Relationships as Regulatory Systems

Katherine S. Zee

Submitted in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
under the Executive Committee
of the Graduate School of Arts and Sciences

COLUMBIA UNIVERSITY

2021

ABSTRACT

Relationships as Regulatory Systems

Katherine S. Zee

Interpersonal relationships are among the most important contributors to health and well-being. This dissertation investigates how and why relationships confer such benefits and proposes that relationships function as dynamic regulatory systems that enable people to cope effectively with challenging situations and pursue important goals. Across five Chapters, this work reveals the role of relationships in scaffolding effective individual self-regulation, dyadic coregulation (how partners dynamically modulate each other's responses and regulate as a unit), and developmental regulation (adaptation to age-related challenges across the lifespan), particularly in the context of social support interactions. Chapter 1 introduces past research on the importance of social relationships, summarizes the rationale for focusing on social support interactions as a key context in which interpersonal regulation occurs, and presents an overview of the research and methods discussed in this dissertation. Chapter 2 investigates the role of social support in promoting effective *self-regulation* by conceptualizing, validating, and testing a new theoretical construct, Regulatory Effectiveness of Social Support (RES). RES proposes that recipients benefit from social support to the extent that it addresses their motivations to understand and manage their situation. In eight studies and a meta-analysis, this chapter reveals that receiving social support higher on RES predicts downstream outcomes that are important for effective self-regulation. Chapter 3 examines how social support interactions give rise to dyadic *coregulation*—dynamic coupling of partners' physiological states. Results from this chapter demonstrate that social support interactions may be a context in which such coregulation is especially likely to occur, in order to help partners return to an equilibrium of responding, and underscore the importance of considering how dyads regulate as a single, interdependent unit. Chapter 4 presents preliminary evidence for how coregulation among older couples might influence *developmental regulation.* This chapter shows how between-dyad differences in coregulation processes in turn predict individual self-regulation processes in the face of a stressor. Chapter 5 synthesizes findings across chapters and highlights new avenues for future research. Overall, these findings suggests important self- and coregulatory implications of social support interactions, which may be a crucial mechanism through which interpersonal relationships influence health and well-being over time.

Contents

List of Tables

List of Figures

Acknowledgements

What better way to introduce this dissertation on the importance of relationships and social support than to acknowledge the many people who have given me such tremendous support, guidance, and kindness throughout this journey.

First, to my outstanding advisors, Niall Bolger and Tory Higgins: Thank you for embodying how to be both world-class scholars and incredibly nice people.

Niall, you have fundamentally changed the way I think about research and, especially, about data. Thank you for opening my eyes to this exciting new world and inviting me to tag along for so many statistical adventures, from random effects, to Bayes Factors, to dynamical systems, and more. What a gift. I hope this is just the beginning.

Tory, you have shown me first-hand the power of theory. Thank you for reminding me to always take the work seriously. I have appreciated your open-mindedness and enthusiasm, ever since our first conversation way back when (about ballet and regulatory focus, of all things!). To use your phrase, it's been magic!

Thank you to my committee: Colin Leach, Kevin Ochsner, and Eli Finkel. Colin, thank you for always asking the hard questions. Working with you has sharpened my writing and my thinking. Kevin, thanks for exemplifying how to bridge disciplines and teaching me how to communicate my work. Eli, thank you for showing me early on what a great research program on relationships and self-regulation looks like.

I am indebted to the many hardworking and talented undergraduate and post-baccalaureate students who so generously contributed their time and efforts to this research. Thank you for teaching me so much.

I would also like to thank my wonderful collaborators and mentors from the last 10 years, in particular Justin Cavallo, Madoka Kumashiro, Joy McClure, David Weiss, and Bert Uchino. It has been an honor to work with you, and I am a better scientist for it.

To my fellow grad students at Columbia, having the opportunity to learn alongside you has been so special. Michelle VanTieghem, I couldn't imagine starting grad school with a better cohort buddy. Thank you for reading a million drafts of my Specific Aims, taking yoga breaks with me, and lending an ear whenever I needed one. To my Couples Lab and Higgins Lab "siblings"—Megan Goldring, Federica Pinelli, Emily Nakkawita, Marika Yip-Bannicq, and Ana DiGiovanni—you are effective social support personified. Mark Conley, thanks for the humor and the perspective. Becca Mohr, Travis Riddle, Maneeza Dawood, Dara Huggins, Sydney Krueger, Jocelyn Shu, Matti Vuorre, and many others: Thanks for your camaraderie and for being great teachers and co-TAs.

I am grateful to Maya Rossignac-Milon and Kaytee Turetsky, two of the most brilliant researchers and best humans I know. Maya, thank you for all you have taught me about relationships, both academically and personally. Kaytee, thanks for broadening my horizons and being a sounding board, no matter how small or big the issue.

Finally, thank you to my amazing family for cheering me on every step of the way.

Dedication

To M. and G.

Chapter 1: Introduction

Playwright Euripides is credited with saying, *"Life has no blessing like a wise friend."* These words from thousands of years ago continue to ring true today. Decades of research from psychology and other disciplines have consistently pointed to the importance of social relationships for health and well-being, to the degree that an absence of such relationships poses health risks on par with smoking (Holt-Lunstad, Smith, & Layton, 2010).

Despite clear evidence that relationships matter for well-being, critical open questions remain: *How* and *why* relationships do confer these benefits? Past research has suggested factors such as relationship satisfaction (Robles, Slatcher, Trombello, & McGinn, 2014; Slatcher & Selcuk, 2017), belonging (Baumeister & Leary, 1995), and stress-buffering (S. Cohen & Wills, 1985) as possible contributors. Yet, there has been increasing awareness that close relationships can do more than satisfy basic needs (Finkel, Cheung, Emery, Carswell, & Larson, 2015). They can also serve as powerful self-regulatory forces that enable people to cope effectively with challenging circumstances and pursue important goals.

With roots in earlier work on interdependence in relationships (Rusbult & Van Lange, 2003), such perspectives have highlighted that individuals do not self-regulate in isolation. Instead, their self-regulatory efforts are tightly linked to their interpersonal context. Close others can shape how people regulate their emotions (Reeck, Ames, & Ochsner, 2016), pursue goals individually and together (Fitzsimons, Finkel, & VanDellen, 2015; Rusbult, Kumashiro, Kubacka, & Finkel, 2009), engage in coping behaviors (Thoits, 1986), and even regulate as a single, dyadic unit (Butler & Randall, 2013). Collectively, such work suggests that relationships function as *regulatory systems*, in which partners influence each other's emotions, physiology, and goals and dynamically coordinate to manage challenging circumstances. This could ultimately contribute to beneficial effects of relationships over time.

