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Physiological Linkage in Couples and its Implications for Individual and Interpersonal Functioning: A Literature Review

Adela C. Timmons, **Gayla Margolin**, and **Darby E. Saxbe**

University of Southern California

Abstract

Do partners' levels of physiological arousal become linked in close relationships? The term "physiological linkage" describes covariation between people in their moment-to-moment physiological states. The current review presents a conceptual framework to guide research on linkage in romantic relationships and discusses the potential implications of being "linked." Evidence of linkage was found across a broad range of physiological indices and in a variety of contexts, including during laboratory-based conflict and in daily life. Four hypotheses regarding how linkage relates to individual and interpersonal functioning are evaluated: (1) co-activation of the sympathetic nervous system or hypothalamic-pituitary adrenal axis is "bad," (2) moderate physiological linkage is "just right," (3) physiological linkage is problematic if the individual or couple is overloaded, and (4) the implications of physiological linkage depend on the emotional context. We found partial support for the first hypothesis and determined that more research is needed to evaluate the remaining hypotheses. Linkage in cortisol was negatively associated with relationship satisfaction; but at the same time, linkage in multiple systems was positively associated with indices of relationship connectedness, such as the amount of time spent together and the ability to identify the emotions of one's partner. These results suggest that linkage may confer benefits but also may put couples at risk if they become entrenched in patterns of conflict or stress. With research in this area burgeoning in recent years, this review indicates that linkage is a promising construct with applications for interventions targeting individual health and couple functioning.

Keywords

physiological linkage; coregulation; synchrony; romantic relationships

It may seem intuitive that people in romantic relationships are attuned to, and perhaps even share, the emotions and stress states of their partners. When one person in a relationship is stressed or upset, the other member of that relationship often feels such emotions as well. In addition to self-reported stress and emotion, however, romantic partners may actually be linked in their levels of physiological arousal (Butler, 2011). This phenomenon, known as physiological linkage, synchrony, or coregulation, is defined as covariation between two

Correspondence regarding this article should be addressed to Adela C. Timmons, Department of Psychology, University of Southern California, SGM 921, 3620 South McClintock Avenue, Los Angeles, California 90089-1061, adelatim@usc.edu.

people in their physiological states. Although documented as early as the 1950s in client-therapist dyads (Di Mascio, Boyd, Greenblat, & Solomon, 1955), interest in physiological linkage, especially in romantic couples, has been increasing in the past few years (Helm, Sbarra, & Ferrer, 2012, 2014; Liu, Rovine, Cousino Klein, Almeida, 2013; Papp, Pendry, Simon, & Adam, 2013; Saxbe et al., 2014; Saxbe & Repetti, 2010). The advent of more sophisticated technological and quantitative techniques for capturing dynamic inter-individual physiological processes (Ferrer & Helm, 2013; McAssey, Helm, Hsieh, Sbarra, & Ferrer, 2013; Poh, Swensen, & Picard, 2010) has primed the field for continuing advances.

Beyond documenting this phenomenon in couples, researchers are increasingly turning their attention to understanding the risks and benefits of being "linked." Though linkage has been associated with other variables, such as relationship satisfaction, the implications of sharing in physiological states with a partner are still poorly understood. Physiological linkage could be associated with positive factors, for example emotional connectedness and empathy; or, linkage could be associated with negative factors, for example, negative affect contagion and conflict escalation. A better question to ask than *whether* linkage is "good" or "bad" may be *when* is linkage "good" or "bad." Answering this question is imperative for connecting basic research on physiological linkage to research on health, emotional wellbeing, and clinical intervention. The current paper summarizes the literature via a systematic review and investigates the individual and interpersonal implications of physiological linkage in romantic relationships.

Theoretical Background

Relationships as regulators

Biologically, humans appear to be programmed for social connection. Social connectedness may be evolutionarily advantageous through the sharing of resources and the conservation of energy. According to social baseline theory (Beckes & Coan, 2011), it is more cost-effective, metabolically speaking, to regulate emotions in a social context rather than in an individual context. This idea is supported by research indicating that the areas of the brain associated with threat are less active when in the presence of others (Coan, Schaefer, & Davidson, 2006). Other research has noted dysregulation of physiological systems following separation or loss (Field, 2012; Sbarra & Hazan, 2008). Hofer (1984) posited that the symptoms of bereavement (e.g., changes in appetite or sleep) might be accounted for by the loss of a social regulator. In animal studies, separations from attachment figures have been linked to cardiac arrhythmias and disruptions in eating and sleeping (Sbarra & Hazan, 2008). Although research in humans is more limited, travel-related separations from romantic partners are associated with changes in sleep patterns (Diamond, Hicks, & Otter-Henderson, 2008). Together, these studies indicate that physiological regulation occurs within the context of social relationships and that connection to others is an important factor in maintaining autonomic homeostasis.

Family systems theory and couple theories of relationship conflict

Both family systems theory and couple theories of relationship conflict highlight the interdependent nature of close relationships and provide a framework for understanding how

physiological responses might be transferred and maintained within couple systems. In family systems theory, family processes are conceptualized in terms of feedback loops that can amplify (e.g., when having conflict), de-amplify (e.g., when recovering from conflict), or can maintain homeostasis in the family system (Cox & Paley, 1997). Within this framework, Gottman, Markman, and Notarius (1977) theorized that relationship conflict is characterized by negative affect reciprocity in which negative affect in one romantic partner is met with negative affect in the other partner. Christensen (1988) similarly theorized that distressed couples engage in a pattern of interaction characterized by demand-withdraw behavior. In this pattern, one partner "demands," or attempts to elicit action or change, resulting in the other partner "withdrawing" or refusing, which then results in increased demanding behavior in the original partner.

