact, there are an unlimited number of possible states for the system, and where the system goes is completely unpredictable. The flexibility of the system is defined by its ability to transition between multiple states versus the likelihood that it will perseverate or get stuck in a small number of states (Dishion, et. al, 2004). Attractor basins are regions within the state space that a system may be drawn to as the interaction continues, and may keep the system from other potential states, reducing the system's flexibility (Granic, 2000). The stronger the attractor, the more likely it will pull the system in that direction, and the more effort required to pull the system away from it (Granic & Patterson, 2003). During a conversation, a newly forming interpersonal system can fluctuate between periods of open, unpredictable behavior and topics (i.e., higher flexibility), to points of repetition where the conversation partners stay on a particular topic or emotion (e.g., anger) and do not shift away from it. Also involved in the system formation is physiological linkage, or the idea that one person's physiological response can be predicted by their interaction partner's physiological response (Levenson & Gottman, 1983). Physiological linkage is a form of information exchange between the partners that has the potential to decrease or increase the connection felt between the two people, which can affect the flexibility of the system.

The information exchanged between two strangers during their first meeting contains both verbal and non-verbal components. The content of the conversation can drive the behavioral, cognitive and physiological responses that occur in each person, which will in turn relate back to the content and duration of the conversation. Consider two possible conversation scenarios. First, a heated argument develops. Here, the system may be quickly drawn to a region of the space defined by conflict or anger (a potential attractor basin) and the heightened physiological arousal of both partners (physiological linkage) may prevent the system from moving to a more positive place (reduced flexibility). Or, alternatively, a pleasant conversation emerges, the content shifts to various topics (high flexibility, limited attractor basins), and both people stay mutually engaged in the conversation for some time (physiological linkage).

In conclusion, DS theory provides a framework for examining circular feedback processes between higher (dyadic) and lower (individual) elements during the real-time formation of spontaneous order during an interaction. The two examples above also highlight the role of emotion in the information exchange between two strangers as system patterns develop. Attractor basins, flexibility, and physiological linkage likely occur during interpersonal relationship development, but current theories have not adequately described or understood them.

Emotion and Emotion Regulation

Emotions are a ubiquitous feature of human life. Without emotions it would be difficult to interpret the significance or meaning of the events in our day to day existence and no one portion of our lives would have importance over another (Gross, 1999). Most

theorists agree that emotions have developed through the course of evolutionary history to prepare organisms to respond to a number of environmental stimuli and challenges (Kring, 2001; Tooby & Cosmides, 1990). Gross (1999) presents research on the human emotional experience, detailing its multidimensionality and origins in biological and social processes, then proposes a model that integrates the different approaches and distinguishes between emotion regulation and related constructs. Emotions are whole-body processes that involve changes in the domains of subjective experience, behavioral expression, and central and peripheral physiology (Lang, Rice & Sternbach, 1972). These domains or components of emotion are often coordinated within the individual (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). When experiencing a strong emotion, it can be difficult to separate these coordinated components. We not only feel something inside, but we feel like doing something. Phrases like "fighting mad" and "frozen with fear" describe this combination of physical, cognitive, and behavioral responses.

Although emotions are often practical, they need to be regulated for optimal functioning. Emotion regulation strategies are developed across the lifespan and are utilized both automatically and consciously to achieve goals, whether it is simply feeling good, manipulating a romantic partner, or giving ourselves energy for a task (Charles & Carstensen, 2007). These regulation processes may target positive or negative emotions, and they may attempt to diminish, elevate, or replace a given emotion (Gross, 1998). Gross and John (2003) investigated individual differences in emotion regulation strategies and found, overall, that individuals differ in their habitual regulation strategies

and these differences are associated with divergent individual and social outcomes. An important distinction they make when discussing regulation strategies is between behavioral forms of regulation, which alter an individual's responses to events, and cognitive forms of regulation which alter the subjective meaning that events have to an individual (Gross, 1998, 1999).

Expressive suppression provides a prototypical example of behavioral regulation involving reduced or inhibited emotional expressive behavior while the individual is aroused (Butler, Egloff, Wilhelm, Smith, Erickson, & Gross, 2003; Gross & Levenson, 1993). In contrast, cognitive reappraisal is a prototypical exemplar of cognitive strategy and involves thinking about a situation in such a way that it changes its emotional impact (Butler, et al, 2003; Gross, 1998, 1999; Lazarus & Alfert, 1964). Both suppression and reappraisal are common in daily life and they have been associated with divergent psychological and physical health outcomes (Gross & John, 2003), adding to the pragmatic and clinical relevance

Suppression is a response-focused strategy occurring late in the emotion generation process and primarily modifies the behavioral aspect of the emotion response (Gross & Levenson, 1993, 1997). Suppression is effective in reducing the outward display of negative emotion, but has the unintended side effects of decreasing the experience of positive emotion, while not reducing the experience of the negative emotion (Butler, et. al, 2003, 2007; Gross & John, 2003). People who habitually suppress often experience themselves as inauthentic, misleading others about their true self, and deal with stressful situations by masking their inner feelings and clamping down

on their displays of emotion (Gross & John, 2003). Because it comes late in the emotion

process, suppression requires the individual to actively manage emotion response

tendencies as they arise, creating a cognitive demand that can disrupt social memory

possibly alienating the individual from others (Butler et al., 2003; Butler & Gross, 2004;

Richards, Butler, & Gross, 2003). Physiologically, suppression is accompanied by an

increase in sympathetic cardiovascular responding (Butler, 2003; Gross & Levenson,

1993, 1997). In contrast, cognitive reappraisal (or 'reappraisal') is an antecedent-focused

strategy, occurring early and intervenes before emotion response tendencies have been

fully activated (Gross & John, 2003). Reappraisal can efficiently alter the entire emotion

trajectory for the individual. When used to down-regulate negative emotion, reappraisal

successfully reduces the experiential and behavioral components of negative emotion and

increases experiences of positive emotion (Folkman & Moskowitz, 2000; Gross, 1998;

Gross & John, 2003; John & Gross, 2004).

Interpersonal Emotion Systems

Efforts to bridge intrapersonal emotion theory and DS theory are beginning to

emerge. Lewis (2005) was the first to propose a DS based model for synchronizing

neural perspectives with intrapersonal emotion systems to inform the relations between

cognition, behavior, and individual traits. Granic (2000) provided a strong paradigm shift

for how obstacles in current emotional development and socialization theories can be

overcome by applying the principles of self-organization. She presented literature from

intrapersonal, neurobiological and interpersonal perspectives, specifically in the area of

aggressive parent-child interactions, outlining research directions to extend the present

models. In addition, although intrapersonal emotion models provide information relevant to the individual level of psychological and physical well-being, most of our daily lives occur in the presence of others. Social interactions affect us emotionally, requiring differing levels of emotion regulation to fit the situation. If a person is late to a meeting with you, you may react differently depending upon whether that person is your boss or your parent. You may find it less appropriate to express disapproval of your boss's time management skills than with your parent, leading you to suppress your level of anger or frustration in the former situation but not the latter. Furthermore, it is possible that one boss would accept a humorous jab about their tardiness to ease the tension, while another may find that as a sign of insubordination with the effect of increasing conflict. Your decisions regarding how much anger to express would partially depend upon your knowledge of each boss's likely reaction.

As we grow, we learn how to use different regulation strategies and how to fit different strategies to different situations. Over time, we may begin to favor certain regulation strategies (John & Gross, 2004). Habitual use of certain regulation strategies has been shown to be associated with different socio-emotional profiles (Eisenberg, Hofer, & Vaughan, 2007). For example, people who tend to primarily use reappraisal are more likely to share their emotions, have closer relationships, and are more liked by their friends than those who suppress their emotions (Gross & John, 2003). Suppressors seem reluctant to share both positive and negative emotions with others, avoid close relationships, have lower levels of self-esteem, and higher levels of depression compared to their non-suppressor peers (Gross & John, 2003). Within the physiological domain,

Butler et. al, (2003) found that interacting with a partner using suppression is more stressful than interacting with a partner using reappraisal, as indexed by increases in blood pressure.

Findings such as these demonstrate the importance of understanding emotion regulation within an interpersonal context. Furthermore DS theory suggests that these social outcomes should self-organize in much the same way as psychological and neural outcomes within individuals (Lewis & Granic, 2000). Two people interacting each have individual intrapersonal emotion systems that are mutually influencing the dyadic system developing between them, and both individual systems are being simultaneously affected by the dyadic system. The dyadic emotion system is based on the two individuals' systems that have become coupled and formed the unique structure of their dyadic interaction. The evolution of the interaction depends on each partner integrating the verbal and non-verbal cues from their partner while simultaneously adjusting their own verbal and non-verbal cues. As a conversation develops over time, topics shift slightly, pauses occur, and non-verbal cues are given to each conversation partner in reaction to what the other is saying and how they are saying it. The conversation may become increasingly negative or positive; the conversation may become repetitive, with the partners perseverating on one topic, or highly variable, bouncing from issue to issue. The partners may even become physiologically in synch as they share in the emotional exchange If each partner is in tune, the conversation could last a very long time. If the partners are not in tune with one another, the conversation could end abruptly or turn to conflict (Bernieri & Rosenthal, 1991).