Overview of Dissertation Research

This dissertation forwards this notion by proposing that social support interactions are a primary context in which the self-regulatory and coregulatory influence of relationships is revealed. This focus on social support interactions is theoretically relevant and supported by previous research. Social support interactions[1] are often characterized by heightened regulatory needs, such as the need to alleviate one's

[1]Past research has proposed two ways that social support is linked to longer-term outcomes: *perceived support* and *enacted support* (also known as *enacted support*) (Rafaeli & Gleason, 2009; Uchino, 2009). As discussed in greater detail in the following chapters, *perceived support* refers to people's general perceptions that support is available to them from relationship partners should the need for it arise, and *enacted support* refers to specific helping behaviors (e.g., advice, reassurance) given in response to a particular problem or situation. This dissertation focuses on enacted social support, as this is a context in which recipients'

negative mood or perform well on a demanding task or goal (Feeney & Collins, 2015; Reeck et al., 2016; Rimé, 2009; Rusbult et al., 2009). Social support also occurs in a range of interpersonal relationships, from romantic relationships, to friendships, workplace relationships, and more. Thus, studying social support can offer insights into relationships and regulation processes more broadly, as they unfold in many interpersonal contexts. Moreover, because receiving social support can be both beneficial and detrimental for recipients (Bolger & Amarel, 2007; Bolger, Zuckerman, & Kessler, 2000; Gleason, Iida, Shrout, & Bolger, 2008; Rafaeli & Gleason, 2009; Uchino, 2009), I can capitalize on the variability in the support process to understand what kinds of support behaviors and responses within a dyad might lead to self-regulatory benefits.

Thus, this research investigates the role of relationship partners and social support interactions in fostering effective individual self-regulation (Chapter 2), dyadic coregulation (Chapter 3), and developmental regulation (managing age-related changes across the lifespan; Chapter 4). Collectively, these streams of research offer evidence for how relationships function as regulatory systems and ultimately contribute to important benefits over time.

Chapter 2: Relationships and Self-Regulation

Chapter 2 reviews theory and empirical evidence on effective social support and presents a new theoretical construct: Regulatory Effectiveness of Support (RES). RES proposes that receiving social support that addresses recipients' *self-regulatory* needs to understand their situation (*truth*) and to feel in control of their situation (*control*) is most beneficial for recipients, and is especially important for promoting support outcomes that have implications for effective self-regulation, such as better mood regulation, coping, and motivation to persist on challenging tasks. Across eight studies and a meta-analysis aggregating across studies, Chapter 2 demonstrates the role of RES in predicting social support benefits. This work further reveals how the effects of RES differ from the effects of perceived responsiveness, a relationship construct that captures the degree to which a partner conveys caring, validation, and understanding (Reis, Clark, & Holmes, 2004) but that is not about self-regulatory needs. These results highlight the importance of providing support so that it addresses recipients' self-regulatory needs for truth and control. This work offers novel insights into theories proposing the importance of tailoring support to recipients' needs generally by revealing specific needs that matter in support contexts and their implications for recipients.

self-regulatory needs are typically heightened and in which interpersonal regulation attempts occur.

Chapter 3: Relationships and Dyadic Coregulation

Chapter 3 examines dyadic coregulation—dynamic bidirectional emotional linkage between partners that enables them to maintain or restore an equilibrium level of responding. Specifically, Chapter 3 investigates an important open question: When is coregulation likely to occur? Social support interactions are typically characterized by explicit interpersonal regulation attempts designed to help a distressed person return to a calmer state. Therefore, they might be especially likely to engender physiological coregulation between partners, compared with other types of dyadic interaction that involve interdependence (i.e., a discussion of a joint goal) but that do not involve these heightened regulation needs. This chapter investigates the emergence and patterns of physiological coregulation during couples' laboratory discussions and uses dynamical systems modeling to quantify coregulation. This approach models the frequency of oscillations and changes in amplitudes towards an equilibrium level and cross-partner influence in these processes. Results suggest that stabilizing patterns of coregulation (patterns of dynamic trajectories that pull partners' responses towards an equilibrium level) were more apparent during social support (vs. control) discussions and were especially pronounced when the male partner received support. There was also substantial between-dyad heterogeneity in couples' physiological trajectories, with some couples showing strong coregulatory influence and others showing little coregulatory influence. Thus, these results suggest that close dyads can regulate as a single, interdependent unit at the physiological level, which may have important implications for how relationship partners contribute to health and well-being over time.

Chapter 4: Relationships and Developmental Regulation

Chapter 4 examines links between coregulatory and self-regulatory processes as a way to gain insights into how relationships contribute to *developmental regulation*—adaptation to age-related changes across the lifespan. Although a traditional focus of research on aging and lifespan development has centered on how individuals influence their own development (e.g., via aging attitudes, lifestyle behaviors), there is increasing awareness of the role that relationship partners play in supporting developmental regulation. Chapter 4 investigates dyadic interactions among older couples and tests possible implications of dyadic coregulation for individual self-regulation. This study examined physiological coregulation dynamics as older couples completed a non-support control discussion and then a social support discussion as one partner prepared to deliver a stressful speech. With age, people tend to be more physiologically reactive to acute stressors (Charles, 2010; Uchino, Holt-Lunstad, Bloor, & Campo, 2005), thus an aspect of developmental regulation involves finding ways to manage this reactivity. Results suggested that, on average, couples showed greater *codysregulation* during the support discussion in anticipation of the speech, consistent with prior work indicating that people become more physiologically reactive to stressors with age. However, variability in how cross-partner coregulatory influence changed between the two discussions had important implications for how older adults coped with the stressor: Among dyads show who showed smaller increases in codysregulation during the support discussion, individual partners, in turn, showed calmer self-regulation trajectories during the stressful speech. This is some of the first evidence, to our knowledge, to demonstrate how differences in dyadic coregulation subsequently predict differences in individual *self*-regulation in adulthood. Coregulation between partners might be a key way that relationship partners help older adults compensate for age-related challenges and ultimately contribute to healthy aging.

Chapter 5: Implications and Conclusions

Chapter 5 presents a synthesis of the findings and implications from across these streams of research. Chapter 5 highlights new research questions made possible by considering findings this dissertation in concert and concludes by underscoring the contributions of this work to multiple literatures.

Overview of Methods

Investigation of these questions was accomplished with a multi-method approach, using a combination of naturalistic and experimental approaches, studies of real relationship partners participating together, physiological measures, and statistical methods.

Dyadic Designs

First, I make use of several dyadic study designs. In Chapters 2, 3, and 4, I examine social support interactions among romantic couples and friend pairs in a laboratory setting. Studying real relationship partners together allows for inferences about social support occurring in meaningful social contexts. Furthermore, Chapters 3 and 4 use dyadic experimental designs to investigate coregulation processes, which capture the coordination of the dyad as a whole. Having dyads engage in different types of discussions made it possible to compare within-dyad changes in patterns of coregulation across contexts to sharpen our inferences about the role of social support.

Intensive Longitudinal Methods

This work leverages intensive longitudinal methods through both daily diary data and repeated-measures cardiovascular data. Intensive longitudinal methods are valuable because they allow for examination of within-person (or within-dyad) change (Bolger & Laurenceau, 2013). Through the use of daily diary methods, these results can also speak to how support from a close relationship partner might relate to self-regulation relevant support outcomes in participants' everyday lives.

This work also makes use of intensively sampled psychophysiological assessments, specifically repeated-measures cardiovascular data. The inclusion of cardiovascular data can help to draw more direct connections to the potential implications of relationships for health as well as provide real-time, moment-to-moment insights into participants' responding as they interact naturally.

In addition to permitting inferences about within-subject processes, intensive longitudinal methods can also reveal the extent of *between-subject heterogeneity* in these processes (Bolger & Zee, 2019a; Bolger, Zee, Rossignac-Milon, & Hassin, 2019). This dissertation capitalizes on this feature of intensive longitudinal data in several ways. First, in studies with intensive longitudinal data, I provide follow-up tests and subject-specific visualizations to reveal the extent of heterogeneity in our effects. This can help to reveal the generalizability of results and signal the presence of important moderating variables, which can be examined in future work. Second, I also translate similar logic regarding heterogeneity to meta-analyze results across studies in Chapter 2, by modeling heterogeneity due to both studies and outcomes. Third, in Chapter 4, I use between-subject heterogeneity in coregulation processes to explain between-subject heterogeneity in individuals' self-regulation processes when facing a laboratory stressor—a research hypothesis and statistical analysis made possible only through the use of intensive longitudinal methods.