Each of these theories emphasizes the reciprocal and inflexible nature of relationship conflict, with behaviors and response patterns escalating and becoming increasingly entrenched over time. Although these theories focus on observable behavior and emotion, they are likely characterized by specific patterns of interdependent physiological responding within the couple system. These response patterns may be one mechanism by which physiology is transferred between romantic partners. For example, negative affect in one partner might be accompanied by increases in physiological arousal, leading to increased arousal in the other partner. Individuals engaging in withdrawing behavior, in contrast, may be overly activated and attempting to down-regulate their responses. Physiological linkage in this context may be associated with distressed relationship functioning, especially if such linkage is repeated and chronic.

Physiological Linkage in the Current Review

The process of sharing in levels of physiological arousal with close others has been referred to by various terms in the literature, including coregulation, synchrony, contagion, and transmission, among others. In the current review, we adopt the broad term physiological linkage, which we view as encompassing multiple subtypes of linkage processes. In line with recommendations made by others (e.g., Butler, 2011), we consider coregulation or synchrony to reflect a homeostatic, regulatory process in which partners jointly pull each other towards a baseline level characterized by greater stability in the system. Contagion or transmission, in contrast, is defined as linkage that occurs with a change in level, for example as might occur during relationship conflict where levels of arousal increase over time. Definitions regarding the subtypes of physiological linkage are still evolving, though the field's understanding of what exactly constitutes coregulation versus other types of linkage has been increasing in precision and clarity (see Butler, 2011 for a discussion). Possible physiological indices in this review include but are not limited to: blood pressure (BP), cortisol, electrodermal activity (EDA), finger temperature (FT), functional magnetic resonance imaging (fMRI), heart rate (HR), pulse (P), respiration (RES), respiratory sinus arrhythmia (RSA), and thoracic impedance (TI). Also included is linkage in sleep timing. Sleep reflects biologically based biorhythms and is linked to cycles of arousal; others have argued for the inclusion of sleep in the study of linkage processes (Troxel, 2013). For definitions of specific indices, refer to Hugdahl (1995).

Scope of the Current Review

Shared physiology in romantic relationships can be viewed as one subset of a broader research area that includes multiple types of relationships (e.g., parent-child, client-therapist, romantic) and types of experiences (e.g., self-reported or coded emotion or stress, physiology). Several integrative reviews have been written regarding this broader topic (e.g., Butler, 2011; Sbarra & Hazan, 2008). The focus of the current paper is not to summarize this greater literature as has been done elsewhere but rather to provide an in-depth analysis of one area of this work and to investigate the implications of sharing in biological processes with a romantic partner—a question that has not yet been systematically examined. Research on physiological linkage in couples in particular has been advancing rapidly, especially given an increased focus on the biological underpinnings of couple interaction and advances in the ability to statistically model such processes. Despite these exciting innovations, this nascent literature has lacked a framework to guide its development. Thus, the aim of this paper is to evaluate this early literature to provide an organizing theoretical framework for future work. As such, linkage in non-romantic dyads and linkage in self-reported emotion, behavior, or stress are not included.

Physiology, Emotion, and Stress

It should be noted that there is overlap between stress, physiology, and emotion. In this paper, we take the view that these constructs are related but not synonymous. That is, physiology is an index of emotion and stress but can also represent other processes (e.g., cognitive effort, biorhythms). Moreover, physiological activation is associated with multiple types of emotions, and can occur when excited, as well as when stressed. As part of our review, we examine how emotional states and stress are associated with physiological linkage and explore how linkage in these different contexts might impact individual and interpersonal functioning.

Physiological Linkage Characteristics

Because physiological linkage is a broad term, we categorize studies according to several theoretically relevant dimensions. First, we report the nature of the task or event surrounding the study of linkage. Linkage during certain situations (e.g., discussing a pleasant activity) might operate differently than linkage in other situations, (e.g., arguing with your partner). Second, we list the time span of the linkage; current studies vary widely in their time span, with some testing linkage over minutes (e.g., second-to-second linkage in EDA during a 10-minute discussion) and others looking across weeks or even months (e.g., day-to-day linkage in cortisol across 1 week). Third, studies are categorized in terms of whether they were conducted in naturalistic settings or in the laboratory environment. Studies in naturalistic settings typically have less experimental control but also have greater ecological validity because they capture linkage as it unfolds in real life contexts (Bolger, Davis, & Rafaeli, 2003; Laurenceau & Bolger, 2005). Fourth, results are classified by the physiological index tested. Helm et al. (2014) suggested that the implications of linkage depend on the response system measured. The autonomic nervous system consists of the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS). The SNS is associated with

arousal and the "fight or flight" response. Linkage in the SNS may be linked to particular emotional responses (e.g., anger or stress) and thus may be more likely to occur during conflict. The PNS, in contrast, is associated with rest and digestion (Hugdahl, 1995); linkage in the PNS may be associated with more relationship satisfaction if it reflects mutual dampening of negative emotion. Also of interest is the endocrine system, e.g., the hypothalamic-pituitary-adrenal (HPA) axis, which releases the glucocorticoid hormone cortisol in response to stress.

Physiological Linkage Hypotheses

Below, we present four hypotheses that explain how physiological linkage might be related to individual and interpersonal functioning. Though presented as competing hypotheses, these explanations are not mutually exclusive. Using relationship satisfaction as an example, Figure 1 illustrates each of the hypothesized associations.

1. Co-activation of the SNS or HPA axis is "bad"

Consistent with the concept of negative affect reciprocity, physiological linkage may represent reciprocal patterns of critical behavior and conflict escalation in which levels of activation amplify from homeostatic levels. Given that both the SNS and HPA axis are associated with heightened arousal and stress responding (Hugdahl, 1995), linkage in these systems in particular may reflect poor relationship functioning (see Figure 1, Panel A). For example, when one romantic partner becomes angry or physiologically activated, his or her partner may respond similarly, which could contribute to greater physiological activation in the original partner. There are various moderators that might amplify the likelihood that one person will respond to the mood or physiology of another person. For instance, individuals who grew up in high-risk or violent environments may have developed an increased capacity to attend and activate in response to interpersonal stressors.