        The emotion system, like any other complex system, self-organizes as a function of the cooperativeness of the components that comprise it (Lewis, 2005). System stability is maintained through the organizational cooperation of the systems' components. Change in one component of the system may destabilize the system, forcing a new level of organization in the relations that exist among the components (Witherington & Crichton, 2007). To understand the influence of an individual's emotion regulation on a dyadic interaction, it is important to think about the interaction as its own interpersonal system comprised of two lower-order intraindividual systems. By assessing each individual's behavioral, experiential and physiological responses, one can measure the interplay between the two individual's information during the interaction, leading to the structure of the dyadic interaction. The dyadic interpersonal system's behavior is fluid, dynamic, and contextually bound with novel patterns emerging as information from the lower states (the individuals) is integrated and organized at the higher state (the dyad). In the context of a new relationship or friendship, emotion regulation by one person can alter the give and take of emotional communication, and this has the potential to either undermine social functioning (e.g., loss of connection for suppression, inappropriate positivity for reappraisal) or promote social functioning (e.g., restraining annoyances for suppression, increased likability for reappraisal). Understanding potentially divergent social consequences of emotion regulation requires research that embraces the complexities of open, self-organizing systems. To accomplish this, the present research examined whether suppression and reappraisal differ in their impact on social functioning with a specific focus on three features of dynamic systems:

attractor basins, flexibility/entropy, and physiological linkage. Each of these are reviewed in the following sections.

Attractor Basins

Although dynamic systems have the potential to exhibit an enormous number of behavioral patterns as they self-organize, they tend to stabilize in a limited range of stable states called attractors. Attractors emerge through feedback loops and cooperation between the higher and lower order elements of the system; they can be thought of as absorbing states that "pull" the system from other potential states (Granic, 2000). Attractors have been depicted topographically as valleys on a dynamic landscape. The deeper the attractor, the more likely it is for behavior to fall into and remain there, and the more resistant it is to changes in the environment. The general region surrounding attractors are known as the attractor basin.

Attractors can be unique states, called fixed point attractors, but they can also be a whole range of states in the case of periodic or quasi-periodic attractors. Fixed point attractors generally occur regularly in the system, and terminate in a single point in a phase space. Periodic or cyclical attractors cycle periodically through an ordered sequence of states, often characterized by sinusoidal functions (Bell, 2008). Over developmental time, attractors represent recurrent patterns that have stabilized and are increasingly predictable (Granic & Patterson, 2003). Living systems are characterized by multistability (Kelso, 1995), that is, several attractors coexisting in a system.

Emotion regulation during an interaction may disrupt the normal ebb and flow of the conversation, altering which attractors form and stabilize the system. When two

strangers meet, it is nearly impossible to predict the trajectory of their interaction. Over

time, the two may part ways, become friends, or even begin a romantic relationship

depending on a myriad of psychological and social factors. In a non-regulating dyad, all

possible states of emotional expression and experience are possible, and the formation

and type of attractors will depend on the content and context of the discussion. For

example, the attractor I predict for the non-regulating dyads in the present study is

determined by the negative film content and social norms about how to interact with a

stranger.   If one person in the interaction is actively regulating her emotional response,

however, this may limit the range of possible states of the system and lead to the

formation of attractors that are not expected from a non-regulating pair.

Granic and Hollenstein (2003) describe multiple modeling techniques to

demonstrate dynamic systems principles in psychological research and introduce a novel

method well suited for assessing attractor basins and flexibility. This method, state space

grid (SSG) analysis (Lewis, Lamey, & Douglas, 1999) is a graphical and statistical

strategy that captures the state space for the system. These grids are two-dimensional

representations of the dyad, with the x and y axes each representing the behavior (or

whatever feature of the participants has been measured) for one individual in a pair. Each

individual's values for the behavior (or other assessed feature) at each time point are

plotted in reference to her partner's behavior in the grid space. After the time sequence is

plotted, what is left is a representation of the dyad's course during the conversation,

indicating where and how much time they spent in different sections of the grid space. In

the context of the present study, attractor basins for both emotional behavior and

experience were assessed using SSG analysis. Lewis and colleagues (2004) have developed a number of quantitative strategies for identifying attractor-like patterns on a SSG. Once potential attractor states are identified and the corresponding cells on the grid are selected, the computed parameters for those cells serve to characterize the *strength*, *endurance*, and *stability* of the attractor for comparison purposes. In this analysis, the present research examined patterns that have the potential to be fixed-point attractors and compared the strength (as measured by the SSG parameters) of these patterns between the three emotion regulation conditions.

In the original experiment two strangers met and discussed a negative war film. Partners who were not instructed to regulate their emotions in any particular way were likely to express negative emotions about the film, yet respond generally positively toward their partner, suggesting that they should stabilize in a behavioral state that includes negativity about the film but positivity towards each other (see Figures 1 & 2 in the Research Aims for specific grid examples). Overall, as they rated their experience during the conversation, they were likely to have a negative experience due to the upsetting nature of the film. As such, these participants should stabilize in a negative experiential state for both partners. In the suppression dyads, the suppressor was asked to restrict her emotional behaviors during the conversation. Thus behaviorally the suppressor should maintain stability in the "neutral" non-emotional space of the grid, but her partner was expected initially to show negative emotional expressions about the film. As the interaction developed, however, the partners would not be emotionally in sync and the non-suppressing partner may be likely to give up and also appear neutral about the

film, or to begin reacting negatively toward the partner. Experientially, behavioral

suppression is known to reduce the experience of positive emotion and have no effect on

negative emotion (Butler et. al, 2003), thus both the suppressors and their partners were

expected to report high levels of negative experience similar to that of the control dyads.

Cognitive reappraisal is known to increase the likelihood of positive emotion expression

and experience (Gross & John, 1993), so despite the negative nature of the topic, it was

expected that the reappraisal dyads would stabilize within the positive areas of the

behavioral and experience SSGs.

Flexibility/Entropy

Historically, flexibility, or the ability to adapt to changes in the environment, has

been a central tenet of theories of personality and psychopathology. Freud's theory

(Freud, 1905) was based on conflict and conflict resolution within the individual as the

central processes underlying rigidity (i.e., fixation) and healthy development. Cognitive-

behavioral traditions focus on opening closed and rigid cognitive-behavioral-emotive

systems to new information to combat rigid or extreme belief systems (Lauterbach,

1996). Interpersonal researchers have expanded on these notions, employing various

strategies to avoid repetitive conflict and fixation within relationships to improve

relationship functioning and developmental outcomes (Dishion et. al, 2004; Granic,

2007).

Placing the flexibility-rigidity continuum within the context of self-organizing

systems may help explain why conflict appears to involve rigidity both within and

between individuals (McGregor, Zanna, Holmes, & Spencer, 2001) and why generally

speaking, healthier systems tend to be more complex, displaying a more flexible range of

adaptive responses (Frederickson & Losada, 2005; Pincus, Fox, Perez, Turner &

McGeehan, 2008). Granic and Patterson (2006) present research connecting flexibility

and DS theory to classical models of child psychopathology based on parent-child

behavioral reciprocity and social learning. This group has studied a number of

developmental outcomes and shown that family dynamics tend to become more complex

during early adolescence (Granic, Hollenstein, Dishion, & Patterson, 2003) and that

rigidity within parent-child and peer interactions predicts trajectories toward

psychopathology such as antisocial and aggressive behavior (Hollenstein, Granic,

Stoolmeier, & Snyder, 2004), as well as negative emotion expression in both conflict and

non-conflict situations (Hollenstein & Lewis, 2006). The primary method used in these

studies to demonstrate flexibility and rigidity in developmental psychopathology is SSGs

(Lewis, Lamey, & Douglas, 1999).

Flexibility can be operationalized in several ways that correspond to state space

grids, including the range or number of different behavioral states that can occur, the

number of transitions between those states, and the tendency to perseverate or "get stuck"

in a small number of states. The present study focused on one of these measures –

entropy - supplied by state space grid analysis. Entropy (H) refers to the amount of

information in a message as measured by the logarithm of the number of possible

equivalent messages (Dishion, et al, 2004) and is computed using the distribution of

conditional probabilities within an action-reaction transition matrix. Higher levels of

repetition yield lower values of entropy and lower repetition yields higher values of

entropy. Specifically, transitions between certain cells are conceptualized as the units of information that may repeat during a dyadic interaction. The general idea is that less information is needed to predict the reactions from actions in a low entropy dyad compared to a high entropy dyad (Dishion et al. 2004). Therefore, dyads with low entropy would have a transition matrix with many zero cells in a state space grid, and one or two transitions that are heavily used by the dyad (Dishion et al, 2004). Low entropy indicates a highly organized pattern, whereas high entropy indicates a relatively unpredictable pattern (Hollenstein, 2007).

Within the context of the present study, the uninstructed control condition was the only condition where emotions were not purposefully regulated. This would imply that those participants were free to express and feel what they normally would during non-experimental conversations, which should create high levels of flexibility/entropy. Since participants had not met prior to the experiment, no patterns of interactions had been established that may have interfered with emotional responding. In contrast, in the suppression condition, where one partner was told to try to appear as if she felt nothing at all, the possibilities for emotional expression were limited, implying the pattern would appear more rigid. As the partner interacted with the suppressor and tried to emotionally bond, her attempts would have been met with an absence of emotion. Eventually, she may also disengage from the conversation, further limiting the potential for dyadic emotional expression and creating more rigidity in the dynamic pattern. Finally, in the reappraisal condition, one partner was instructed to think about the events in the film in as positive a way as possible. Even though reappraisal is generally considered a positive

attribute related to closer relationships and being well-liked by their peers (Gross & John, 2003), using reappraisal inappropriately is likely to disrupt early relationship formation. In this context, the positive reappraisal of horrific war film footage was expected to restrict (at least at first) the emotional expression between the partners. The reappraisers' partners may not fully engage in the conversation at first because the reappraiser is not behaving as they might expect, but they may acquiesce during the course of the conversation as they learn more about their partner's point of view, especially if the woman reappraising was successful in positively reframing the film content. Such an interaction may start off appearing rigid, but as the conversation progresses, if the two partners reach equal ground, the interaction should "loosen up" and emotional expression should become more flexible. Due to the early restriction of their emotional expression, but eventual opening of the system, reappraisal dyad entropy levels should fall somewhere between the entropy levels for control and suppression dyads.