Bayesian Estimation

For all predictive models, I analyzed data using Bayesian estimation with the *brms* package for R (Burkner, 2017). This involves a computational approach known as Markov Chain Monte Carlo, which performs estimation by using an iterative process to generate a distribution of potential values. Thus, Bayesian models generate a distribution of possible parameter values (referred to as the posterior distribution), and this distribution can be used to obtain credibility intervals (typically 95% intervals). For all Bayesian analyses, I used the default settings of *brms*. I used noninformative, default priors (unless otherwise noted), which typically yield results very similar to those that would have been obtained using the Frequentist approach.

Bayesian inference involves using the posterior distribution to capture uncertainty regarding parameter values of hypothesized effects given the data, which is accomplished using a probability distribution. In contrast, Frequentist inferences are about the probability distributions of datasets given a hypothesis. In short, a primary difference between Bayesian statistics and the Frequentist statistics is that Bayesian statistics allow one to draw probability-based inferences about the evidence in favor of a particular effect. In addition to benefits around ease of interpretation, using Bayesian estimation was also necessary for the present investigations due to its facility in handling random effects (subject-specific intercepts and slopes when working with repeated-measures data), which enabled me to model the appropriate random effects to adequately capture real-world variability in our results for multiple studies.

Ultimately, analyzing data with a Bayesian framework uniquely allowed me to test hypotheses about patterns of effects involving multiple model parameters and to conduct specialized analyses to understand the extent of heterogeneity in our effects. I did this by using Bayesian model comparison approaches and tests aggregating samples from the posterior distributions to estimate the probability of particular combinations of effects. These approaches are only possible using a Bayesian framework and have offered the chance to gain novel insights into our results that would not have been feasible using conventional statistical approaches.

Dynamical Systems Modeling

Lastly, Chapters 3 and 4 apply dynamical systems modeling to assess self- and coregulation processes. Dynamical systems models are statistical translations of regulation processes (Boker, 2012). In particular, I use the damped oscillator model, which features parameters that directly capture aspects of a regulation process: They include parameters for *cycling* (the frequency of oscillations around an equilibrium level) and *damping* (changes in amplitudes over time). These models can also include parameters to capture cross-partner influence in dyads, which collectively suggest patterns of coregulation (Boker & Laurenceau, 2006). These models can reveal moment-to-moment dynamic changes in dyads' regulation processes, such as how partners entrain each other's responses towards an equilibrium level or disrupt each other's responses and push each other away from equilibrium (Butler & Barnard, 2019). Ultimately, relative to traditional linear models assessing interpersonal linkage (Butler & Randall, 2013), these models are essential to the present investigations because they enable more nuanced and hypothesis-driven insights about the nature of self- and coregulation in relationships.

Chapter 2: Social Support and Self-Regulation

Abstract

Receiving social support can entail both costs and benefits for recipients. Thus, theories of effective support have proposed that support should address recipients' needs in order to be beneficial. This paper proposes the importance of support that addresses recipients' *self-regulatory* needs. We present a novel construct—Regulatory Effectiveness of Support (RES)—which posits that support that addresses recipients' needs to understand their situation (*truth*) and to feel capable of managing their situation (*control*) will engender support benefits. We hypothesized that receiving support higher on RES would predict beneficial support outcomes. We further hypothesized that these effects would be especially pronounced for self-regulation relevant outcomes, such as better mood and increased motivation, which, in turn, can be important for successful self-regulation. We established the construct validity of RES and then investigated its effects in daily life and in laboratory support discussions. In eight studies and a meta-analysis pooling across studies, results showed that RES predicted self-regulation relevant support outcomes, and these effects of RES were stronger than the effects of perceived responsiveness, a construct that is known to enhance interpersonal relationships. Furthermore, RES was linked to self-regulatory success: Participants who received support higher on RES were more motivated to perform well on a stressful speech, which subsequently predicted better speech performance. These findings enhance knowledge of effective social support by underscoring the importance of addressing recipients' self-regulatory needs in the support process[2].

[2]This chapter was previously published in Zee, K. S., Bolger, N., & Higgins, E. T. (2020). Regulatory effectiveness of support. *Journal of Personality and Social Psychology.* Advance online publication. https://doi.org/10.1037/pspi0000235. Some content has been revised for the purposes of this dissertation.

Introduction

Interpersonal relationships can be a source of practical and emotional help (social support) in times of difficulty and beyond. Indeed, perceiving that others are available for support should the need arise (known as *perceived support*) has been consistently linked to health benefits (Uchino, 2009). However, support that is actually received in response to a specific situation (known as *received support* or *enacted support*) is not always effective, and the implications of such support for well-being are less clear (Uchino, 2009). Although overt support can sometimes benefit recipients (Feeney & Collins, 2015), it can also worsen recipients' distress and undermine their coping efforts (Bolger & Amarel, 2007; Bolger et al., 2000).

In light of these mixed effects of enacted support, there is a pressing need to reveal features of enacted support that benefit recipients and to understand how they might ultimately contribute to well-being. To this end, this paper presents a new theoretical construct: Regulatory Effectiveness of Support (RES). RES posits that enacted social support benefits recipients to the extent that it addresses their self-regulatory needs to better understand their situation (*truth*) and to feel capable of managing their situation (*control*). RES further posits that support that addresses these self-regulatory needs will give rise to psychological states and behaviors that, in turn, can help recipients engage in effective self-regulation.

The present paper synthesizes theories of social support and self-regulation to present the theoretical foundation for RES, tests the validity of RES, and examines the effects of RES in daily life and dyadic support discussions. We hypothesized that RES would emerge as a unique construct and predict beneficial support outcomes; in particular, outcomes such as better mood and increased motivation that can have downstream implications for successful self-regulation, such as enhanced performance. Finally, we predicted that the effects of RES would be independent from responsiveness, a construct frequently used to assess the quality of enacted support. Overall, this work reveals the importance of addressing recipients' *self-regulatory* needs in the support process.

What Makes Enacted Support Effective?

It has been proposed that social relationships might benefit well-being over time because enacted support from relationship partners can buffer individuals from the negative effects of stressful experiences (e.g., Uchino, Cacioppo, & Kiecolt-Glaser, 1996) and shape perceptions of support availability, which have consistently been linked to health benefits (Uchino, 2009). Yet, empirical evidence for benefits of enacted support has been mixed. Several lines of research have proposed that the question of whether social support is beneficial versus costly may be explained by how well the support is able to address recipients' needs

(Cutrona, 1990; Rini & Dunkel Schetter, 2010; Rini, Dunkel Schetter, Hobel, Glynn, & Sandman, 2006). Broadly, these theories, termed theories of support matching, have proposed that the more support is attuned to recipients' needs, such as their need for a specific type or quantity of support, the more it will benefit them (Cutrona, 1990; Cutrona, Shaffer, Wesner, & Gardner, 2007; Rini & Dunkel Schetter, 2010).