2. Moderate physiological linkage is "just right"

Based on the idea of feedback loops in family systems theory, some amount of interpersonal connectedness is likely normative and even adaptive; however, too little or too much interdependence in couples may be detrimental to relationship functioning. As shown in Figure 1 (Panel B), the association between physiological linkage and relationship satisfaction could be curvilinear such that low linkage is associated with low relationship satisfaction, moderate linkage is associated with high relationship satisfaction, and high linkage is associated with low relationship satisfaction. Too little linkage may indicate a lack of connection whereas too much could result in conflict escalation if partners are overly reactive or susceptible to each other's negative emotions. Low linkage might also reflect the end stages of a relationship if partners become "burned out" and disengage from one another.

3. Physiological linkage is problematic if the individual or couple is overloaded

Social baseline theory suggests that individuals regulate their physiology in the context of social relationships by down regulating each other's levels of activation. Although these processes may be evolutionarily adaptive by conserving energy in the face of environmental

threat, such connectedness might also overwhelm the system in cases of extreme or chronic stress. In such circumstances, rather than down regulating each other, partners may "catch" one another's stress responses, which could negatively impact both people, as well as the relationship more generally (see Figure 1; Panel C).

4. The implications of physiological linkage depend on the emotional context

Past work on linkage in close relationships has not adequately addressed the role of the emotional context in linkage processes, though the intervention literature provides some information about how connection in particular emotional states could be associated with relationship functioning. In emotion focused couple therapy, therapists attempt to change the climate of couples' interactions by encouraging couples to express "soft affect," or sad and vulnerable emotions, rather than "hard affect," or angry and hostile emotions (Johnson & Greenberg, 1995). Similarly, in integrative behavioral couple therapy, therapists help clients to express their pain regarding their conflict, rather than blaming or criticizing their partners (Jones, Christensen, & Jacobson, 2000). This technique, known as empathic joining, is thought to foster emotional connectedness. These therapeutic approaches suggest that the emotional context in which couples interact and connect has implications for relationship functioning. It is possible that physiological linkage operates similarly, with linkage during anger being associated with poor relationship functioning and linkage during sadness or happiness being associated with positive functioning (see Figure 1, Panel D).

Goals of the Current Review

The goals of this review are to summarize the literature and provide a framework for future work. Results are divided into three categories: participant characteristics, physiological linkage characteristics, and variables associated with physiological linkage. In the discussion, three interrelated questions are examined: (1) what is the evidence that physiological linkage exists (2) what is the nature of linkage, (3) and when is linkage good or bad for individual and interpersonal functioning. Each of the four hypotheses presented above is then discussed.

Method

Inclusion and Exclusion Criteria

Articles in the current review met the following criteria: (1) included human romantic partners; (2) included at least one index of physiological arousal measured in both of the partners; and (3) tested linkage between the partners in this physiological index and/or examined the association between linkage and another variable. There were no restrictions for inclusion in terms of the relationship type (e.g., married, dating, etc.), relationship length, or type of sample (e.g., clinical). Unpublished dissertations that emerged in the search were also included.

Literature Search

Articles meeting criteria were identified by searching the databases *PsycINFO* and *PubMed* using the terms: coregulation, synchrony, physiological linkage, affect* covariation, affect*

reciprocity, affect* interdependence, emotion* coordination, emotion* transmission, emotion* contagion, couples, dating, romantic, marital, married, and spouses, with restrictions set to studies published before December 31, 2014. Reference lists of articles meeting criteria were then examined to identify other articles, as were reference lists of relevant review articles (Butler, 2011; Repetti, Wang, & Saxbe, 2011; Sbarra & Hazan, 2008). This search produced 24 articles meeting criteria.

Classification of Linkage Effects

Studies testing physiological linkage used diverse methodology and statistical techniques; in this review, a study was considered to have evidence of linkage if the authors reported: (1) a significant linkage parameter (i.e., a coefficient defined by the authors as representing linkage in physiology, e.g., a regression coefficient); (2) significantly greater linkage in matched versus randomly paired dyads; (3) significant improvement in model fit when linkage parameters were included in the model; or (4) a significant increase in linkage across tasks. In Appendix A, we include additional information about the linkage analyses used in specific studies.

Results

Participant Characteristics

Sample size ranged from 4 to 221 couples, with 71 percent of studies including 50 or fewer couples. The average or median age of the samples ranged from 19.1 to 62.1. Out of 17 studies providing information regarding relationship type, 47% included married couples only. Average or median relationship length ranged from 2.4 months to 40.7 years. Across the studies, the majority of participants was Caucasian and had attended at least some college. Relationship satisfaction was generally high, and no studies included entirely clinical samples. No studies reported including same-sex couples. See Appendix B for additional participant information.

Physiological Linkage Characteristics

Table 1 summarizes the characteristics of physiological linkage for those studies included in the review. The strongest evidence was found for cortisol, with eight out of nine studies reporting significant associations (Berg & Wynne-Edwards, 2002; Laurent & Powers, 2007; Liu et al., 2013; Papp et al., 2013; Saxbe et al., 2014; Saxbe & Repetti, 2010; Schneiderman, Kanat-Maymon, Zagoory-Sharon, & Feldman, 2014; Schreiber et al., 2006; Storey, Walsh, Quinton, & Wynne-Edwards, 2000). Evidence of linkage was also found in HR, BP, EDA, fMRI, prolactin, P, RSA, RES, and TI (Atzil, Hendler, Zagoory-Sharon, Winetraub, & Feldman, 2012; Chatel-Goldman, Congedo, Jutten, & Schwartz, 2014; Ferrer & Helm, 2013; Helm et al., 2012, 2014; Hubler, 2013; McAssey et al., 2013; Reed, Randall, Post, & Butler, 2013; Schneiderman et al., 2014). No evidence of linkage was found for estradiol, oxytocin, dehydroepiandrosterone sulfate, or testosterone (Berg & Wynne-Edwards, 2002; Schneiderman et al., 2014). However, there were some cross-hormone links, for example testosterone and cortisol were associated (Berg & Wynne-Edwards, 2002). One study reported non-significant findings for a composite of multiple indices (Bloch, Haase, & Levenson, 2014) and another found non-significant results for HR and EDA (Reed et al.,

2013). Eleven studies used laboratory-based discussions tasks (e.g., Laurent & Powers, 2007; Saxbe et al., 2014); the majority of these tasks involved engaging in conflict or problem solving. Seven studies tested linkage in the home environment; all of these measured endocrine system markers (e.g., cortisol; Saxbe & Repetti, 2010; Storey et al., 2000), except for one study that examined linkage in sleep timing (Hasler & Troxel, 2010).