Physiological Linkage

Physiology is almost always viewed as a private, intrapersonal phenomenon. However, the physiological responses of two interacting people can evidence considerable relatedness and linkage (Levenson & Reuf, 1992). Observing a person in distress can produce signs of emotional arousal (i.e., autonomic nervous system, facial expressions, and subjective responses) in observers (Eisenberg et al, 1988). Also, observing emotional displays of another person can result in similar emotional displays and autonomic arousal from the observer (Dimberg, 1982).

Shared physiology, or physiological linkage (PL), occurs when the elevation levels of cardiovascular or peripheral physiological indicators (i.e. skin conductance) of one person are associated closely in time by the same indicators of another person during an interaction (Gottman & Levenson, 1986; Levenson & Gottman, 1983). PL is believed to be a by-product of the behavioral and emotional experience that occurs when people are engrossed in a conversation (Guastello, Pincus, & Gunderson, 2006). A dynamic systems approach would suggest that PL between two people is the result of self-organizing phenomena wherein information flows between two subsystems, each affecting the other. As PL increases, this form of connection reduces entropy in the behavior of either subsystem (Guastello, et. al., 2006).

PL was first demonstrated in studies of psychotherapy between a therapist and patient when conflict was anticipated (DiMasco, Boyd, & Greenblatt, 1957) and was interpreted as a physiological component of conflict. In small group research Kaplan, Burch and Bloom (1964) reported that the correlation among group member's skin conductance increased to the extent that they disliked each other. Later, Levenson and Gottman (1983) began studying PL between spouses during marital interaction and discovered PL was higher for unhappily married couples than for happily married ones during attempted resolution of marital conflicts. The authors interpreted these findings as patterns in autonomic activation resulting from similarities in patterns of negative affect. In subsequent research, they found strong linkage between the physiological responses a person evidenced during a marital interaction with that of their own physiological responses days later while viewing and rating a video of that interaction (Gottman &

Levenson, 1985). These findings were interpreted as suggesting subjects "relived" the experience of the interaction when viewing it at a later date.

The typical behavior patterns involved in conflict and associated with PL include negative affect, reciprocity, and predictability (Gottman, Murray, Swanson, Tyson, & Swanson, 2002). Yet, the conflict explanation for PL does not address the role of cognition in the phenomenon of PL between individuals during an interaction when there is no conflict (Guastello, Bock, Caldwell, & Bond, 2005; Guastello et al, 2006), and it does not fully account for cases when individuals are not actually engaged in the conflict, but might be "reliving" the experience after the fact. The cognitive appraisal of a situation interacts with the other components of emotion, such as experience and physiology, to produce an integrated response to a situation (Lewis, 2005). Since cognition can affect the physiological reactions of those interacting, and non-hostile interactions have shown signs of linkage, this suggests other mechanisms besides conflict could be responsible for linkage.

The literature on empathy suggests other factors that may need to be considered for understanding PL. The subject of empathy has a vast literature and in general refers to three qualities; (a) *knowing* what another person is feeling; (b) *feeling* what another person is feeling; and (c) *responding* compassionately to another person's distress (see Iacoboni, 2009 & Izard, 2009 for reviews). Levenson and Reuf (1992) explored PL and its possible relation to empathy by assessing shared physiological states and empathic accuracy, or the ability of the observer to accurately perceive the feelings of another. Subjects reviewed videotapes of a conflictual marital interaction and rated a target

spouse's level of emotion during the session. The authors then compared physiological recordings and the emotional ratings of the observer and the target spouse from the marital interaction. PL was highest when subjects were best able to accurately rate the negative affect of the target. When able to accurately rate positive affect, the authors did not see the corresponding PL, but rather subjects evidenced lower cardiovascular arousal (Levenson & Reuf, 1992). These findings suggest that 1) some level of arousal-inducing situation likely needs to be present for PL and 2) some degree of empathy, or cognitive effort to understand one another, may need to exist on the part of either or both partners for PL to take place. In other words, for PL to occur, either conflict or some other emotionally arousing conversational focus may need to be present, along with some degree of mutual engagement.

PL is a promising process to examine in the context of a self-organizing interpersonal emotion system because its two main components are physiological arousal and the emotional experience of each partner. As such, we can think of PL as evidence of emotional permeability between social partners. If there are many openings in the barrier between them, information will flow rapidly back and forth. But as the openings in the barrier are restricted, as in the case of suppression, the information flow between individuals may not be as powerful or rapid. PL may serve as the proxy for the dynamic coupling of these two components and may provide a way to examine the emotional permeability between partners. It is possible that PL will only occur if people are open to engaging with one another, either positively or negatively, and emotional regulation may

alter the permeability by restricting it (i.e., suppression) or increasing it (i.e., positive reappraisal if the optimistic outlook is adopted by the non-regulating partner as well).

In the present study, the non-regulating dyads should demonstrate PL because they were discussing a shared negative experience and neither partner was instructed to manipulate her emotional response. Both participants should be aroused by the film and the opportunity for empathic shared understanding and connectedness was not constricted. Considering the content of the film, both emotion regulation conditions required the participant to act in a way that is not socially normative. Having either no emotional reaction to the film or having an overly optimistic outlook about the content may seem odd to the partner and could potentially increase the level of arousal and negative emotions between the pair. Emotion regulation by one person could, however, reduce the negative impact of the film on their partner by reducing their investment in discussing the film at all (i.e., if paired with a suppressing partner) or by taking the more positive perspective of the reappraising partner. These variations in arousal and connectedness within the regulating dyads could indicate different PL patterns compared to the non-regulating dyads.

The suppression dyads, should show very little to no PL because suppression creates a barrier to people "connecting". If a partner "gives up" during the interaction, levels of arousal should also decrease (Björkqvist, 2001). The reappraisal dyads should show some form of linkage because the exchange of emotional information is not restricted as in suppression dyads, but this should differ from the control condition since one partner was actively manipulating her emotional responding. One possibility is that

the emotional permeability between the partners was restricted due to one partner's regulation, thus PL would be lower than controls. However, due to research suggesting those who reappraise have a greater ability to connect with people, the physiological linkage could be higher than that of the controls.

CHAPTER II. RESEARCH AIMS & HYPOTHESES

In order to assess the impact of different emotion regulation strategies on interpersonal emotion dynamics, this study compared the dyadic dynamics between three conditions: reappraisal, suppression, and a control condition. Specific aims for the study were:

I. To evaluate the potential attractor basins of the reappraisal and suppression dyads as compared to each other and to the controls within behavioral and experiential state space grids.

>   Hypothesis 1. The control condition dyads will establish an attractor basin within the Positive At Partner/Negative About the Film space for behavior and in the negative space for experience (see Figure 1 & 2).
>
>   Hypothesis 2. The suppressor condition dyads will establish a neutral attractor basin for behavior, but a negative attractor basin for experience (see Figure 1 & 2).
>
>   Hypothesis 3. The reappraisal condition dyads will establish an attractor basin within the Positive About the Film/ Neutral space for behavior and in the positive-neutral space for experience (see Figure 1 &2).

II. To assess differences in behavioral and experiential entropy between the suppression, reappraisal and control dyads.

>   1. Behavioral Entropy: (control > reappraisal > suppression)
>
>   *Hypothesis 1a.* Dyads in the control condition will have greater levels of behavioral entropy as compared to the reappraisal and suppression conditions because they are able to express the full range of behavioral possibilities.

Hypothesis 1b. Since the suppressors should be engaging in the least amount of emotional behavior, they will have the lowest levels of behavioral entropy.

Hypothesis 1c. The reappraisal condition will have greater levels of behavioral entropy compared to the suppression condition because they will engage in both positive and negative behavioral expression, but they will be lower in entropy than the control condition because the interaction may be more rigid initially until their partners become acquainted with the reappraiser's point of view and the conversation opens up.

2. Experiential Entropy: (reappraisal > control > suppression)

Hypothesis 2a. The control dyads will have lower values of experience entropy than reappraisers because of the shared, predominantly negative experience between the control partners as compared to the reappraisers who are more likely to experience positive emotion as well. The control dyads may have higher values of entropy than the suppression condition, however, because their negative experience may range between the neutral, low and high levels of negative experience rather than the predominantly high negative category of the suppression dyads.

Hypothesis 2b. Suppression dyads should have the lowest values of experience entropy because they will not experience the full range of emotions on the positive-negative continuum, and will be more likely to remain in the high negative category.

Hypothesis 2c. The experience entropy will be highest for the reappraisal condition because reappraisers are instructed to reframe the information in a more positive light, and past research has shown reappraisers will report more positive emotion when actively reappraising negative information (Nezlek & Kuppens, 2008). Thus, reappraisal dyads will report a combination of positive and negative experience creating higher entropy values.

III. To compare differences in physiological linkage between the suppression, reappraisal and control dyads.

Hypothesis 1. The control dyads should show physiological linkage because they are discussing a shared negative experience and neither partner is instructed to manipulate her emotional response.

Hypothesis 2. The suppression dyads should show very little to no physiological linkage because suppression creates a barrier to people "connecting".

Hypothesis 3. The reappraisal condition should also show physiological linkage, but because one partner is actively manipulating her emotional responding it should make linkage different than the control condition. One possible explanation would suggest the emotional permeability between the partners is restricted due to one partner's regulation, thus physiological linkage would be lower than controls. However, research suggesting reappraisers have a greater ability to connect with people suggests that physiological linkage could be higher than that of the controls.

IV. To explore relationships between the dynamic features (attractors, entropy, PL)

based on findings from Specific Aims I-III.

Research Question 1. How does physiological linkage relate to entropy

measures? Do higher levels of linkage reduce the entropy within the system?

Is the relationship the same with behavioral entropy and experiential entropy?

Research Question 2. How do the measures of behavioral entropy relate to

experiential entropy? Are the two regulation conditions different in this

relationship from the control?