Insight into effective enacted support also comes from perceived responsiveness, which refers to perceptions that a relationship partner "attends to and reacts supportively to central, core defining features of the self" (Reis et al., 2004, p. 203). Perceived responsiveness plays an important role in fostering relationship benefits, such as intimacy, and has been examined in a variety of interpersonal contexts (Reis & Gable, 2015). Although perceived responsiveness is not a type of support, it has nevertheless emerged as an important component of effective enacted support (Maisel, Gable, & Strachman, 2008), such that it can mitigate the costs associated with overt support attempts (Maisel & Gable, 2009).

Which Needs Matter in Social Support Contexts?

As such work suggests, providing support so that it addresses recipients' needs may play a pivotal role in determining its effectiveness. However, several open questions remain. First, most theories of support matching have stressed the importance of attending to recipients' needs in a broad sense, or have discussed needs in regards to a specific type or quantity of support. However, if support must address recipients' needs to be beneficial, a theoretical framework specifying *which needs* matter in support contexts is necessary.

Second, it is unknown whether the potential benefits of receiving support that is tailored to particular needs are distinct from the benefits of receiving good quality support in general (e.g., support that is given in a caring manner) or from the benefits of receiving support that addresses other kinds of needs. Support outcomes may look different depending on which needs the support has addressed. For example, enacted support that addresses the recipient's need for care and positive regard may play a critical role in fostering feelings of closeness between the recipient and provider, as it may help the distressed person feel accepted and loved. However, it might play a lesser role in promoting the recipient's efforts to cope if it has not addressed the recipients' feelings or cognitions regarding the problem itself.

Despite the potential importance of giving the right type of support, it is also possible that recipients have needs that can be addressed effectively by multiple types (and subtypes) of support in a particular context. For example, when dealing with a demanding group project, a support recipient might need assistance reframing the situation so that it seems less demanding, but not necessarily need or want validation of her negative evaluation of the situation. Importantly, reframing and validation are both instantiations of emotional support. As this example illustrates, however, even if a support attempt involves emotional support, more specificity about the recipient's underlying concerns (e.g., to understand the situation better *vs.* to feel listened to) is necessary in order to address them properly. Providing validation, although a form of emotional support, would not necessarily address the recipient's needs in this context.

Further underscoring the need for more theorizing in this area, the evidence for matching support by type has been mixed. For example, one study found that the effects of matched support (informational support provided in response to requests for information) and mismatched support (emotional support provided in response to requests for information) on perceptions of responsiveness were both positive, and these effects did not differ significantly from each other (Cutrona et al., 2007). This is also consistent with additional work suggesting that emotional support was viewed as more helpful even when tangible support was needed (Cutrona, Cohen, & Igram, 1990). This suggests that there may be additional ways of addressing recipients' needs that are independent from or not captured by support type alone.

Addressing Recipients' Self-Regulatory Needs

One approach that has not been emphasized traditionally in theories of effective social support is addressing recipients' *self-regulatory needs*, which refers to attending to recipients' motives and goals. Recent research has begun to demonstrate the importance of addressing recipients' self-regulatory needs in social support contexts. For example, one investigation found that the benefits of invisible (indirect) and visible (direct) social support depended on the recipient's self-regulatory orientation (Zee, Cavallo, Flores, Bolger, & Higgins, 2018). Prior work had found that visible support is generally costly for recipients because it undermines their sense of competence (Bolger & Amarel, 2007). Consistent with this, Zee and colleagues (2018) found that invisible support, but not visible support, was a match for recipients with a predominant assessment self-regulatory orientation, who are concerned with measuring up to evaluative standards. In contrast, invisible support was not a match for recipients with a predominant locomotion self-regulatory orientation, who are concerned with taking action and moving to a new state as swiftly as possible. Instead, visible support was a match. Importantly, these effects persisted even when accounting for perceived responsiveness. Other lines of research have also found beneficial effects of addressing recipients' self-regulatory needs, such that receiving support that better addressed recipients' self-regulatory needs subsequently predicted mood improvement (Cavallo, Zee, & Higgins, 2016).

Newer theoretical perspectives also suggest the importance of addressing self-regulatory needs in the support process. Such work has proposed that enacted support can do more than buffer stress responses;

it can also help people thrive through adversity, such as overcoming challenges or persisting in the face of difficulty (Feeney & Collins, 2015). These features of support imply that support may enable recipients to self-regulate more effectively, such as by increasing their motivation and helping them to successfully pursue goals.

Self-Regulatory Needs: Truth and Control

Such findings provide preliminary evidence for the importance of addressing recipients' self-regulatory needs in engendering beneficial support outcomes. To assess whether support has addressed recipients' self-regulatory needs, however, it is necessary to have a framework for understanding which needs are important in the first place.

We integrated advances in motivation and self-regulation research to answer this question. Higgins's (2012, 2018) theory of self-regulatory effectiveness broadly posits that people are motivated by more than the pursuit of desired outcomes and the avoidance of undesired outcomes; they are also motivated to feel effective in their life pursuits. This is accomplished by enhancing their understanding of their situation (addressing their need for *truth*) and by feeling able to manage their situation (addressing their need for *control*).

This theory also specified the importance of *value* effectiveness (obtaining desired outcomes)[3]. An important feature that distinguishes value from truth and control is that it is about outcomes or endpoints, whereas truth and control are about a *process*, that is, *how* a particular endpoint is achieved. The three types of effectiveness are related in that experiencing truth and control effectiveness can enable recipients to achieve their desired outcomes (value effectiveness). For these reasons and due to our interest in support *processes*, we focused our discussion and investigations on truth and control.

In addition to identifying truth and control and their role in contributing to feelings of effectiveness, several programs of research have found that the combination of high truth and high control can lead to successful goal pursuit, including performance (Higgins, 2012, 2018; Pierro, Chernikova, Lo Destro, Higgins, & Kruglanski, 2018). Truth and control are both necessary for performing well on complex tasks (Chernikova et al., 2016; Higgins, 2012, 2018; Pierro et al., 2018). Moreover, even if truth and control do not directly give rise to a desired outcome, experiencing truth effectiveness and control effectiveness can be motivating in

[3]In our earlier theorizing about Regulatory Effectiveness of Support (RES), we included a value facet to reflect Higgins's theory. However, our current theorizing on RES only encompasses truth and control for several reasons. First, as noted above, truth and control reflect a process, whereas value does not. Because our goal was to understand features of the support process leading to beneficial outcomes, focusing on the process-oriented aspects of the theory was warranted. Second, in the course of carrying out this work, newer research emerged which demonstrated the importance of high truth and high control. Such work generally indicated the benefits of experiencing high truth effectiveness and high control effectiveness for goal pursuit, performance, and health behaviors—the types of downstream self-regulatory outcomes that are relevant to social support and of interest in our investigation.

its own right: This creates a self-regulatory force that increases motivation, which in turn can increase the likelihood of successful goal pursuit and attainment (Higgins, 2018).

Regulatory Effectiveness of Support: Addressing Truth and Control

We reasoned that addressing truth and control needs might also be important in the context of enacted support given that concepts similar to truth and control have been shown to predict beneficial support outcomes in prior work, as we discuss below. We developed a construct capturing the degree to which enacted support addresses these self-regulatory needs: Regulatory Effectiveness of Support (RES). RES posits that enacted support benefits recipients to the extent that the support addresses their self-regulatory needs to understand their situation (truth) and to feel capable of managing the situation (control).