Variables Associated with Physiological Linkage

Of the 24 studies included in the review, 17 examined associations between linkage and other variables. Typically, these studies tested moderators of linkage or they created indices of linkage that were correlated with other variables. Table 2 presents the results for the 17 studies.

Relationship satisfaction—The most commonly tested variables were relationship and marital satisfaction, with several other studies examining related variables, such as relationship conflict, hostility, and the quality of daily interactions between the partners. Typically, these measures were obtained through self-report questionnaires or behavioral coding. Out of 17 tests, 13 significant (e.g., Hasler & Troxel, 2010; Helm et al., 2012, 2014; Hubler, 2013; Levenson & Gottman, 1983; Liu et al., 2013; Saxbe & Repetti, 2010; Schneiderman et al., 2014) and 4 non-significant effects (Levenson & Gottman, 1985; Reed et al., 2013; Sauder, 2001; Thomsen & Gilbert, 1998) were reported. Positive associations in cortisol were linked to poorer relationship quality in daily life (Liu et al., 2013; Saxbe & Repetti, 2010) and during laboratory-based conflict (Schneiderman et al., 2014). Similarly, Levenson and Gottman (1983) found that linkage in a composite of indices was associated with less satisfaction during laboratory conflict. Helm et al. (2012) reported that the association varied by the task, with linkage in RES being associated with greater satisfaction in females during the resting task but lower satisfaction in males during the imitation task (an experimental task in which the researchers explicitly instructed the couples to try to synchronize their physiology). Other work showed that linkage in RSA was related to more relationship satisfaction (Helm et al., 2014) and that linkage in sleep onset was related to better quality interactions between partners (Hasler & Troxel, 2010).

Empathy—Reuf (2001) investigated the association between physiological linkage and empathic accuracy. Results showed that for females, greater accuracy in identifying the emotions of their romantic partners was associated with greater physiological linkage. Chatel-Goldman et al. (2014) similarly reported that greater empathy was associated with greater linkage in EDA. In contrast, Schneiderman et al. (2014) found that greater empathy was associated with less linkage in cortisol during laboratory conflict.

Physical proximity—Two studies examined physical proximity as a moderator of linkage in partners' cortisol. Saxbe and Repetti (2010) compared linkage mid-day (when couples were likely at work and therefore apart) to linkage during mornings and evenings (when couples were likely at home and therefore together) and found evidence for linkage only in the mornings and evenings. In a similar study, participants reported on whether or not they were with their spouses at several points in the day (Papp et al., 2013); results showed no evidence that being together at a given point in time heightened linkage in cortisol.

However, the proportion of time that males spent with their partners over the period of data collection was associated with increased linkage.

Emotional experience—Four studies tested the relation between linkage and emotions during laboratory discussions (Chatel-Goldman et al., 2014; Levenson & Gottman, 1983; Reed et al., 2013; Thomsen & Gilbert, 1998); no significant associations were reported.

Other variables—Reed et al. (2013) tested the association between linkage and demand-withdraw behavior; at low levels of demand-withdraw behavior, the association between partners' BP was negative whereas at high levels, the association was positive. Chatel-Goldman et al. (2014) reported that linkage in EDA was heightened when partners were touching one another. Only one study examined the association between linkage in HR and RES and attachment style (Helm et al., 2012). Results were complex; the pattern varied depending on the laboratory task and the physiological index. One study tested the relation between linkage in sleep onset and depressive symptoms and did not find an association (Hasler & Troxel, 2010). Helm et al. (2012) found that linkage in HR and RES was not associated with relationship length, and Hubler (2001) did not find an association between linkage in HR and self-reported stress.

Discussion

Physiological linkage in romantic relationships is a compelling area of research. While work in this area is exciting, several aspects of linkage theory await empirical validation. Early work on linkage has been somewhat disjointed and has lacked clarity in terminology, as others have pointed out (e.g., Butler, 2011). Below, we describe the extent to which proof of concept of linkage has been demonstrated, discuss the implications of linkage in romantic relationships, and make recommendation for future research.

What is the Evidence that Physiological Linkage Exists?

Evidence of linkage was observed in cortisol, HR, BP, EDA, fMRI, prolactin, P, RSA, RES, and TI. While these initial results are encouraging, it is worth nothing that the results may have been inflated by publication bias, though we did include several unpublished dissertations in the review. In addition, it is important to remember that these findings may be driven by third-variables confounds such as diet, sleep routines, or other shared environmental factors. Studies connecting linkage to other variables, such as relationship satisfaction, have provided initial evidence that linkage is related to interpersonal functioning and is not a methodological artifact. Future research should work to rule out these confounds and provide stronger proof-of-concept of these processes. One possibility is to compare the strength of linkage in romantic partners to strangers to determine whether linkage is heightened within the context of close relationships.

What is the Nature of Physiological Linkage?