CHAPTER III. METHODS

Participants

The data for this study come from a Stanford University doctoral dissertation project. Prior to use, the data were entered in electronic databases and deidentified. In the original study, 190 undergraduate women were recruited from Stanford University and received either partial course credit or were paid $50 for their participation. The mean age of participants was 20 years (SD = 1.9 years). Of the participants, 48% described themselves as Caucasian, 43% as Asian Americans, 3.6% as Latin American, 2.6% as African American, and 2.6% did not respond (Butler, et al, 2007).

Design

Random assignment resulted in 33 suppression dyads, 26 reappraisal dyads, and 36 uninstructed control dyads. In addition, ethnicity was balanced such that in each condition approximately one third of the dyads were Caucasian-Caucasian, one third were Asian-Asian , and one third were Caucasian-Asian to examine the potential for cultural moderators in emotion regulation (Butler, et. al, 2007, 2009). Cultural differences were not examined in the present study, however, since this would be premature given the lack of existing research integrating dynamic systems, emotion regulation, and interpersonal systems in any cultural context.

Procedure

Unacquainted pairs of women were briefly introduced to each other and it was verified the women had never spoken to each other before. They were then seated 2m apart with an opaque partition between them. Subjects were connected to the

physiological recording equipment and the experimenter explained the purpose of the study was to better understand conversational processes. A television was positioned so that each subject could view the monitor but not see each other. Participants first watched a 3-min nature film which provided a physiological baseline. To create the shared negative emotional experience, participants were shown an upsetting 11-min documentary war film. This film shows graphic footage of the aftermath of the nuclear bomb being dropped on Hiroshima and Nagasaki during World War II. Pilot testing demonstrated this film elicits high levels of negative emotions such as anger, disgust, and sadness.

Random assignment to conditions took place immediately after viewing the film. The first step assigned dyads to the suppression, reappraisal, or control group. Second, the women in each dyad were assigned to be either the regulator or the uninstructed partner. Each of the women then placed headphones on and received either instructions on regulation or listened to a bland music segment. The suppressor instructions were "During the conversation, behave in such a way that your partner does not know you are feeling any emotions at all". The reappraisal instructions were "During the conversation, think about the events in the film and about your conversation with your partner in as positive a way as possible". The experimenter then removed the partition and asked the participants to discuss their thoughts and feelings during the film, the implications of the film for human nature, and its relevance to their religious and political beliefs. The participants were told to signal the end of their conversation when they so chose.

After some questionnaires were completed (not relevant to the present analyses), the videotape of the conversation was replayed for them to watch. While watching themselves on the videotape they were asked to try to recall how they had felt at the time, and to use a rating dial (described in more detail in Measures section) to indicate their experience. Participants were left alone to watch the video and provide the ratings. The rating dial could be turned 180 degrees to indicate positive, through neutral, to negative emotion experience. Participants were instructed to move the dial continuously to track the small fluctuations in their experience, and they were explicitly told to indicate their remembered experience, not their current experience. Finally, participants were debriefed and given a chance to converse with each other about the experiment.

Measures

Behavioral expression. Emotional expressions were rated from videotapes of the conversations. Emotional expression, however, can be differentiated based upon whether it is "about" a referential topic or third party, or directed "at" a conversational partner. While the former is usually assumed to be a communication about a person's internal state, the latter typically functions as a social signal of relationship intentions or goals (Davis, Haymaker, Hermecz, & Gilbert, 1988; Frijda & Mesquita, 1994; Keltner & Kring, 1998; Kennedy-Moore & Watson, 2001; Timmers, Fischer, & Manstead, 1998; Tomaka et al., 1999). For example, smiling and laughing generally signal that a person is willing to affiliate, while a glare or sneer communicates hostility.

Participants were videotaped using two cameras hidden behind darkened glass and positioned so that one camera focused on each participant's face and upper torso. The

two camera images were then combined into a single split-screen image using a special

effects generator. The videos were scored for each participants' behavior using custom

designed computer software (CodeBlue, R. Levenson) that allows real-time coding of

behaviors with 1 second resolution. A "cultural informant" approach to coding was used

in which the gestalt of all simultaneously occurring communicative signals, both verbal

and nonverbal, is taken into account when assigning a behavioral segment to one of the

coding categories.

Positive expressions about the topic were almost exclusively verbal, such as,

"Well, at least the bomb ended the war and probably prevented a lot of other people from

dying." Negative expressions about the topic came both in the form of explicit

statements, such as "The film was really upsetting," as well as in non-verbal grimaces

and frowns that clearly referred to the topic. Positive expressions directed at the partner

(affiliative expressions) included smiling, laughing, and agreements, which could be

either verbal or non-verbal (for example a nod of agreement). Negative expressions

directed at the partner (hostile expressions) were exclusively non-verbal and included

looks of disgust, annoyance, and frustration.

Coders were blind to the participants' experimental condition. One person coded

all videotapes, while four others provided reliability ratings on 15 tapes each. Thus 60 of

the 95 tapes were coded by 2 raters. Reliabilities were excellent (positive expression

about topic: average $r = .90$; negative expression about topic: average $r = .95$; positive

expression at partner: $r = .78$; negative expression at partner: average $r = .82$). For tapes

that were coded by two raters the mean of the ratings was used for final analyses (Butler et. al, 2006).

Emotional experience. The experience rating dial was developed by Levenson and Gottman (1983) to provide a continuous report of participant's emotional experience while watching a videotape of their own conversation. The participant manipulated the dial which turns through 180 degrees, with one end anchored by "positive", the other by "negative", and with "neutral" in the middle. They were explicitly told to indicate their remembered experience, not their current experience. The dial was attached to a potentiometer in a voltage dividing circuit that fed into the same computer that collected the physiological measures. This procedure, originally developed by Gottman and Levenson (1983), has been shown to be a valid and sensitive measure of emotional experience (Fredrickson & Levenson, 1998; Gottman & Levenson, 1988; Tsai & Levenson, 1997).

Physiological responding. Multiple physiological assessments were recorded, including blood pressure, heart rate, beat-to-beat stroke volume, vascular resistance, and skin conductance. The present study focused on skin conductance and cardiac inter-beat interval as the measures of PL, following in the tradition of Gottmann and Levenson (1993) and Guastello et. al (2006). Heart rate was measured using a Finepres 2300 (Ohmeda, Louisville, CO). The inter-beat interval is the amount of seconds between each beat. Skin conductance was recorded by attaching electrodes to the first and second fingers of the participant's non-dominant hand. The signal was conditioned with an SA

Instruments 12-channel bioamplifier and sampled at 400 Hz using a Data Translation

3001 PCI 12-bit 16-channel analog-to-digital converter.

CHAPTER IV. DATA ANALYSIS

All of the data analyses are based on measures computed at the individual level.

Although each participant is in a dyad, the dependent variables are computed using one

member's data as it is related to their partner's lagged measure for the same variable. For

example, the suppressors' moment to moment information is compared to their partners'

subsequent action a few seconds later and vice versa. As such, although each member of

the dyad is engaged in the same conversation, the suppressor's behavioral computations

are similar, but not identical, to their partner's computation. Once the dependent

measures are computed, SAS Proc Mixed models were used for all analyses. Following

Kenney's (2006) recommendation for indistinguishable dyadic members, the Proc Mixed

models used a random dyad intercept and Satterthwaite degrees of freedom to account for

interdependence within the dyads. Since the control group members are indistinguishable

from one another, all dyad members were treated as indistinguishable when specifying

the stochastic part of the model. For the fixed portion of the model, however, a 5-level

categorical variable was created to classify each person's regulation status (i.e.,

suppressor, suppressor partner, reappraiser, reappraiser partner, or control) to identify the

regulators and their partners. An example of the syntax for the behavior attractor model

is below:

```
proc mixed data = Diss.behave_lag5 method = ml covtest noclprint;
      class dyad vs_c ;
      model NeutralDuration = vs_c gridDuration / solution ddfm =
satterthwaite;
      random intercept / sub = dyad;
      lsmeans vs_c;
run;
```

Gridware (version 1.15a; Lamey, et. al, 2004) was used to compute the dependent variables for the attractor regions, entropy, and dispersion. Within Gridware, a grid is constructed for each individual plotting her own behavior or experience on the x-axis with her partner's lagged behavior or experience on the y-axis. Gridware exports the variables for total duration, entropy, dispersion, and duration within each of the selected regions of interest (i.e., attractors) for each individual. The exported data is then converted to a SAS file for analysis.

Aim I

To measure the strength of the proposed attractor patterns, I investigated whether the duration in each attractor region exceeded that of chance. The number of visits in the attractor region (total duration) was output from Gridware. The Proc Mixed model described above was used to compare the time spent in the attractor region between the five regulation types while controlling for the length of the conversation. The first round of results indicated no differences between the regulators and their partners in terms of the direction and size of effects, therefore for simplicity of presentation the same model was recomputed using a 3-level categorical variable signifying the three dyad conditions (i.e., suppression, reappraisal, control).

Aim II

Using the concept of entropy from information theory (Shannon & Weaver, 1949), we can investigate the structural organization of the dyadic interactions, specifically examining patterns of repetition within an interaction. Entropy (H) refers to the amount of information in a message as measured by the logarithm of the number of

possible equivalent messages (Dishion, et al, 2004) and is computed using the

distribution of conditional probabilities within an action-reaction transition matrix, H =

Sum (p_{ij} x ln[1/ p_{ij}]) To apply this formula to the present study, p refers to the

distribution of conditional probabilities in a lag 1 transition matrix; p_{ij} refers to the

conditional probability that a behavior was followed by another behavior in the state

transition matrix.

