Introduction to the special issue: Nonlinear effects and dynamics in close relationships

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Abstract
Relationship processes often involve fluctuating, variable, or tumultuous dynamics. Yet, close relationship models have traditionally focused on linear processes. The purpose of this Journal of Social and Personal Relationships special issue is to provide examples of how modeling nonlinear effects and dynamics can: (I) test nonlinear theoretical assumptions, (II) reconcile inconsistencies and reveal novel effects, (III) detect dynamic shifts in core relationship constructs, and (IV) capture temporal and spatial synchrony between partners within dyads. By showcasing a variety of nonlinear applications, we hope to encourage close relationship scholars to utilize similar nonlinear methods in order to advance relationship science by discovering common and important, but currently under-examined, relationship processes.

Keywords
nonlinear, fluctuations, variation, curvilinear, synchrony, dyadic

A call to action
Close relationships are a central determinant of health and wellbeing (Holt-Lunstad, 2018; Robles et al., 2014), but understanding how they develop and remain secure, satisfying, and stable over time has been challenging. Understanding how and why the desires,
needs, and beliefs of one person are associated with these outcomes is complicated enough. How, then, can relationship scholars comprehend the even more complex, interconnected relationships between two people that change across time, sometimes in tumultuous and unpredictable ways? For example, Marie and Lydia are a committed couple who describe the early stages of their relationship as a “whirlwind romance”, but they have noticed that passion in their relationship ebbs and flows now that they have young children (a process involving greater variation or fluctuation). Morgan and Mateo, another committed couple, experience relationship conflicts that tend to escalate unpredictably (a process involving abrupt shifts), making it challenging for each of them to regulate their emotions and become attuned with each other (or find dyadic synchrony). Priya and Jason have just started a relationship. Initially, Priya thought it was sweet when Jason got a little jealous when she spent time with her male friends, but recently Jason has gotten overly jealous, leading Priya to reconsider whether she wants to stay in the relationship (a curvilinear effect of jealousy).

To date, relationship scientists have explored these different types of relationship phenomena by employing statistical techniques that account for the inherent interdependence that exists between relationship partners (Kenny et al., 2006; also see Cook & Kenny, 2005). Scholars also have utilized within-person (as opposed to between-group) analyses to investigate how relationship processes unfold within each individual (partner) or dyad in different social contexts and across time (Bolger & Laurenceau, 2013; Gable & Reis, 1999). These statistical methods have enhanced our understanding of close relationship processes, but they have predominately been used to examine linear effects. Yet, as the three examples above illustrate, many important relationship processes operate in non-linear ways, leading to calls for the application of nonlinear models within relationship science (e.g., Gable & Reis, 1999; Girme, 2020; Gottman, 2002). Though growing, there are relatively few empirical examinations of non-linear effects in the field of close relationships (for exceptions, see Arriaga, 2001; Don et al., 2022; Eller et al., in press; Girme et al., 2015, 2018, 2021a; Gunaydin et al., 2021; Muise et al., 2016; Overall, 2020), and even fewer theoretical models that explicitly incorporate nonlinear dynamics (for exceptions, see Eastwick et al., 2019; Solomon & Knobloch, 2004). The current special issue showcases new tools to assess and model different types of non-linear dynamics in close relationships. While doing so, it highlights the value of adopting non-linear perspectives, including: (I) testing nonlinear theoretical assumptions, (II) reconciling inconsistencies and revealing novel relationship effects, (III) detecting dynamic shifts in core relationship constructs, and (IV) capturing temporal and spatial synchrony between relationship partners.

**Special issue aims and resources**

The fundamental aim of this special issue is to illustrate ways in which modeling nonlinear effects and dynamics can facilitate our understanding of common relationship experiences and broaden our understanding of complex relationship processes. We construe “nonlinear” effects and dynamics broadly, and the papers in this special issue demonstrate a range of statistical techniques designed to capture different relationship
processes that can change in tumultuous and variable ways across time, situations, and partners. For example, nonlinearity can be defined as a function of patterns between variables (e.g., curvilinear effects, Chopik et al., 2022, Lafit et al., 2022; also see correlated intercepts, slopes or residuals, Dugan et al., 2022), within variables over time (e.g., within-person variation, Eller et al., 2022), and/or within variables between dyads (e.g., time-series analyses, Ogolsky et al., 2021). More complex models can reveal the dynamic ways in which partners’ emotions (e.g., change point detection, Sels et al., 2022), behaviors (e.g., sequence analysis, Solomon et al., 2022), or physiological responses (e.g., couple-oscillator model, Kuelz et al., 2022), unfold or shift abruptly across time. We recognize that most of these analyses are inherently linear in that they involve extracting variables that represent nonlinear effects or dynamics to include in linear-based models to predict outcomes. We believe that these applications provide an important first step to encourage wider theoretical and empirical applications examining nonlinear processes in close relationships. The applications that appear in this special issue do not represent an exhaustive list; instead, they serve as examples of how nonlinear methods can be applied to address important questions and processes targeted within the field.