Physiological linkage was remarkably diverse, occurring across a variety of physiological indices and time scales. The relatively large number of studies testing cortisol provided strong evidence that linkage occurs in the HPA axis. Linkage in both the SNS and PNS was

also observed (e.g., Helm et al., 2012, 2014), although differentiating these two systems is difficult given that many organs, such as the heart, are dually innervated by the SNS and PNS (Hugdahl, 1995). Studies varied by location (e.g., home versus laboratory), the time frame sampled, and the interval measured; for example, some studies measured physiology in 10-second intervals across 20 minutes (e.g., Reed et al. 2013) while others sampled weekly across months (e.g., Berg & Wynne-Edwards, 2002). When testing linkage processes, it is particularly important to choose the measurement interval carefully; it is unclear exactly how long it takes for the physiology of one person to affect the other, and these effects likely vary as a function of the physiological index used (e.g., cortisol, EDA, HR). Relatedly, it has been recommended (e.g., Butler, 2011) that coregulation be differentiated from other types of linkage, such as transmission. Though likely important, most studies did not distinguish between different types of linkage processes.

When Is Physiological Linkage Good Versus Bad?

The implications of sharing in physiology with a romantic partner are complex and likely depend upon on context in which linkage occurs. This review provides preliminary information regarding when linkage is “good” or “bad” and identifies areas in need of more research. Each linkage hypothesis presented in the introduction is reviewed below.

1. Co-activation of the SNS or HPA axis is “bad”—The first hypothesis, that linkage in the SNS or HPA axis is “bad,” was partially supported. Co-activation in a variety of indices was associated with poorer functioning, for example relationship dissatisfaction and more demand-withdraw behavior (Levenson & Gottman, 1983; Reed et al., 2013); however, there were several exceptions to this pattern. For example, Helm et al. (2012) found that the association between linkage and relationship satisfaction depended on the laboratory task used. Moreover, physical proximity, proportion of time together, touch, and empathic accuracy were all associated with greater linkage, suggesting that physical and emotional connectedness may amplify linkage between partners. Such findings are in line with other work examining linkage in self-reported emotion and linkage in non-romantic dyads. Husbands who are high in perspective taking are more likely to co-vary with their wives’ soft affect (Schoebi, 2008). Time together, number of shared activities, and parental supervision are associated with greater linkage in mothers and adolescents (Papp, Pendry, & Adam, 2009), and empathic accuracy is associated with increased linkage in strangers (Levenson & Reuf, 1992). Additional research investigating associations between linkage and emotional and physical connectedness is needed to better understand the implications of these processes. Linkage may be a double-edged sword in that the ability to take on the emotions of others increases as a function of closeness and empathy but also puts couples at risk if they become locked in patterns of negative affect reciprocity and stress responding.

Interestingly, several studies reported inverse associations in partners’ physiology (i.e., as one person’s activation increased, the other person’s activation decreased). Low levels of demand-withdraw behavior, spousal disagreement, spousal strain, and negative influence (i.e., the use of negative control strategies such as guilt or nagging) were all associated with negative linkage whereas high levels of these variables were associated with positive linkage (Liu et al., 2013; Reed et al., 2013). One explanation for these findings is that more satisfied

couples show a pattern of responding in which one partner de-activates when the other activates, resulting in a regulation process that occurs around a stable point rather than partners jointly activating in their stress levels. Another possibility is that these negative associations are caused by turn taking in conversation, though this would not explain the inverse associations observed in cortisol (Liu et al., 2013). In either case, it is important to remember that linkage can take on multiple forms and that these forms might be important for understanding how linkage relates to other variables.

2. Moderate physiological linkage is "just right"—Only one study tested a curvilinear association between physiological linkage and marital satisfaction and did not find a significant effect (Thomsen & Gilbert, 1998). However, given that linkage has been associated with both positive and negative factors, the possibility that physiological linkage is nonlinearly related to other variables should be given consideration in future work.

3. Physiological linkage is problematic if the individual or couple is overloaded—Given clear theoretical links between couples, stress, and physiology, it is surprising that more research has not focused on the role of stress in physiological linkage processes. Stress has been connected to both relationship functioning and health outcomes (Randall & Bodenmann, 2009; Robles & Kiecolt-Glaser, 2003). In the emotional transmission literature, Larson and Almeida (1999) proposed a class of moderators, called "psychological resources," which were thought to decrease the likelihood that negative emotions are transmitted in couples and families. Findings in this literature generally show that psychopathology and stress heighten emotional transmission (Larson & Richards, 1994; Repetti & Wood, 1997). In particular, external stressors that affect both partners, e.g., a sick child or a natural catastrophe, might lead to a "shared" physiological reaction in which couples link together in their negative emotions and stress responding. Only one study in this review examined the moderating role of self-reported stress and did not find a significant link. Similarly, only one study in this review tested psychopathology as a moderator, again not finding a significant effect; however, this study tested individual psychopathology and linkage in partners' sleep onsets (Hasler & Troxel, 2010); associations using other physiological indices have not to our knowledge been examined.

4. The implications of physiological linkage depend on the emotional context —Four studies found non-significant associations between emotion and physiological linkage. These results suggest that the degree of linkage that couples evidence is not dependent on the type of emotion they experience (Chatel-Goldman et al. 2014; Levenson & Gottman, 1983; Reed et al., 2013; Thomsen & Gilbert, 1998). However, it still possible that the implications for relationship functioning do vary according to the emotional context. In line with this idea, Levenson and Gottman (1983) found that the association between linkage and marital dissatisfaction occurred only during the conflict discussion and not during the neutral task. Though emotion was not formally tested as a moderator, the conflict discussion was likely characterized by more hostile emotion. Perhaps when discussing vulnerability or loss, linkage in physiology reflects greater emotional bonding. In one study testing self-reported affect, linkage in hard affect was linked to greater interpersonal insecurity whereas linkage in soft affect was linked to greater perspective taking in husbands (Schoebi, 2008).

In addition to distinguishing between hard and soft affect, future research should measure whether these emotions are directed towards each other or to a third person. Uniting in anger towards another person may operate differently than anger that is directed towards one's romantic partner.