Higher levels of repetition yield lower values of entropy and lower repetition

yields higher values of entropy. Entropy was calculated using the built-in feature of the

Gridware 1.5 program (Lewis, Lamey, & Douglas, 1999; Lamey, Hollenstein, Lewis &

Granic, 2004). Since levels of repetition are dependent on the length of the signal, all

equations controlled for the length of individual dyads' conversations. The Proc Mixed

model described above was used to compare levels of behavioral and experience entropy

between the five regulation conditions. As before, no differences were observed between

the effects for the regulators and their partners, therefore the three category regulation

variable was used for subsequent analyses.

Aim III

The skin conductance (SC) readings and interbeat interval (IBI) from each partner

were used to assess physiological linkage. Estimates of linkage were obtained by

predicting each individual's SC (or IBI) from her partner's SC (or IBI) assessed at a prior

time point, while controlling for the target person's own SC (or IBI) at the prior time. As

such, linkage values show how much variance in the target person's physiological

fluctuations can be accounted for by her partner's fluctuations, controlling for the target

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person's own autocorrelation. Autocorrelation occurs when a person's score at any time

point is significantly predicted by her own score at an earlier time point. The first step is

to produce a lag function indicating, at every time point, a person's score 20 seconds

prior and their partner's score 20 seconds prior. Then, a multi-level model, using SAS

Proc Mixed, was used to output empirical best linear unbiased predictor (EBLUP)

estimates of the intercept and slope for each dyad that were then used for the group

comparisons. The syntax for outputting the linkage estimates (i.e. the lagged partner

effect) is provided below:

```
proc mixed data = Diss.agg20 method = ml covtest;
        class  dyad time;
        model ibi =  ibil2 ibil2p /  solution;
        random intercept ibil2p/ solution type = vc sub = dyad;
     ods output SolutionR = Diss.dyadIBI;
run;
```

        After the estimates for each person were computed, the same Proc Mixed model

from Aims I and II was used, including as fixed predictors a person's regulation type, her

own lag score, her partner's lag score, and an interaction term of the partner's lag score

with regulation type. See syntax below:

```
proc mixed data = Diss.agg20_2 method = ml covtest;
        class  dyad vs_c;
        model ibi = vs_c ibil2 ibil2p vs_c*ibil2p/  solution;
        random intercept /  type = vc sub = dyad;
     lsmeans vs_c;
run;
```

Because differences were found between the effects for regulators and their partners, the

five level categorical variable for regulation type was used for all computations.

Aim IV

       Interrelationships between the dynamic systems features were examined using correlations and a multi-level model to control for dyadic interdependence. First, the relationship of physiological linkage to both behavioral and experience entropy were examined separately. Each individual's slope (linkage estimate), output during the Aim III analyses, was used as the independent variable to predict entropy. First, the linkage slope was used to determine what the main effect was on entropy, then regulation type (i.e., reappraiser, suppressor, reappraiser partner, etc) was entered to see if the relationship between linkage and entropy varied by type of person. Second, behavioral entropy and experience entropy were first compared using a multi-level model to account for the correlation between members within the dyads. The main effects were tested, and then group membership (i.e., control, suppression, reappraisal) was added to test if the relationship between entropy varies by dyad type.

CHAPTER V. RESULTS

In the following sections I report the results comparing differences between the suppression, reappraisal and control dyads for: (a) the potential attractor basins within behavioral and experiential state space grids, (b behavioral and experience entropy, (c) physiological linkage as measured by interbeat interval and skin conductance and finally, (d) interrelationships between the dynamic features.

Behavior Attractor Basins

Three attractor basins were hypothesized for behavior (see Figure 1): 1) Positive At Partner/Negative About the Film, 2) Neutral, and 3) Positive About the Film/Neutral behavior. Figure 3 presents means and standard errors for the duration of time spent in the hypothesized behavior attractor basins. As expected, the control dyads spent more time in the Positive At Partner/Negative About Film attractor space than both suppression (b= -21.65, t(93) = -8.57, p<.0001) and reappraisal dyads (b= -15.20, t(93) = -5.58, p<.0001). Reappraisal dyads also spent more time in this space than suppression dyads (b= -6.45, t(93) = -2.34, p<.05). Since this attractor space characterizes the most culturally normative response to the film stimuli, the data suggests the behavioral responses of both reappraisal and suppressor dyads were altered by the emotion regulation instructions. The suppressors were instructed to not show any feelings about the film, thus their time in any emotional behavior space would be reduced. Reappraisers were instructed to be as positive as possible, therefore their time spent in speaking negatively about the film would be reduced, but not as much as for suppression as the

results indicate. While the behavior of the regulators (i.e., reappraisers and suppressors) is explained by the instructions given, the results show that the partners were drawn along with them into differing dyadic states as compared to the control dyads. This supports the contention that emotion regulation by one partner can produce emergent, higher-order dyadic behavioral patterns.

Suppressor dyads spent significantly more time than control dyads in the Neutral behavior space, (b= 98.83, t(93) = 5.81, p<.0001). Suppression dyads also spent more time in the Neutral space than did reappraisal dyads (b= 77.17, t(93) = 4.16, p<.0001). Reappraisal and control dyads did not significantly differ in their duration in the Neutral behavior space. Suppressors were instructed to not show any emotion during the interaction, and this finding supports that when this emotion regulation strategy was used, the partners were likely to respond in a similar way, thus keeping the dyad in a neutral behavioral space.

Reappraisal dyads spent more time than controls (b= 48.19, t(93) = 5.95, p<.0001) and suppressor dyads (b= 56.81, t(93) = 6.93, p<.0001) in the Positive About the Film/Neutral behavior space. Although control dyads spent more time in this attractor space than suppressor dyads, the differences were not significant. As hypothesized, reappraisers were instructed to think about the film in a positive way and this is reflected in the increased amount of time spent in this space. The partners were also in this space suggesting that they began to adopt the reappraiser's more optimistic view point. If the partner's had not adopted the reappraiser's view point, we would see the pattern of the

reappraiser being in the Positive About the Film Space while the partner would be in a different space on the grid, locating the attractor region elsewhere.

Based on the findings from the three hypothesized behavior attractor basins, reappraisal and suppression distinguished themselves from controls and each other in their behavioral expression profiles. The dyads where one partner was using positive reappraisal were characterized by neutral and positive behavioral expressions with their partners while discussing the film. Suppressor dyads were characterized by long periods of unemotional, neutral behavior during the discussion. Control dyads demonstrated activity across a variety of the behavioral expression categories, but spent the most time speaking negatively about the film while behaving positively towards their partners.

Experience Attractor Basins

As shown in Figure 2, two attractor basins were hypothesized for emotional experience: 1) Positive and 2) Negative/Neutral experience. Figure 4 presents means and standard errors for the duration of time spent in the hypothesized experience attractor basins. As hypothesized, reappraisal dyads spent significantly more time in the Positive experience space than control (b= 4.11, t(89) = 3.16, p<.001) and suppression dyads (b= 4.39, t(89) = 3.30, p<.001), yet control and suppression dyads do not differ. As noted in the behavioral attractors, the rationale for the reappraiser to be in the Positive experience attractor is due to the instructions given at the beginning of the conversation. The fact that both partners in reappraisal dyads rate their experiences as positive is evidence of interpersonal contagion, or an emergent more positive emotional space for the entire dyad.

For the Negative/Neutral attractor basin, the control dyads spent significantly more time in the attractor space than reappraisal dyads (b= 4.12, t(89) = 3.16, p<.01). In addition, the suppressor dyads also spent more time in the Negative/Neutral experience space than reappraisal dyads (b= 4.40, t(89) = 3.30, p<.001), but control and suppression dyads did not significantly differ, as hypothesized. Being in the Negative/Neutral experience space is the culturally normative response to the film stimuli, thus it is not surprising that the control dyads rate their experience as predominantly negative. Emotional suppression is only expected to reduce negative emotional behavior and not experience, and it is linked with higher levels of depression and decreased positive emotion for those suppressing (Gross & John, 2003), as well as more stressful interactions for their partners (Butler, et. al, 2003). Therefore, it was expected that suppressors and their partners would rate their experiences as negatively as did the controls.

Overall, the hypotheses regarding attractor basins were supported for both emotion expression and experience. These findings suggest that behavioral expression and emotional experience were affected by the type of emotion regulation being used by one partner. Control and suppression dyads were more likely than reappraisal dyads to have a negative or neutral experience during the interaction, yet they differed on their behavioral expression. Control dyads were positive towards their partners while discussing the negative aspects of the film, while those in suppression dyads maintained neutral behavior throughout the discussion while one partner suppressed their reactions to the film. In contrast, the reappraisal dyads differed from control and suppression dyads

in both their behavioral expression and emotional experience; they remained positive and neutral towards their partners, about the film, and in their self-reported experiences. The findings provided by SSG analysis add a layer of additional information to traditional ANOVA comparisons of mean level differences between individual members of the dyads. The SSGs provide information about the dyadic connection of the behavior patterns between the two members, not just independent measures of each person's level.

Behavioral and Experience Entropy

The means and standard deviations for behavior and experience entropy are presented in Figure 5. The hypothesis was supported that the suppression dyads would have the lowest levels of behavioral entropy compared to the control (b= -0.29, t(93) = -8.06, p<.0001) and reappraisal dyads (b= -0.30, t(93) = -7.67, p<.0001) signifying more rigidity in their interactions, but the reappraisal and control conditions did not have statistically significant differences in their levels of behavioral entropy.

For experience entropy, reappraisal dyads demonstrated higher mean levels of experience entropy (M=2.72, SD =0.06) compared to control (M=2.63, SD =0.05) and suppression dyads (M=2.60, SD=.06), however these differences were not statistically significant. A post-hoc analysis using dispersion, an alternative measure of flexibility that assesses grid "stickiness", or the likelihood that the behavior of the system is contained within a few cells, was used to examine if the dyads differ in their use of the state space. Dispersion scores range from 0 (no dispersion at all – all behavior in one cell) to 1 (maximum dispersion). The results indicated that reappraisal dyads were marginally more dispersed than suppressor dyads (b= 0.01, t(89) = 1.79, p<.10), and

control dyads (b= 0.01, t(89) = 1.56, p<.13), but control and suppressor dyads do not differ as shown in Figure 5.