To facilitate the aim of providing scholars with good examples of how nonlinear models can advance close relationships research, we asked the authors invited for this special issue to include the following information in their papers: Identify why nonlinear processes are theoretically important for addressing their research question(s), or what types of research questions can be answered using their proposed methodological or statistical tool. We also encouraged the authors to provide clear and detailed information so scholars interested in replicating their methods/analyses can do so easily by: (1) providing details about how to structure datasets, (2) providing example code and output for analyses, and (3) making publicly available the data and code for the results they presented. This information appears in the papers, but authors also included online supplementary materials (OSM) and/or used the open science framework (OSF) to provide more detailed information.

One resource appearing in this special issue that we hope will be applicable to many scholars is a power analysis app called “PowerLAPIM”. Lafit et al., (2022) provide details about the “PowerLAPIM” app, which they have developed for conducting power analyses for linear and quadratic (curvilinear) longitudinal APIM models. Lafit and colleagues outline 24 different possible models, based on whether dyads are distinguishable, whether the models include linear and/or quadratic effects, and the inclusion of various types of moderators. “PowerLAPIM” is a user-friendly web-based tool that provides scholars with information about the number of dyads required to conduct well-powered dyadic longitudinal analyses, and it is especially relevant for scholars interested in estimating statistical power for curvilinear longitudinal effects. In sum, we hope that the variety of nonlinear applications and additional resources provided in this special issue will encourage a growing number of close relationships scholars to adopt nonlinear methods.
Why are nonlinear effects and dynamics important?

There are several advantages of examining nonlinear effects and dynamics in close relationships. We briefly highlight four key reasons why modelling nonlinear effects and dynamics are important for advancing close relationships theory and research, each of which dovetail with salient themes that emerged across the papers in this special issue.

Theme I: Central relationship theories imply nonlinear effects and dynamics

Several theories involving close relationships allude to underlying processes that are nonlinear by nature, yet have only been tested using linear modelling. Properly modelling nonlinear effects and dynamics, however, can directly test these pivotal processes. Two papers in this special issue utilize nonlinear models to test central tenets of one of the most influential theories in close relationships – attachment theory. According to attachment theory, both high quality and consistent caregiving is required to foster greater attachment security. Although quality caregiving has been studied extensively, most work on attachment has not paid much attention to consistency versus fluctuations in caregivers’ responsiveness (see Girme et al., 2021b; Gunaydin et al., 2021; Eller et al, in press, for exceptions). Eller et al., (2022) show that, beyond mean levels in the quality of maternal sensitivity received across early-to-middle childhood, inconsistent caregiving (i.e., greater within-person standard deviation in maternal sensitivity) has unique, deleterious consequences for the development of attachment security and relationship effectiveness years later in adulthood.

Another core tenet of attachment theory is that attachment working models are hierarchically structured (Overall et al., 2003), with people having both relationship-specific and global working models. Prior research has documented ways in which attachment representations can and do change over time (e.g., Simpson et al., 2003), but it remains unclear exactly how these changes occur. Dugan et al. (2022) employ bivariate growth curve models to examine associations among long-term changes (slope-slope correlations) and short-term fluctuations (correlations among residuals) in different working models or attachment representations. Their results provide important theoretical insights into the dynamic ways in which attachment representations change and how short-term fluctuations in working models can “reverberate through [people’s] network of attachment representations” (pg. 23).

Theme II: Nonlinear applications can reconcile inconsistencies and reveal novel effects

As is true of many fields, relationship science is fraught with inconsistent findings: social support is beneficial, but can also backfire (Girme et al., 2015); conflict is destructive, but it can also be diagnostic and helpful (Overall, 2020); sexual frequency is important for relationship functioning, but life often gets in the way (Muise et al., 2016). Linear models may reveal inconsistent effects because they do not model the association between variables along the full range of values (e.g., curvilinear effects) or because they mask
important sources of variation in the data (e.g., fluctuation effects; see Girme, 2020). Nonlinear applications can reconcile inconsistencies in associations that occur at different levels and can sometimes reveal novel effects that may be missed when simply modelling linear effects. In this special issue, Chopik et al. (2022) provide one such example. The literature on the association between age and gratitude is mixed: Different studies have produced contrary evidence that gratitude peaks either in younger age, middle age, or older age, with some studies revealing null associations (see Chopik et al., 2019). Chopik et al. (2022) report a cubic effect of age ($age^3$) that is consistent across cultures, with gratitude levels being low and stable among adolescence, then gradually increasing across middle age, and finally stabilizing in older age. This pattern reflects nonlinear changes in gratitude across the lifespan that has never been captured by previous studies examining linear associations.