Recommendations for Future Research

Directional effects and mediating factors—While extant research suggests that linkage may be meaningfully associated with relationship processes, many basic questions about the nature of linkage remain unanswered. For example, who drives whom? Does the direction of influence depend on gender? Or, is it related to individual characteristics, such as dominance or reactivity? Similarly, what mediates the transfer of physiology between partners? Is it transferred by vocal, facial, tactile, or olfactory cues? Future work could test these questions by measuring linkage in the laboratory and testing associations in physiology from one time point to the next. Observational coding of vocal or facial cues could be used to test whether specific interpersonal signals precede the transfer of physiology across partners. This information would be especially useful for applying work on physiological linkage to clinical interventions. In therapy settings, partners often experience increasing anger and stress as they discuss their relationship problems. Finding ways to disrupt joint escalation of stress responding by interrupting certain behavioral cues could help partners express their perspectives without being flooded with negative emotion.

Longitudinal follow up—One particularly important area of future work is the use of longitudinal data to examine how physiological linkage measured at one time point is associated with other variables assessed months or years later. Most studies included in this review examined concurrent associations between linkage and other variables, making it difficult to determine if linkage is a cause, an outcome, or a third variable correlate of interpersonal functioning. Longitudinal follow up designs could help to identify the antecedents and sequelae of linkage processes. For example, researchers could obtain indices of linkage in the laboratory at one time point and could test how linkage is associated with relationship status later in time. To date, two studies have tested longitudinal associations between linkage and relationship functioning; one study did not find a significant association (Levenson & Gottman, 1985) and the other study reported that when both partners had high cortisol, they showed less empathy and were more likely to break up 6 months later (Schneiderman et al. 2014). In contrast, no studies investigated links between childhood experiences and linkage. Given that early adverse experiences may impact physiological reactivity (Luecken & Lemery, 2004; Repetti, Robles, & Reynolds, 2011), it is possible that childhood violence exposure could influence physiological linkage in adulthood or at salient life transitions, (e.g., the transition to parenthood).

Linkage in different contexts—It is important that future work on linkage carefully considers the role of context. The majority of studies included in this review measured linkage during conflict, which may have pulled for specific types of processes in which couples linked together in their anger or stress responding. While typical paradigms for studying couple functioning involve having couples discuss problems in their relationship, it is also possible for laboratory based discussion tasks to pull for different emotional

experiences (e.g., vulnerability, loss, happiness). Researchers could examine how linkage during different discussion tasks relates to individual and interpersonal functioning. For example, greater linkage when sharing a positive experience or a personal loss with one's romantic partner could be associated with greater empathy or connectedness in the relationship. Another potentially important contextual factor is culture; several studies have reported cultural differences in the tendency for partners to co-vary in daily self-reported moods, though results of this research have been mixed (Randall, 2013; Schoebi, Wang, Ababkov, & Perez, 2010).

Technological and methodological innovation—Cross-discipline advances in theory, quantitative techniques, and physiological measurement have converged to create exciting new methods for studying couple processes and will likely result in increased work on linkage in coming years. First, the use of ambulatory physiological monitors to capture indices such as EDA and HR outside the laboratory is becoming more widespread (e.g., Poh et al., 2010). Work combining ambulatory physiological monitoring with ecological momentary assessment methods and other technologies (e.g., GPS, audio recordings) could be especially powerful for studying physiological linkage and family dynamics more broadly. Such methods would allow researchers to capture these processes in real-life contexts and could decrease participant reactivity. Second, other technologies, such as fMRI or electroencephalogram, could provide moment-to-moment information about couples' linkage at the neural level. Third, increased accessibility of statistical methods (e.g., multilevel modeling) has made it more feasible to examine linkage hypotheses. Recent studies applying dynamical systems models to couple physiology also hold promise for advancing work in this area (e.g., Ferrer & Helm, 2013). The studies included in this review used a range of statistical methods (e.g., time series, multilevel modeling) with no gold standard in terms of what exactly constitutes linkage (see Appendix A). As different methods become more widely used, the criteria regarding how to test and classify linkage processes will likely increase in precision. Once methods for characterizing linkage become more standardized across studies, an important next step will be to conduct a meta-analysis of linkage processes.

Clinical Applications

Beyond the use of new methodologies for investigating couple dynamics, research on physiological linkage in couples likely has important implications for interventions targeting individual and couple functioning. Early life experiences, such as attachment to caregivers or violence exposure, could affect individuals' tendencies to respond to the physiology of others, possibly by being withdrawn and avoidant—or by being reactive and vigilant. These tendencies may then impact couple functioning. In particular, physiological reactivity and linkage could be important factors in understanding the intergenerational transmission of violence. Relatedly, if couples are reactive to each other's stress and physiology, this could create a pattern of conflict escalation, which could have implications for physical health if partners experience chronically heightened levels of physiological arousal. As others have suggested, small daily behaviors and emotions may have cumulative effects on couple functioning and health outcomes if couples experience repeated and chronic activation of the SNS or HPA axis (Repetti, Wang, & Saxbe, 2009). These processes might help explain why

being in a distressed marriage is a risk factor for negative health outcomes, including heart disease and cancer (Burman & Margolin, 1992; Robles & Kiecolt-Glaser, 2003). Interventions could take the form of helping partners de-escalate during conflict or by redirecting couples to express vulnerability rather than anger. Therapy could be administered using biofeedback during sessions or through the use of mobile physiological sensors to provide real-time feedback as such processes unfold in naturally occurring contexts.

Conclusion

Understandably, increased theoretical and empirical interest in physiological linkage is coinciding with methodological and technological innovations in detecting linkage processes. This paper organized and summarized the existing literature on physiological linkage in romantic partners, bringing into sharper focus what is known about linkage and identifying what questions remain. Linkage was evidenced in a variety of physiological indices and contexts. Its association with a number of other variables suggests that it is an important factor in individual and interpersonal functioning. The first hypothesis, that co-activation in the HPA axis or SNS is "bad," was partially supported. Co-activation in the HPA axis was linked to poorer relationship functioning, but the findings for the SNS were more complex. Specifically, it was difficult to differentiate the effects of the SNS from the PNS, and co-activation in the SNS was sometimes associated with positive factors, such as empathy. Perhaps co-activation in the HPA axis, which is more specific to stress responding, is associated with poorer relationship quality but the association for the SNS depends more heavily upon the context. The endocrine system represents a slower stress response system than the SNS, which responds more rapidly to threat and also returns to baseline more rapidly. Therefore, the different patterns of the HPA axis and SNS might reflect whether couples show brief episodes of co-activation or more sustained linkage in their stress responding. Even so, co-activation in the HPA axis was linked to a greater proportion of time spent together, suggesting that connectedness also amplifies these processes.