The hypotheses for behavioral expression entropy and emotional experience entropy were mostly supported. The entropy findings suggest suppressor dyads were more rigid in their behavioral expressions and emotional experience, while reappraisal and control dyads were more flexible, although the findings for emotional experience were only marginally significant. Reappraisal and control dyads did not demonstrate entropy differences in behavioral expression as predicted, however, there was a trend for reappraisal dyads to show greater entropy than controls for emotional experience, as hypothesized. Although the control and reappraisal interactions are both considered flexible in comparison to suppressor dyads, the findings from the attractor analyses tell us reappraisal and control dyads are interacting in different segments of the state space, therefore their flexibility is qualitatively different. Control dyad flexibility is characterized by visiting almost all of the possible cells within the grid, transitioning frequently between cells, and concentrating in the culturally appropriate area for the conversation (Positive At the Partner/Negative About the Film). Reappraisal flexibility values are slightly less than controls, meaning they visited fewer cells and transitioned less than controls, but they were more flexible than suppression dyads. However, in contrast to controls, reappraisal dyads concentrated their time in the Positive At the Partner/ Positive About the Film region.

Physiological Linkage

As predicted, significant IBI linkage differences emerged between the three experimental conditions ($F(4, 4759) = 2.47$, $p<.05$), however the hypothesis that suppression dyads would show the least linkage was not supported. Simple contrasts, reported in Table 1, showed that IBI linkage with their partner was greatest for the individuals instructed to suppress, suggesting that the suppressor's IBI was more likely predicted by their partners IBI than participants in the control and reappraisal dyads. There was also a trend for the suppression partner to be predicted by the suppressor when compared to control dyads. Figure 6 displays the means and standard deviations for IBI linkage.

Skin conductance linkage differences were also found between the three experimental conditions ($F(4, 4674) = 3.47$, $p<.01$), but again did not match the hypothesized effects. Simple contrasts presented in Table 2 show that skin conductance linkage with their partner was greatest for the suppression partners. Additionally, skin conductance linkage with their partner was lower for reappraisal partners compared to the controls, as well as being marginally lower than reappraisers, but it was not significantly different from that of suppressors. Figure 7 displays the means and standard deviations for skin conductance linkage.

These findings differ from those that were hypothesized. In addition, the reappraisal partner's skin conductance showed the only positive linkage, while all other observed linkages were negative. Positive and negative linkages may indicate different explanatory models, such that positive linkage is characterized with a more empathic

response, while negative linkages may indicate higher levels of conflict. I return to this issue in the Discussion.

Interrelationships between Dynamic Components

Physiological linkage values were not significantly related to behavioral or experiential entropy, and the inclusion of group in the model did not change this relationship. This was examined for the continuous value of linkage and for a dichotomous variable indicating whether linkage was negative or positive. Similarly, behavior and experience entropy were not significantly related. This finding also did not change with the inclusion of group in the model. The absence of correlations among the components is contrary to what would be predicted by interpersonal emotion and dynamic systems theories. I return to this point in the Discussion.

CHAPTER VI. DISCUSSION

This study is the first known attempt to integrate the components of emotional responding with features of dynamic systems theory. Based on the findings, there is evidence for differences in the emergence of structure and patterns in real-time dyadic interactions between pairs of female strangers where one partner is purposefully regulating her emotional responding. Emotional behaviors, experience and physiological responding all demonstrated different patterns based on the type of emotion regulation being used by one partner, compared to control dyads where neither person was purposefully regulating their emotions. Most hypotheses were supported, although some intriguing relationships in physiological linkage and flexibility were discovered that did not correspond to the predictions, yet shed light on possible future directions for this research.

Differing Dynamics of Emotion Regulation Conditions

Control Dyads. Overall, control dyads demonstrated flexibility in their behavioral expressions and emotional experience as measured by entropy, yet partners did not share high levels of physiological linkage. The small values of linkage suggest there was minimal conflict and only a weak shared experience during their interaction. In the behavioral state space, control dyads were more likely to discuss the film in a negative light while being positive with their partners, and despite their higher duration within this attractor space, these dyads still had higher levels of flexibility compared to suppressors.

This indicates that their interactions traveled through both positive and negative features of the state space, but settled into one particular area the majority of the time.

Despite maintaining positive behaviors towards their partners, control dyads did tend to rate their experiences as more negative or neutral than reappraisal dyads. Although they did not statistically differ with suppression dyads on their time in the Negative/Neutral attractor space, control dyads had a slightly more flexible experience overall, measured by dispersion, than suppression dyads, suggesting they may have been more likely than suppressors to rate positive experiences during the interactions in addition to negative experiences.

Suppression Dyads. Dyads using suppression were characterized by rigid dynamics in behavior and experience, and had the highest levels of physiological linkage with their partners signifying high levels of conflict or shared negative experience. Suppression dyads spent longer amounts of their time in the Neutral behavior attractor space compared to control and reappraisal dyads, as hypothesized. Since the dyads were composed of strangers, one partner's restricted emotional response was likely to result in a non-response or potentially negative response from the partner during the interaction. This hypothesis was supported by the higher amount of time spent in the Negative/Neutral attractor space for self-rated experience and their lower levels of both behavioral flexibility (statistically significant) and experience flexibility (marginally significant) as compared to reappraisal or control dyads.

Physiological linkage was the strongest for suppression dyads, and the linkages tended to be in the negative direction. There is little published information about the

significance of differences between negative or positive linkage values, although

DiMascio et. al (1957) suggest that negative linkages result from antagonism, while

positive linkages indicate a synchronous or shared experience. In this analysis, the

conflict hypothesis is indicated due to the higher duration in the negative experience

space and previous publications based on a similar study suggesting that suppressors

were the least well-liked by their partners (Butler et. al, 2003).

     Reappraisal Dyads. The dyads using reappraisal tended to be more flexible in

their behavior and experience than suppression dyads, yet, although not always

statistically different from controls, reappraisal dyads tended to occupy different portions

of the state spaces (i.e. attractors) than control dyads. The Positive About the

Film/Neutral behavior space was occupied by reappraisal dyads more than both control

and suppression dyads, yet levels of behavior flexibility were not different between

reappraisers and controls. This means that both reappraisal and control dyads traveled

through both negative and positive aspects of the behavioral state space, but as

hypothesized, the instructions to think about the film in a positive way did pull

reappraisal dyads into the more positive attractor space. Reappraisal dyads spent

significantly more time in the Positive experience space than the Negative/Neutral

experience space. The reappraisal dyads showed a trend for higher flexibility when using

dispersion compared to suppressor control dyads. This implies that reappraisal dyads

were more likely to rate both positive and negative experience compared to the controls

and suppressors, with the majority of their ratings in the positive experience domain.

Finally, reappraisal dyads did show signs of physiological linkage in skin conductance,

although most strongly in the positive direction, again suggesting the potential for further examination of the associations between positive (synchronous, empathic interaction) and negative (conflictual interactions) linkage values (DiMascio et. al, 1957; Kaplan & Bloom, 1964).

Dynamic Features of Interpersonal Systems

Attractor Basins. It was proposed that the dyadic interpersonal system is fluid, dynamic, and contextually bound with novel patterns emerging as information is integrated and organized. The results of this analysis support varying patterns of self-organizing systems occurring in short term interactions with a stranger, and that the emergence of patterns is affected by emotion regulation. The SSG analysis provides information about dyadic connectedness that is otherwise not seen when using mean level comparisons of individuals within dyads. The analysis provides evidence that the observed mean levels are arising through dyadic mechanisms, not through independent influence on the partners.   In the attractor basin analysis, the differences seen between the non-regulation and regulation dyads indicates that the content and context of the interaction are important variables in predicting the type of attractors that may emerge, but knowledge of the content does not guarantee knowledge of the dyad's behavior. The predictability of the regulator's behavior in this experiment is explicable from the instructions given, but the partner's behavior is not. The fact that the occupation of attractor spaces varied by regulation type supports the notion that regulation by one individual can influence the interpersonal dynamic since the regulator's behavior drew their partner into a pattern that differed from the non-regulated dyad patterns.

Flexibility/Entropy.   Significant differences in flexibility measures were found between the three groups signifying that repetitious and predictable interaction patterns formed most rapidly when one person was suppressing her emotional responses. Combining the findings for flexibility with the attractor basins, the suppression dyads were not only rigid, but on average maintained their behavior in the region of non-emotional response during the majority of their interaction. Control and reappraisal dyads were more flexible than suppression dyads, but both dyads showed evidence of attractor regions emerging. Even though there were certain periods where their interactions would enter a fairly steady state, the flexibility findings show that at least reappraisal and control dyads also have periods of moving around between states. This finding lends support to DS principles that open systems can fluctuate between ordered states and complex, more chaotic states, even during a short period of time.

Physiological Linkage. Physiological linkage is thought to be a by-product of the emotional behavior and experience that occurs when people are engrossed in a conversation (Guastello, Pincus, & Gunderson, 2006), and occurs when there are 1) arousal-inducing situations, and 2) some degree of effort to understand one another is made by at least one partner. Conflict and empathy are thought to be two possible mechanisms behind physiological linkage. It was proposed that linkage may provide a way to examine the emotional permeability between partners. Negative linkage was demonstrated most strongly for those using suppression as well as their partners, and positive linkage was found for the partners of reappraisers. It has been suggested by Kaplan and Bloom (1964) that negative and positive linkage may indicate different forms

of communication patterns; conflict and antagonism for negative linkage, and synchrony or empathy when positive linkages exist. In this experiment, there is evidence suggesting that watching the film is emotionally-arousing (Butler et. al, 2003), and therefore it was expected that a shared negative experience would result in some form of linkage. However, it was expected that suppression dyads would not demonstrate linkage because suppression restricts emotional information, decreasing the permeability of emotional information exchange between partners. The fact that linkage was found for suppression dyads, and not as strongly for control dyads, lends more support towards the idea that feeling uncomfortable and not liking your interaction partner is one mechanism for physiological linkage.