In line with this premise, prior research has identified features of effective enacted support that reflect truth and control. Regarding truth, support providers can offer information or appraisals that clarify or change recipients' understanding of the problem. Concepts related to truth are known to be important for enacted social support. Although work on stress appraisals and emotion regulation strategies, such as cognitive reappraisal, are frequently studied as intra-individual processes (Folkman, Lazarus, Dunkel Schetter, DeLongis, & Gruen, 1986; Gross & John, 2003), they can also be accomplished via social support (S. Cohen, Sherrod, & Clark, 1986; Marroquín, 2011; Pauw, Sauter, Kleef, & Fischer, 2017; Reeck et al., 2016; Zaki & Williams, 2013). This overlaps with experiencing truth effectiveness due to an emphasis on changing one's interpretation of a negative experience. Furthermore, it is known that changing one's understanding of a problem can promote coping and lessen negative affect (Folkman et al., 1986; Gross, 2002), and receiving support can help individuals obtain this changed understanding (Rimé, 2009; Thoits, 1986). Researchers have also proposed that in order for social support interventions to be successful, they will need to enhance people's understanding of the problem they are facing through cognitive modification (Cutrona & Cole, 2000).

Regarding control, effective support can boost recipients' feelings of competence (Bolger & Amarel, 2007; Howland & Simpson, 2010). For instance, when people are experiencing low self-efficacy, explicit social support can help them to restore their self-efficacy, which in turn reduces stress (Crockett, Morrow, & Muyshondt, 2016). Related to this, perceived threats to recipients' efficacy are a primary reason that explicit support attempts sometimes fail. Control is congruent with this explanation of support's costs. Recipients may interpret that the reason they are being helped is that the provider views them as incapable of managing the situation, thereby undermining their sense of efficacy (Bolger & Amarel, 2007; Fisher, Nadler, & Whitcher-Alagna, 1982; Newsom, 1999). In contrast, support that enhances recipients' sense of efficacy leads to more positive outcomes, such as reduced distress (Bolger & Amarel, 2007). These and other findings suggest that, to make support effective, the support needs to help recipients feel that they are able to manage the situation.

Relation of Regulatory Effectiveness of Support to Existing Theories of Support

Regulatory Effectiveness of Support (RES) offers a new theoretical construct to illuminate components of beneficial enacted support and to generate predictions regarding support outcomes and downstream implications of receiving support that addresses recipients' self-regulatory needs. In this section, we briefly outline the relation of RES to existing theories of enacted support and highlight ways in which RES differs from these theories. We acknowledge that this is not an exhaustive discussion of enacted support theories, and we do not discuss theories of perceived support due to our focus on enacted support.

Theories of support matching have proposed that support should be matched to recipients' needs in order to be effective. While several theories touch on the notion of matching, we consider two theories in particular. The first is Cutrona and colleagues' Optimal Matching model (Cutrona, 1990). Empirical investigations of this model have emphasized the importance of matching support by type, such as the provision of informational support in response to requests for information and emotional support in response to emotional disclosures (Cutrona et al., 2007). The second is Rini and Dunkel Schetter's Support Effectiveness Model (Rini & Dunkel Schetter, 2010; Rini et al., 2006). This model specifies several dimensions of effective support. Because providing the right type and quantity of support are included in these dimensions, it can also be considered a support matching theory. RES is compatible with these and other matching theories in its emphasis on addressing recipients' needs, but it is distinct from these theories in its emphasis on *self-regulatory* needs.

Relatedly, work on support types developed to understand mechanisms through which enacted support might benefit recipients. Some common types of support that have been discussed include emotional support, informational support, and tangible support. RES proposes the importance of addressing recipients' need for truth effectiveness and control effectiveness, but it is agnostic regarding the support types or behaviors through which this is accomplished. Emotional support could be enacted in such a way that it addresses control effectiveness (e.g., reassurance about one's ability to manage the problem) and/or addresses truth effectiveness (e.g., reappraising the situation), but it could also be enacted in a way that it addresses neither of these needs. Thus, knowing what type of support was given does not necessarily reveal the degree to which such support addressed recipients' truth and control needs. For example, if an emotional support attempt only entailed validating the recipients' negative feelings, it would not have addressed the recipient's self-regulatory needs for truth and control. For these reasons, support types can be thought of as tactics that may be used in the service of addressing truth and control. However, support types alone do not necessarily elucidate how well recipients' self-regulatory needs were addressed.

Other perspectives have emphasized the notion of skillful support (Bolger et al., 2000; Rafaeli & Gleason, 2009; Zee & Bolger, 2019). In particular, autonomy support may be considered one form of skillful support. Autonomy support, which stems from Self-Determination Theory, gives the recipient agency in dictating how a support interaction unfolds. This involves allowing recipients to freely express themselves and providing help that respects the recipient's sense of self (Ryan & Solky, 1996; Weinstein, Legate, Kumashiro, & Ryan, 2015). Although there are some surface level similarities between autonomy support and the control facet of RES, they differ in an important way: While autonomy support is about allowing recipients to exert control over the *support process*, the control facet of RES is about allowing recipients to experience a greater sense of efficacy in their ability to manage *the problem or situation itself.* In addition, work on autonomy support does not include the notion of truth per se, which further differentiates RES from this construct.

Contemporary support theories have expanded the field's understanding of the relevance and function of social support. Work by Feeney and Collins (2015) has proposed that social support does more than simply buffer the negative effects of stressful experiences; support can play a role in enabling individuals to thrive through adversity and to engage in life's opportunities beyond adversity (e.g., becoming one's ideal self). This work also highlights the function of support in "helping others to emerge from the stressor in ways that enable them to flourish" and "developing close other's strengths and abilities relevant to coping with the adversity." This is congruent with RES in its emphasis on support as a process that helps recipients to feel effective in regards to the situation they are facing.

It is also noteworthy that this theory explicitly highlights perceived responsiveness as a component of effective enacted support. However, additional components are also proposed: fortification, reframing, reconstruction, and persistence. To our knowledge, specific constructs and measures for assessing these support functions do not presently exist. RES can help to address this gap, although it was not developed for this purpose. Processes such as fortification involve bolstering the recipient's ability to manage the stressor, which is related to control. Processes such as reframing and reconstruction involve altering the recipient's understanding, which is related to truth. When truth and control motives are both addressed, this helps the recipient to feel more effective and in turn persist in the face of challenges.

Lastly, recent perspectives have highlighted the role of enacted support as an interpersonal emotion regulation strategy (Williams, Morelli, Ong, & Zaki, 2018; Zaki & Williams, 2013), which may explain links between social support and depression (Marroquín, 2011). RES is consistent with such theories, but also proposes that support that addresses truth and control can help engender downstream outcomes beyond emotion regulation, such as performance.

Relation of Regulatory Effectiveness of Support to Perceived Responsiveness

Importance of Perceived Responsiveness in Social Support Literature

Notably, perceived responsiveness (PR) is a common thread linking many of these theories of enacted support. As discussed above, responsiveness is related to theories of support matching in its emphasis on attending to recipients' needs. Indeed, responsiveness has been used as an outcome measure to assess support matching effects in prior empirical work (Cutrona et al., 2007). It is also implicated in the notion of skillful support (Maisel & Gable, 2009; Rafaeli & Gleason, 2009), although see Neff & Karney (2005) for a perspective that differentiates between skillfulness and responsiveness. Moreover, some work has highlighted common origins of autonomy promotion (central to autonomy support) and responsiveness (Cutrona & Russell, 2017).