Although we found partial support for a linear relationship between physiological linkage and relationship functioning, future work should begin to test the more nuanced associations presented by the other hypotheses (e.g., nonlinear relationships, moderators). Our understanding of linkage processes will be improved by more fully considering how the implications of linkage are shaped by other factors (conflict versus loss, anger versus sadness, linkage during stress). Past confusion in the literature regarding physiological linkage and its implications may reflect the complexity of the topic and its nuanced associations with relationship functioning. Our view is that linkage is neither wholly "good" nor "bad." Being "linked" to a romantic partner may reflect closeness and attunement but may be maladaptive in other cases, especially if it occurs in the context of repeated and chronic stress responding. Though many questions regarding linkage in romantic partners are not yet answered, this review provides a framework for investigating these complicated associations. Finding ways to capitalize on the benefits of close relationships while avoiding the risks could have implications for interventions aimed at improving individual health and relationship outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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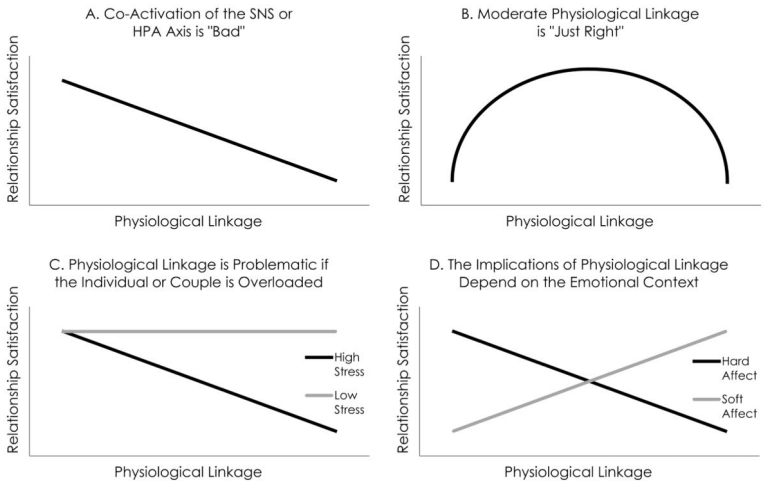

Figure 1.

An illustration of the physiological linkage hypotheses using relationship satisfaction as an example dependent variable. Panels A, B, C, and D correspond to hypotheses 1, 2, 3, and 4, respectively.

Table 1

Physiological Linkage Characteristics

Article	Task(s) or Event(s)	Time Span	Setting	Measure (s)	Linkage
Atzil et al. (2012)	Watch videos of infants	2 mins per trial (8 trials)	Lab	fMRI	Yes
Berg & Wynne-Edwards (2002)	Surrounding birth of first child	At least once a week the months surrounding childbirth	Home	Cortisol	Yes
				Estradiol	No[a]
				Testosterone	No[a]
Bloch et al. (2014)	Discussions: conflict, events of the day, pleasant	15 mins per discussion	Lab	Composite: time to down-regulate EDA, FT, HR, movement, P	No
Chatel-Goldman et al. (2014)	Recalling positive and negative events while touching or not touching	2 mins per trial (10 trials)	Lab	EDA	Yes
				P	Yes[b]
				RES	NR
Ferrer & Helm (2013)	Gazing, try to synchronize their physiology	3 mins per task	Lab	HR	Yes[c]
				RES	Yes[c]
Hasler & Troxel (2010)	Naturalistic	Up to 6 samples a day (7 days)	Home	Sleep onset timing	NR
Helm et al. (2012)	Gazing, try to synchronize their physiology	3 mins per task	Lab	HR	Yes[c]
				RES	Yes[c]
Helm et al. (2014)	Discussions: positive, neutral, and negative	3 mins per task	Lab	RSA	Yes[c]
Hubler (2013)	Discussions: time felt hurt, time felt loved, relationship education pros and cons	5–10 mins per discussion	Lab	HR	Yes[c]
Laurent & Powers (2007)	Conflict discussion	7 samples; taken around 15 min discussion	Lab	Cortisol	Yes
Levenson & Gottman (1983, 1985)	Discussions: events of the day, problem solving	15 mins per discussion	Lab	Composite: EDA, HR, movement, P	NR
Liu et al. (2013)	Naturalistic	4 samples a day (4 days)	Home	Cortisol	Yes[c]
McAssey et al. (2013)	Gazing, try to synchrony their physiology	3 mins per task	Lab	HR	Yes[c]
				RES	Yes[c]
				TI	Yes[c]
Papp et al. (2013)	Naturalistic	7 samples a day (2 days)	Home	Cortisol	Yes

Article	Task(s) or Event(s)	Time Span	Setting	Measure (s)	Linkage
Reed et al. (2013)	Health behavior discussion	20 mins	Lab	BP	Yes
				EDA	No
				HR	No
Reuf (2001)	Discussions: events of the day, conflict, pleasant	15 mins per discussion	Lab	Composite: EDA, FT, movement, P	NR
Sauder (2001)	Discussions: conflict, events of the day	15 mins per discussion	Lab	EDA, EMG, FT, HR, FT, RES	NR
Saxbe et al. (2014)	Family conflict discussion	6 samples; taken around 15 min discussion	Lab	Cortisol	Yes
Saxbe & Repetti (2010)	Naturalistic	4 samples a day (3 days)	Home	Cortisol	Yes
Schneiderman et al. (2014)	Conflict discussion	7 mins	Lab	Cortisol	No
				DHEAS	No
				Oxytocin	No
				Prolactin	Yes
				Testosterone	No
Schreiber et al. (2006)	Naturalistic	1 sample a day (3 days)	Home	Cortisol	Yes
Storey et al. (2000)	Before or after birth, holding doll or child	2 samples over 30 mins	Home/clinic	Cortisol	Yes
				Prolactin	NR[a]
Thomsen & Gilbert (1998)	Conflict discussion	15 mins	Lab	EDA, HR	NR