There is some support from this data for the empathy claims as well. As argued by Levenson and Reuf (1992) and Kaplan and Bloom (1964), feeling similar or understanding your partner's feelings may play a role in physiological linkage. The skin conductance linkage with their partner was positive for the reappraisal partners, indicating a tendency for the reappraisal partner's skin conductance to follow a pattern similar to the reappraiser. If empathy does play a role here, it would imply that there was some perspective-taking occurring for the reappraisers' partners and by the end of the conversation they had begun to adopt to the reappraiser's point of view. In contrast, since the reappraisers were intentionally regulating their emotions in a way that may not have been their normal response, it is not surprising that linkage did not exist for them since being inauthentic could provide a barrier to emotion exchange. In summary, although this analysis has shed new light on the role of physiological linkage in the

interpersonal context, extending the findings of Guastello et. al (2006) and Levenson and Reuf (1992), further analysis is needed, for example by using specific coding to separate empathic and conflictual dyads in order to disentangle the patterns of positive and negative linkage with conflict and empathy.

Interrelationships Between the Dynamic Features

When the interrelationships between the dynamic features were examined, there was no evidence of correlation or predictability of one dynamic feature with another, or of different relationships depending on dyadic condition. Behavioral entropy, experience entropy, and physiological linkage were not correlated suggesting that flexibility in one's experience does not predict flexibility in behavioral expression, and that the level of linkage between partners also does not predict the flexibility or rigidity of their behaviors or experiences. On the one hand this suggests that each feature provides independent information about system dynamics, thus warranting including all of them in research on interpersonal emotion systems. On the other hand, this lack of correlation is perplexing since, independently, the regulation strategies differ on these measures and this might suggest interrelationships amongst them.

A point to consider is that these measures (i.e., entropy, linkage) are being computed independently and then compared as end-state values, rather than being examined simultaneously as the system organization unfolds. DiMascio et. al (1957) demonstrated that physiological linkage between a patient and their therapist can change during the interaction, fluctuating between periods of positive and negative linkages. Granic et. al (2003) have also demonstrated that behavioral flexibility can change over

developmental time, fluctuating between periods of complexity and rigidity.   These

studies both attribute these changes and fluctuations to the content or context of the

interaction during the time of measurement, supporting the notion that the components of

the interpersonal system are themselves dynamic. It is possible then that subtle changes

within one component could have consequences or benefits for the other components,

and this could only be observed as it unfolds over time (Lewis, 2005; Witherington &

Crichton, 2007).

Limitations

      Despite all the strengths of the study there are a few limitations to this analysis.

One limitation of this study is the dyad partners in this experiment are strangers, thus it is

possible that this short amount of interaction time is not enough to see the full impact of

intrapersonal behavioral, emotional, and physiological responding on the interpersonal

level. These dyads are not invested in a relationship together and are not subject to prior

interaction patterns that may influence how a current interaction unfolds or how aroused

one may get during the interaction, although evidence from Gottman and Levenson

(1985) and Levenson and Reuf (1992) suggest that some strangers will show patterns of

synchronous emotion to dyads when viewing videotapes of their past interactions.

      Also, this analysis only includes women, thus these findings are not generalizable

to men or mixed-sex dyads. A further limiting factor is only women who were Caucasian

or Asian-American were selected for this study. The study focus was to demonstrate

these parameters are reasonable to examine at the dyadic level, thus no examination of

cultural differences were examined. Finally, as mentioned above, each of the dependent

variables was computed as end-state parameters, thus limiting the potential for interconnections to be explored.

Future Directions

Despite the few limitations, several avenues of exploration are available based on these findings. First, the features of the dynamic systems (i.e. attractors, flexibility/entropy and linkage) could be used to predict social or relationship outcomes. Granic et. al (2003) and Dishion et. al (2004) have shown that behavioral flexibility and rigidity can predict family and peer-group relationships, and Butler et al (2007; 2009) have demonstrated that certain forms of emotion regulation and physiological responding have social consequences at the dyadic level. It was shown in this research that the two emotion regulation strategies differ in their dyadic functioning, and future research can examine if this disruption in patterning compared to control dyads undermines or promotes social functioning outcomes such as relationship satisfaction, quality, and commitment, or if cultural differences exist that affect the emergence of the attractor basins and flexibility within the regulation types. A number of individual level variables, such as personality characteristics, habitual emotion regulation strategies, or mood, could be examined within the dyads to test how individual traits and states may affect the emergence of the dyadic structure. In DS theory, the emergence of patterns is highly sensitive to the state's own initial conditions (Von Bertalanffy, 1968).

Second, further exploration of physiological linkage is warranted. Participants ranged between positive and negative linkage values, with approximately one third of the dyad members for each condition showing a positive linkage. It is possible that dyads

with incongruent linkage values would have different outcomes than dyads with similar linkages, and furthermore, that dyads where both members are positively linked may differ from dyads where both members are negatively linked. It would be interesting to extend linkage studies to non-stranger dyads such as friendships, dating relationships, and parent-child interactions, assessing social and health outcomes. If physiological linkage is predictive of health and successful marital and non-marital relationships, it may provide insight to help to explain how social support acts as a moderating factor in health outcomes, particularly those areas of research where psychological distress and reactivity has been linked with congestive heart failure (Rohrbaugh, Cranford, Shoham, Nicklas, Sonnega, & Coyne, 2002) and immune response (Gunnar, Talge, & Herrera, 2009; Robles & Kiecolt-Glaser, 2003).

Finally, applying dynamic systems concepts to health and wellness outcomes within individuals and groups is another possibility for further research. Goldberger and colleagues (2002) are exploring the breakdown of long-range (fractal) correlations (i.e., the loss of nonlinear complexity) that accompanies aging and a wide range of disease processes. By comparing heart beats of healthy individuals to those with certain pathologies, some discoveries have been made in assessing cardiac risk and forecasting sudden cardiac death (Goldberger, Amaral, Hausdorff, Ivanov, Peng, & Stanley, 2002). Multiscale entropy and time irreversibility analysis techniques have been applied to cardiovascular signals to better understand the complexity of certain pathological processes associated in physiological dynamics (Costa, Peng, & Goldberger, 2008). Within the physical and psychological domains, healthier systems tend to be more

complex, displaying a more flexible range of adaptive responses. Frederickson & Losada (2005) and Menk-Otto, Howerter, & Bell (in press) have shown how variations in psychological flourishing are related to resiliency, health outcomes, and successful team performance in the workplace. As our knowledge and methods for computing physiological complexity are advanced, these models can be used together with systemic measures of family and relationship functioning to examine the reciprocal effects of lower and higher-order system complexity on our overall health, wellness, and vitality.

The findings from the current study indicate there is potential for interrelationships amongst the features of a dynamic system to be examined more thoroughly, and several sophisticated modeling techniques for dynamic concepts are being introduced that may provide computational support. Gottman et. al (2002) have applied several forms of nonlinear, dynamic models to marital interaction studies. Sbarra and Allen (2009) used latent difference score structural equation modeling to study the dynamics of mood and sleep disturbances, and neurocognition researchers working with dendritic and neuronal synchronization are proposing models to study multi-layer feed-forward networks (Segev, 2003). Lodewyckx, Tuerlinckx, Kuppens, Allen, and Sheeber (in press) introduce a hierarchical extension of the linear Gaussian state space model and apply it to within-person emotion dynamics of parent and their adolescent as they interact in a conflict interaction task. Their model shows promise as an application because it is flexible and general and can be applied to any time series for multiple systems.   In conclusion, this study is the first to attempt an integration of the components of emotional responding with features of dynamic systems theory.   Based on the findings, there is

evidence for differences in the emergence of structure and patterns in real-time dyadic interactions that varies by emotional responding, and several avenues worthy of further exploration have been identified.

APPENDIX A: TABLES

Table 1.

Inter-beat interval linkage values contrasted between participant types.

	β	t(4759)	p
Suppressors versus:			
Controls	0.07	2.71	.007
Reappraisers	0.05	1.68	.09
Reappraisers' Partners	0.07	2.25	.02
Suppressors' Partners	0.02	0.75	.45
Suppressors' Partners versus:			
Controls	0.05	1.77	.08
Reappraisers	0.03	0.93	.35
Reappraisers' Partners	0.05	1.51	.13

Table 2.

Skin conductance linkage values contrasted between participant types.

	β	t (4674)	p
Suppressors' Partners versus:			
Controls	0.009	2.26	.02
Reappraisers	0.008	1.68	.09
Reappraisers' Partners	0.016	3.56	.0004
Suppressors	0.011	2.28	.02
Reappraisal' Partners versus:			
Controls	-0.006	-2.06	.04
Reappraisers	-0.007	-1.70	.09
Suppressors	-0.005	-1.17	.24
Suppressors' Partners	-0.016	-3.56	.0004

APPENDIX B: FIGURES

Figure 1. Hypothesized behavior attractor basins for the three conditions.