In addition, PR has been frequently considered in work on social support over the last several years, especially in social psychology. To illustrate, we examined papers on social support published in the Interpersonal Relations and Group Processes section of the *Journal of Personality and Social Psychology* between 2009 and 2018. Of the 18 papers on social support[4], 13 (72%) referred to the notion of responsiveness in some capacity, and 6 (33%) reported including a measure of responsiveness. These statistics underscore the importance and relevance of responsiveness in the social support literature over the last decade.

Perceived Responsiveness as a Comparison Construct

Due to the relevance and importance of PR in the social support literature, we focused on PR as a comparison construct. PR provides a useful comparison for RES because it was developed as a construct capturing the quality of interpersonal processes and taps into how well a partner attends to one's needs, but was not developed to address questions regarding self-regulatory processes per se. As such, in contrast to RES, PR should predict outcomes that have downstream implications for relationship processes and relationship quality (Reis & Gable, 2015), but may not necessarily predict outcomes that are related to downstream

[4] A paper was classified as being about social support if it listed "social support" or a related term (e.g., "advice") as a keyword, or if it clearly discussed support in the abstract even if it did not include support as a keyword (e.g., a paper on secure base interactions was counted as a support paper). Nineteen papers fit this description, but one paper was excluded from consideration because it was about perceived social support from pets, leaving 18 papers.

self-regulation. For instance, although PR could contribute to mood improvement by making the recipient feel safe and cared for, it might not necessarily improve the recipient's feelings about the problem itself. Supporting this possibility, some findings have shown that support perceived to be high on responsiveness had much larger effects on positive relationship feelings than on negative mood and positive mood (Bar-Kalifa & Rafaeli, 2013). Furthermore, work by Rimé (2009) has suggested that support focused on validation and care is not associated with changes in altered stress appraisals; instead, such support is associated with social variables, such as greater feelings of social integration (for a review, see Rimé, 2009). This suggests that, as originally proposed (Reis et al., 2004), PR may play an especially important role in fostering relational benefits, and this may also apply in the domain of enacted support.

The Present Work

The goal of the present work was to develop a construct capturing the degree to which enacted support addresses recipients' self-regulatory needs and to examine its effects on recipients' support outcomes and downstream self-regulatory success. In Studies 1A, 1B, and 2, we developed and validated a self-report measure of Regulatory Effectiveness of Support (RES) and verified that this construct is distinct from perceived responsiveness (PR). We then examined the predictive and discriminant validity of RES by having participants report on a recent support receipt experience (Study 2) as well as support received in daily life (Studies 3-5) and dyadic laboratory interactions (Studies 6-7). Finally, we performed a meta-analysis pooling data across studies to gauge the overall effects of RES and to compare these effects to PR's effects. With these studies, we investigated three sets of hypotheses:

1. Construct Validity of RES

We hypothesized that RES would emerge as a valid construct, and that this construct would be empirically distinct from PR. Given the inherent interdependence of the truth and control components of self-regulatory effectiveness (Cornwell, Franks, & Higgins, 2014, 2015; Higgins, 2012; Higgins, Cornwell, & Franks, 2014), we also predicted that all RES items would load onto a single factor comprised of two facets: a truth facet and a control facet. We further hypothesized that RES would be strongly associated with perceptions of support effectiveness, thereby providing further evidence of construct validity. We also hypothesized that the effect of RES on perceptions of support effectiveness would be stronger than the effect of PR, as RES was developed specifically to assess the quality of enacted support and PR was developed as a broader construct not specific to enacted support.

2. Predictive Validity of RES

We hypothesized that RES would predict beneficial support outcomes. The outcomes we examined map onto outcomes proposed in a recent theoretical model of social support and thriving (Feeney & Collins, 2015). Such work has explicitly proposed that effective support should influence outcomes such as emotions, motivation, physiological responses, lifestyle behaviors, and relational outcomes (Feeney & Collins, 2015, p. 122). We also expanded this set of outcomes by also considering a marker of effective self-regulation, namely performance.

We anticipated that RES would be related to support outcomes that have been shown to be important for effective self-regulation (self-regulation relevant outcomes). Specifically, we hypothesized that RES would predict better mood regulation (higher positive mood and lower negative mood), coping, and motivation to perform well on demanding tasks, as these variables can be considered *indicators* that recipients feel effective. We then examined effects of RES on self-regulation directly, by assessing goal pursuit and performance (Studies 5 and 7). We also tested effects of RES on physiological responses (Study 7) and lifestyle behaviors (coping in Studies 3-5; sleep in Studies 4-5), reflecting the categories above. Lastly, we conducted an exploratory analysis to examine whether one such self-regulation relevant outcome—increased motivation—mediated the effects of RES on performance (Study 7).

3. Discriminant Validity of RES

Finally, we reasoned that if RES captures the degree to which support addresses recipients' *self-regulatory* needs, then it should be more strongly related to self-regulation relevant outcomes compared to a construct that captures attunement to recipients' needs but was not developed to address questions about self-regulatory processes per se. Thus, we predicted that RES would more strongly predict the self-regulation relevant outcomes discussed above compared to PR.

To assess another type of beneficial outcome not directly related to self-regulation processes, we also examined relational outcomes, specifically inclusion of the other in the self (IOS) and closeness. These variables were examined because they have been studied in prior investigations of support processes (e.g, Gleason et al., 2008) and are relevant to a variety of relationship types in which support often occurs (e.g., romantic relationships, friendships). As discussed in the meta-analysis, however, all of these outcome variables can be thought of as being sampled from a broader "population" of support outcomes.

Because PR has been identified as an important component of relationship development and maintenance (Reis & Gable, 2015) and because the theory from which RES was developed focuses on self-regulatory effectiveness, we predicted that PR would have stronger effects than RES on these relational variables.

Studies 1A & 1B

In Studies 1A and 1B, we sought to develop and validate a self-report measure of Regulatory Effectiveness of Support (RES). In Study 1B, we also examined whether RES could be psychometrically distinguished from perceived responsiveness (PR).

Methods

Participants

In both studies, participants were recruited from Amazon's Mechanical Turk as part of larger studies designed to examine multiple research questions. Participants were required to be involved in a romantic relationship of at least one year to be eligible to participate. Although this was a requirement for another part of the study that was unrelated to the present hypotheses, it had the incidental benefit of allowing us to hold constant the target person participants thought about when responding to our measures.

Sample Size Determination

Sample size determinations were made in regards to several research questions. There were 392 participants in Study 1A. However, 24 participants failed an attention check and were removed prior to analysis. This left a final sample of 368 participants (142 male, 196 female, and 30 unspecified), who were 37 years old on average ($SD = 11.4$). They received $0.30 in exchange for their participation.

There were 198 participants in Study 1B. However, 21 participants failed an attention check and were therefore excluded. This left a final sample of 177 (79 male, 98 female), who were 37 years old on average ($SD = 11.3$). They received $2.50 in exchange for their participation.

Procedure and Materials

In both Studies 1A and 1B, participants responded to a variety of close relationship measures as part of a larger study. As these measures were administered in relation to other hypotheses and were not examined in regards to the present research question, they will not be discussed further. Relevant to the present research question, participants responded to measures of regulatory effectiveness of support (RES) and perceived responsiveness (PR; Study 1B only). Lists of the RES and PR items used across studies are presented in Table 1 and Table 2, respectively.