**Theme III: Relationship interactions involve nonlinear dynamic shifts**

Behavioral observation, such as video-recording dyads engaged in discussions, is one of the strongest methods used to measure and witness interpersonal processes that forecast long-term relationship outcomes (Baumeister et al., 2007; Gottman & Notarius, 2000). Observation methods often involve independent coders who rate each partner’s emotions and behaviors across the discussion, which provides very rich data to examine key dyadic processes in diagnostic social interactions (Overall et al., 2016). The resulting quantitative measures and data analytic techniques, however, typically fail to consider the multitude of ways in which conversations unfold. One paper in the special issue introduces a useful tool to examine how dyadic conversations progress. Solomon et al. (2022) use sequence analysis to identify different patterns of sequential behavior based on categorical shifts during couples’ discussions, such as Morgan disclosing a problem, Mateo clarifying it with a question, Morgan elaborating more, Mateo reflecting on what is said, and then ending with Mateo providing advice. Different sequential patterns, or “conversational motifs,” can then be used to predict key outcomes, such as which conversational motifs are associated with discussion success, or whether individual or dyadic characteristics predict certain conversational motifs, such as what types of couples tend to engage in optimal conversational motifs.

Considering nonlinear dynamics also enhances our understanding of processes within dyadic interactions by highlighting that important and consequential changes in emotion, behavior, or communication may not reflect incremental, linear effects across interactions. Indeed, another paper in this special issue shows how nonlinear models can identify abrupt shifts during conversations. Sels et al. (2022) introduce change point detection analysis, which allows researchers to detect sudden shifts in emotions during dyadic discussions. The method Sels et al. illustrate identifies whether abrupt changes are experienced by both dyad members simultaneously, such as Morgan and Mateo both suddenly getting angry, or whether abrupt changes are isolated to one member of the dyad, such as Morgan suddenly gets angry, but Mateo does not. These critical moments may have important implications for the trajectory of dyadic discussions, such as serving as catalysts for couples to become more versus less attuned or synchronized (“on the same
Theme IV: Nonlinear dynamics involve temporal and spatial synchrony between partners

One defining feature of close relationships is that dyad members (partners) are highly interdependent—each person’s experiences and outcomes are inherently linked by mutual dependence and influence (Kelley et al., 2003; Kelley & Thibaut, 1978). Relationship science typically accounts for this interdependence by examining contemporaneous and longitudinal partner effects (i.e., how Morgan’s behavior impacts Mateo’s outcomes; Cook & Kenny, 2005). Two papers in this special issue, however, illustrate how nonlinear modelling can identify additional dyadic processes involving patterns of synchrony between relationship partners. Kuelz et al., (2022), for example, use the R statistical package rties (Butler & Barnard, 2019) to model different patterns of physiological synchrony between dyad members using a coupled oscillator model. Using this method, they: (a) identify distinct patterns of physiological synchrony (such as when partners’ physiologies counterbalance, but never achieve homeostasis or stability), and (b) illustrate what partner and couple characteristics might predict distinct patterns of physiological synchrony (such as whether dissatisfied couples have more maladaptive patterns of physiological synchrony).

Although typically conceived as unfolding across time during specific interactions, dyadic interactions also occur at varying levels of proximity. Ogolsky et al., (2021) link continuous measures of individuals’ spatial proximity in their homes with their partner’s heart rates during daily life to determine whether and how proximity is associated with both partner’s physiological responses. Data across three time-series profiles illustrate that not only does lagged-feedback (i.e., cross-correlations across time) emerge between husbands’ heart rate, wives’ heart rate, and each couple’s proximity, but that predicting any of these variables requires critical information about the other two variables. For example, Morgan’s heart rate might increase 3 minutes after Mateo’s heart rate increases and as the proximity between Morgan and Mateo decreases. In sum, nonlinear models not only confirm that close relationships are highly interdependent; they also provide nuanced information about distinct patterns of synchrony in dyads and the novel consequences of these interaction dynamics.

Concluding remarks

Nonlinear techniques and methods offer scholars a powerful tool to better understand and reveal unknown or under-explored dynamic processes that both define and affect close relationships. We thank the scholars who contributed to this special issue for offering such good, novel illustrations of how nonlinear effects and dynamics can be fruitfully modelled and applied. These examples dovetailed nicely with the key reasons why we believe modelling nonlinear effects and dynamics are so important for advancing our
understanding of close relationships, including (I) testing nonlinear theoretical assumptions, (II) reconciling inconsistencies and revealing novel effects, (III) detecting dynamics shifts in core relationship constructs, and (IV) capturing temporal and spatial synchrony between partners within dyads. We hope that these examples prove useful to scholars as they consider the new ways in which nonlinearity can be applied to their own scientific work and help advance relationship science.

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**References**


*papers that appear in this special issue.*