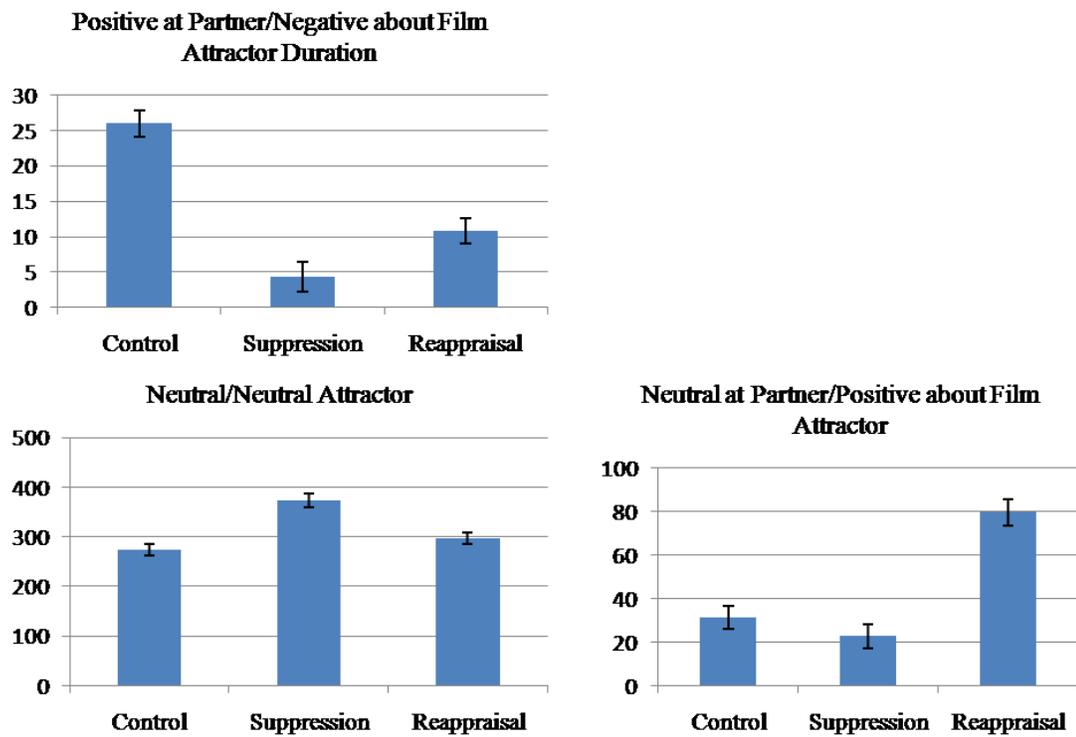Figure 2. Hypothesized experience attractor basins for the three conditions.

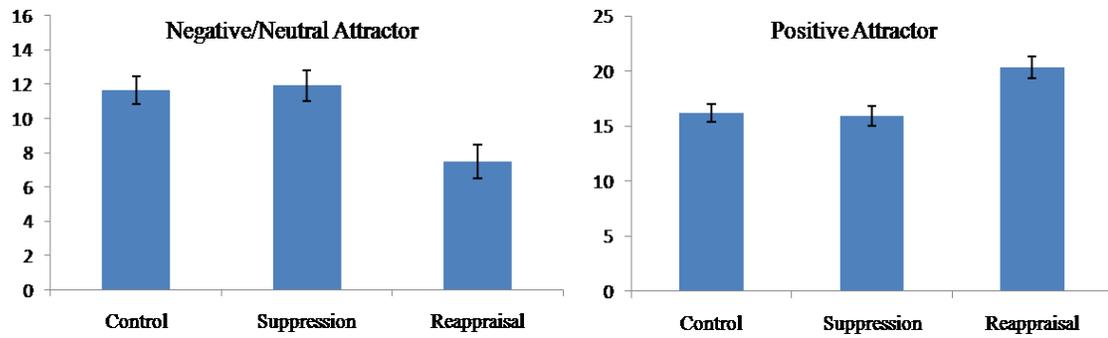Figure 3. Behavior attractor duration means and standard errors across the three conditions.

Figure 4. Experience attractor duration means and standard errors across the three conditions.
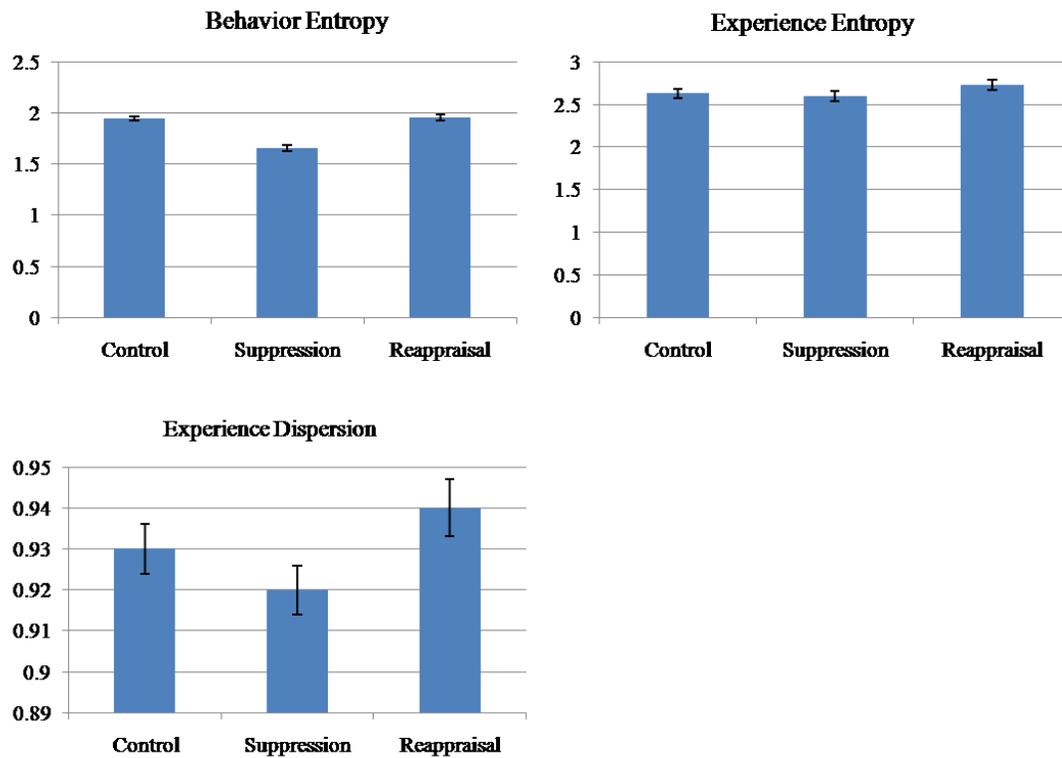
Figure 5. Behavior and experience entropy means and standard errors across the three conditions. Experience dispersion means and standard errors are also presented for the three conditions.
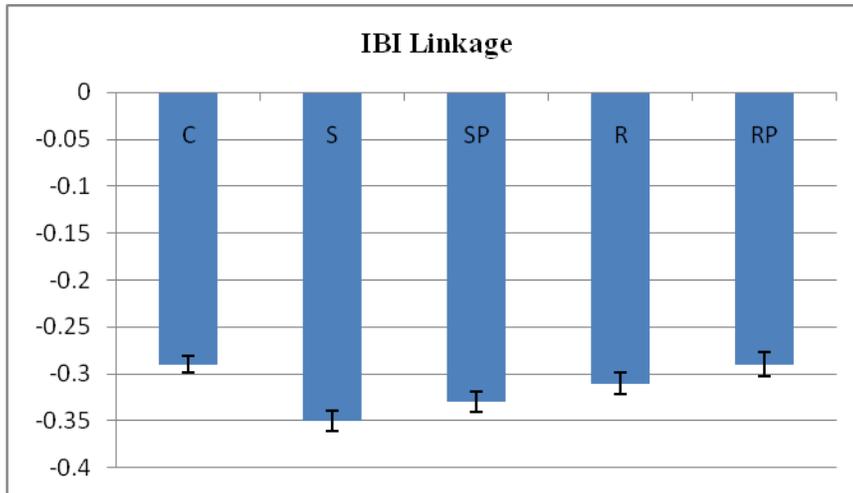
Figure 6. IBI linkage means and standard errors across each participant type. C=control; S=suppressor; SP=suppressor partner; R=reappraiser; RP=reappraisal partner.
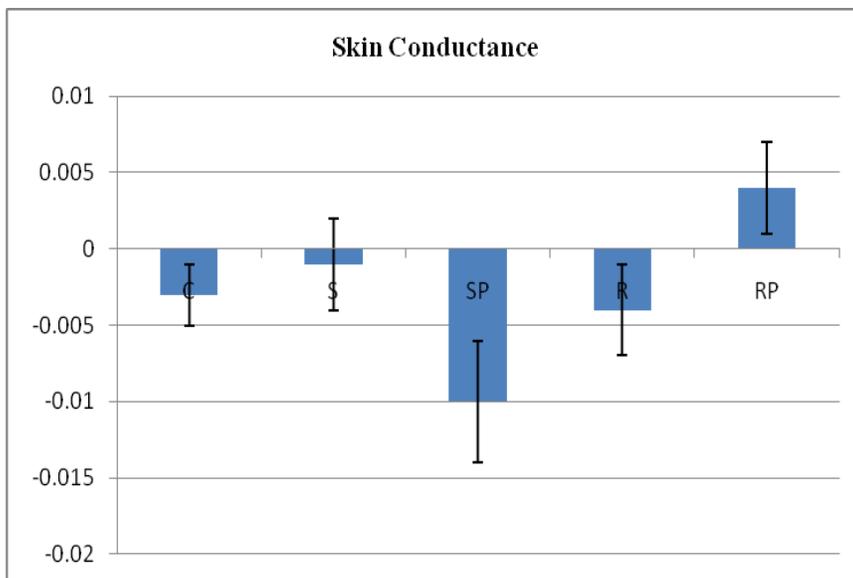

Figure 7. Skin conductance means and standard errors across each participant type. C=control; S=suppressor; SP=suppressor partner; R=reappraiser; RP=reappraisal partner.

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