Regulatory Effectiveness of Support (RES)

Participants completed a self-report measure of RES that we created. Participants were asked to think about a recent time when they received social support from their romantic partner. This measure consisted of three items for each facet of RES (truth and control), for a total of 6 items. Participants indicated their responses along a scale ranging from 1 (*Not at all*) to 7 (*Extremely*). Items were grouped by facet and presented in blocks, and the presentation order of these blocks was randomized to guard against order effects. There were three items corresponding to the truth facet, or the extent to which receiving support enabled recipients to better understand the situation (e.g., *"The help my partner tried to give me left me with a better understanding of the situation"*). There were also three items corresponding to the control facet, or the extent to which receiving support helped participants to feel capable of managing the situation (e.g., *"The help my partner tried to give me made me feel on top of the situation"*).

Perceived Responsiveness (PR) (Study 1B only)

PR was assessed with a 12-item version[5] of the Perceived Responsiveness measure (Reis et al., 2018). This measure asked about participants' general perceptions of their partner's responsiveness using a scale ranging from 1 (*Not at all*) to 7 (*Extremely*). Examples of these items included, *"My partner values my abilities and opinions"* and *"My partner understands me"* ($\alpha = 0.98$).

[5]There were also additional perceived responsiveness items included in this study, for a total of 17 items. Although we present results based on the 12-item version for fidelity to a recently published version of the scale (Reis, Crasta, Rogge, Maniaci, & Carmichael, 2018), we note that including all 17 items yielded essentially the same results.

Table 1: Regulatory Effectiveness of Support items.

Item No.	Item
	Please think about the extent to which the interaction affected your understanding of the situation.
	The help my partner tried to give me
T1	...left me with a better understanding of the situation.
T2	...enabled me to see the situation in a new light.
T3	...helped me get some perspective on the situation.
	Please think about the extent to which the interaction affected how in control of the situation you felt.
	The help my partner tried to give me
C1	...made me feel on top of the situation.
C2	...enabled me to get back on track.
C3	...made me feel more confident about the situation.

Note:
T = Truth, C = Control. The same items were used in all studies.

Table 2: Perceived Responsiveness items.

Study 1B		Study 2		Studies 3-7	
Item No.	Item	Item No.	Item	Item No.	Item
	My partner		This interaction made me feel that my partner		My partner
1	...sees the real me.	1	...saw the real me.	1	...made me feel cared for.
2	...gets the facts right about me.	2	...got the facts right about me.	2	...valued my abilities and opinions.
3	...esteems me, shortcomings and all.	3	...focused on the best side of me.	3	...understood me.
4	...knows me well.	4	...was aware of what I was thinking and feeling.		
5	...values and respects the whole package that is the real me.	5	...understood me.		
6	...understands me.	6	...really listened to me.		
7	...really listens to me.	7	...valued my abilities and opinions.		
8	...expresses liking and encouragement for me.	8	...respected me.		
9	...seems interested in what I am thinking and feeling.	9	...was responsive to my needs.		
10	...values my abilities and opinions.	10	...was on the same wavelength as me.		
11	...is on the same wavelength with me.	11	...expressed liking and encouragement for me.		
12	...is responsive to my needs.	12	...was interested in what I was thinking and feeling.		
		13	...was interested in doing things with me.		

Note:
Items used in Studies 1-2 were drawn from variations on perceived responsiveness items developed by Reis and colleagues (2018). Items used in Studies 3-7 were drawn from Maisel & Gable (2009).

Results

Descriptive Statistics

Participants' average RES values were were 5.42 (*SD* = 1.13) and 5.72 (*SD* = 1.15) for Studies 1A and 1B, respectively. Participants' average PR was 5.98 (*SD* = 1.19), and was assessed in Study 1B only. As anticipated, RES and PR in Study 1B were also positively correlated: $r = 0.74$. Although this correlation is somewhat high, correlations of this size are common among close relationship variables. Moreover, this estimate suggests that despite this correlation between RES and PR, more than 45% of the variance between them was unshared. We also note that correlations between RES and PR generally smaller in subsequent studies, ranging from about .40 to about .65.

Confirmatory Factor Analysis for RES

We conducted a confirmatory factor analysis to determine the construct validity of RES using the *lavaan* package for R (Rosseel, 2012). We used maximum likelihood estimation with robust standard errors (MLR). Based on the theory that informed this research (Higgins, 2012, 2018), we specified a one factor hierarchical structure with two facets for RES. With this hierarchical structure, the facets of truth and control are nested within a single global factor of RES (see Figure 1). By having facets, items grouped within the same facet are permitted to be more highly correlated with each other than with items grouped in the other facets. Fit statistics indicated that this model provided an excellent fit for the data, Study 1A: CFI = 0.986, RMSEA = 0.075, 90% [0.05, 0.101], Study 1B: CFI = 0.995, RMSEA = 0.048, 90% [0.00, 0.097]. Moreover, running this analysis without specifying separate facets for truth and control yielded a significantly poorer fit, Study 1A: CFI = 0.914, RMSEA = 0.163, 90% [0.142, 0.184], $\Delta\ \chi^2 = 85.36$, $p < 0.001$; Study 1B: CFI = 0.228, RMSEA = 0.539, 90% [0.481, 0.599], $\Delta\ \chi^2 = 100.77$, $p < 0.001$.

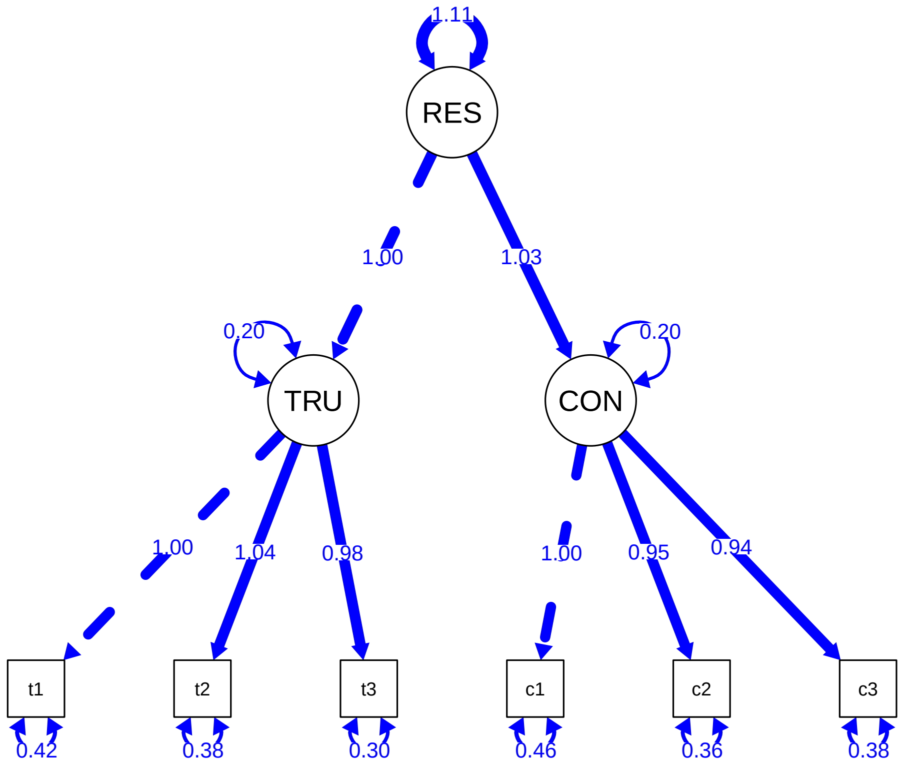

Figure 1: Results from Confirmatory Factor Analysis showing 1-factor hierarchical structure of Regulatory Effectiveness of Support (RES), Study 1A. TRU = Truth facet, and CON = control facet.