Note. Baseline/relaxation tasks not listed. Studies were considered to have evidence of linkage if: parameters representing covariation in physiology were significant, the model fit significantly better with linkage parameters included, linkage was significantly greater in matched versus randomly paired dyads, or there was a significant increase in linkage across tasks (see Appendix B for details). NR = not reported. For studies classified as NR, the study either (1) did not conduct an analysis for a particular index or (2) they used a technique in which each person received a linkage score, but they did not conduct a significance test to determine whether the sample had significance linkage overall; such studies still tested the association between linkage and other variables (see Table 2). BP = blood pressure; EDA = electrodermal activity; DHEAS = dehydroepiandrosterone sulfate; EMG =electromyography; FT = finger temperature; HR = heart rate; P = pulse; RES = respiration; RSA = respiratory sinus arrhythmia; TI = thoracic impedance.

[a]There were some cross-hormone links.

[b]significant at $p < .10$.

[c]Results varied by task or the way the physiological index was computed.

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Table 2

Variables Associated with Physiological Linkage

Article	Main Variable(s) Tested	Summary of Main Result(s)
Chatel-Goldman et al. (2014)	Emotional state	No association
	Empathy	↑ linkage in EDA = ↑ empathy
	Touch	↑ linkage in EDA when touching; effect ↑ in participants with ↓ empathy
Ferrer & Helm (2013)	Linkage in daily affect	In Fs, linkage in physiology (for both HR and RES) was associated with linkage in daily affect
Hasler & Troxel (2010)	Daily interactions	In Fs, ↑ linkage in sleep = ↑ positive and ↓ negative interactions the next day
	Mean of daily interactions	In Fs, ↑ linkage in sleep = ↑ positive and ↓ negative interactions
	Depression	No association
	Relationship satisfaction	In Fs, ↑ linkage in sleep = ↑ relationship satisfaction (marginally)
Helm et al. (2012)	Attachment style	Significantly associated, but varied by physiological index and task
	Relationship length	No association
	Relationship satisfaction	Significantly associated, but varied by physiological index and task
Helm et al. (2014)	Relationship satisfaction	↑ linkage in RSA = ↑ relationship satisfaction
Hubler (2013)	Relationship satisfaction	↓– linkage from Ms to Fs = ↑ relationship satisfaction
	Differences in relationship satisfaction reports	↓– linkage from Ms to Fs = ↑ discrepancy in relationship satisfaction reports
	Stress	No association
Levenson & Gottman (1983)	Marital satisfaction	↑ linkage in composite physiological measure = ↓ marital satisfaction during conflict but not events of the day discussion
	Affect	No association
	Affect reciprocity	No association
Levenson & Gottman (1985)	Marital satisfaction 3 years later	No association
Liu et al. (2013)	Spousal disagreement	For the DCS,[d] linkage = + at ↑ spousal disagreement and − at ↓ spousal disagreement
	Spousal strain	For the DCS,[d] linkage = + at ↑ spousal strain and − at ↓ spousal strain
	Spousal support	No association
Papp et al. (2013)	Being alone	No association
	Being with spouse	No association
	Loneliness	No association
	Proportion time alone	No association

Article	Main Variable(s) Tested	Summary of Main Result(s)
	Proportion of time together	↑ linkage among husbands reporting ↑ proportion of time with wives
	Proportion of time with others	No association
Reed et al. (2013)	Demand behavior	Linkage in BP = + at ↑ demand behavior (marginally); linkage = − at ↓ demand behavior
	Withdraw behavior	Linkage in BP = + at ↑ withdraw behavior; linkage = − at ↓ withdraw behavior
	Emotions during discussion	No association
	Negative influence[a]	No linkage in BP at ↑ negative influence; linkage = − at ↓ negative influence
	Relationship conflict	No association
Reuf (2001)	Empathic accuracy	In Fs, ↑ linkage = ↑ empathic accuracy for positive and negative emotions
Sauder (2001)	Marital satisfaction	No association
Saxbe et al. (2014)	Gender of child	Linkage in cortisol (area under the curve) only in couples with daughters
	Stepparent presence	↓ linkage in cortisol when stepparent present in family discussion task
	Total cortisol output	↑ linkage in cortisol = ↑ total cortisol output
Saxbe & Repetti (2010)	Marital satisfaction	↑ linkage in cortisol = ↓ marital satisfaction
	Physical proximity	Linkage in cortisol when at home (together) but not when at work (apart)
	Daily linkage in mood	↑ linkage in cortisol = ↑ linkage in negative mood but not positive mood
Schneiderman et al. (2014)	Empathy	↑ cortisol = ↓ empathy when partner also had ↑ cortisol
	Hostility	↑ testosterone = ↑ hostility when partner also had ↑ testosterone; ↑ testosterone = ↓ hostility when partner had ↓ testosterone
	Relationship status	When both partners had ↑ cortisol, they had ↓ empathy and had a ↑ likelihood of breaking up 6 months later
Thomsen & Gilbert (1998)	Behaviors during discussion	In Fs, ↑ linkage = ↓ listening; In Fs, ↑ linkage when partner responds well
	Emotions during discussion	No association
	Marital satisfaction	No association (curvilinear effect tested)

Note. Ms = males; Fs = females. ↑ = “more/greater”; ↓ “less/fewer”. Associations are positive unless otherwise specified by + and − symbols.

[d]DCS = diurnal cortisol slope.

[a]Negative influence is the use of control strategies (e.g., guilt, nag) to influence partner.