Confirmatory Factor Analysis Distinguishing RES from PR (Study 1B)

Having confirmed a hierarchical structure for RES when considered in isolation, we next estimated a confirmatory factor model to test our prediction that RES and PR make up distinct constructs. We specified two constructs: one for RES and one for PR. For RES, we again specified a hierarchical structure with two facets. As validating PR was beyond the scope of the present paper (for further information about PR, see Reis et al., 2018), PR was specified as a manifest variable represented by a summary measure, which was the mean of all PR items in standardized units. Fit statistics supported treating RES and PR as separate constructs, CFI = 0.986, RMSEA = 0.071, 90% [0.029, 0.111]. We also specified an alternative version of the model in which we fixed the correlation between RES and PR to 1. This model allowed us to test the possibility that RES and PR make up the same construct; if forcing the two variables to be perfectly correlated results in a better fit, or an equally good fit, then one cannot conclude that they are separate constructs. However, compared to the previous model, which treated RES and PR as separate constructs, this model provided a significantly poorer fit, CFI = 0.944, RMSEA = 0.14, 90% [0.11, 0.17], $\Delta\ \chi^2 = 38.24$, $p < 0.001$. In other words, despite being correlated, treating RES and PR as separate constructs fit the data significantly better than treating them as redundant constructs.

Discussion

Data from Studies 1A and 1B provided initial evidence that RES is a valid construct. Moreover, results from Study 1B further suggested that RES is distinct from another construct frequently used to assess the quality of enacted support, perceived responsiveness (PR) (Cutrona et al., 2007; Gable, Gonzaga, & Strachman, 2006; Gable, Gosnell, Maisel, & Strachman, 2012; Howland & Simpson, 2010; Maisel & Gable, 2009).

However, a limitation of Study 1B is that it asked participants to respond to the PR measure thinking about their interactions with their romantic partner in general. In contrast, we had participants respond to the RES measure with a recent support interaction in mind. Another limitation is that while we asked participants to respond to the RES measure thinking back to the last time their partner had offered them support, we did not include measures of outcomes. Hence, predictive and discriminant validity could not be examined.

Study 2

In Study 2, we aimed to replicate our initial findings demonstrating the factor structure of RES. We also aimed to show the predictive validity of RES and the discriminant validity between RES and PR. Participants were asked to recall the most recent time when their romantic partner tried to give them support for a stressful issue. They then rated RES and PR in regards to that support interaction. They also indicated how negative and positive their partner's support made them feel and how they felt about their partner following the support interaction.

Methods

Participants

Two hundred and four participants were drawn from Amazon's Mechanical Turk. In order to hold the support provider constant across participants and to be consistent with the prior studies, participants were prescreened to be currently involved in a romantic relationship of at least one year. Participants with duplicate entries were excluded (n = 22) and there was one participant who did not contribute data for the relevant variables, resulting in a final sample of 182 participants. There were 93 female participants, 84 male participants, and 5 participants who did not report their gender. The mean age was 34 (SD = 9.7). Participants had been in a relationship with their current partner for 4 years on average (SD = 2.3). The majority of the sample was married (46%) or cohabiting with their partner (31%). Participants received $3 in exchange for their participation.

Although formal power analyses for the predictive models were not performed *a priori* to determine sample size, power calculations conducted after data collection confirmed that this sample size provided more than 80% power to detect a relatively small effect (incremental $f^2 = .05$, where $f^2 = .02$ is a small effect and $f^2 = .15$ is a medium effect; J. Cohen, 1992).

Procedure

Participants were invited to complete a study about "life events." After responding to a brief prescreening questionnaire, eligible participants were directed to the main study. Participants were instructed to *"Think back to the most recent time when you were facing an issue that was important to you, and your current romantic partner tried to give you help."* To help participants bring this experience to mind, participants were guided through a series of open-ended questions about the support interaction, such as what the issue was and what their partner had done to try to help them.

Next, participants rated the support interaction according to the Regulatory Effectiveness of Support (RES) scale. They also rated their perceptions of their partner's responsiveness during the support interaction, how negative and positive they had felt as a result of this support interaction, and their feelings of self-other overlap as a result of this support interaction. Participants also completed additional measures not relevant to the present hypotheses that will not be discussed further.

Measures

Regulatory Effectiveness of Support

We measured RES with the scale developed and validated in Studies 1A and 1B. As in the previous studies, we averaged the items for truth ($\alpha = 0.92$) and control ($\alpha = 0.80$) to create a single index of RES (Spearman-Brown $\rho = 0.72$).

Perceived Responsiveness

Participants responded to a measure of perceived responsiveness (Reis et al., 2018), consisting of 13 items ($\alpha = 0.94$). In contrast to Study 1B, in which items were worded to capture general perceptions of partner responsiveness, in Study 2 we framed items to assess the perceived responsiveness of the support interaction that participants recalled. Examples of these items included, *"During the interaction, my partner valued my abilities and opinions"* and *"During the interaction, my partner really listened to me"* (1 = *Not at all*, 7 = *Extremely*). In order for items to be applicable to a specific support interaction, there are minor differences in some of the items used in Study 2 compared to Study 1B. A full list of the perceived responsiveness items used across all studies is available in Table 2.

Mood

Participants how negative and positive they felt following the support interaction (1 = *Not at all*, 7 = *Extremely*). There were five items measuring negative mood (e.g., *sad*, *overwhelmed*; $\alpha = 0.84$), and five items measuring positive mood (e.g., *happy*, *calm*; $\alpha = 0.84$).

Inclusion of the Other in the Self

To examine a relational outcome, participants responded to the Inclusion of the Other in the Self measure (A. Aron, Aron, & Smollan, 1992). This measure was selected as a relational outcome because it has been linked to a range of relationship quality measures (A. Aron et al., 1992). It is also suitable for use in multiple relationship contexts (e.g., friendships as well as romantic relationships, which were examined in subsequent studies). Participants were shown seven different images, each consisting of two circles, one labeled "self" and the second labeled "other". The images varied in the degree to which the circles overlapped. Participants were prompted to select the image that best represented how they felt about themselves and their partner as a result of the support interaction they brought to mind (1 = *No overlap*, 7 = *Near complete overlap*).

Construct Validity Results

In this study, the mean values for RES and PR were 6.00 (SD = 0.99) and 6.26 (SD = 0.83), respectively. Again, they were correlated, $r = 0.65$, 95% CI [0.56, 0.73]. However, about 58% of the variance between RES and PR was unshared[6]. Correlations among other variables are provided in Appendix A.

We performed a confirmatory factor analysis using data from Study 2. As in Studies 1A and 1B, we specified a hierarchical one-factor model of RES, with two facets (truth and control). Again, results indicated

[6]Regarding the correlation between RES and PR, it is known that issues due to collinearity can arise when predictor variables are highly correlated with each other (Fox, 2016). To gauge whether collinearity was problematic, we computed the variance inflation factor for RES and PR. The Variance Inflation Factor (VIF) is an index that allows one to gauge whether the degree of correlation between two predictor variables is problematic (Fox, 2016). Typically, only VIF values greater than 3 are considered problematic. However, VIFs were below this cutoff for all studies; the only exception was for the physiological results in Study 7, but this was due to the use of dummy coding.

that this model provided an excellent fit for the data, CFI = 0.981, RMSEA = 0.074, 90% [0.013, 0.126], and repeating the confirmatory factor analysis removing the facets provided a significantly poorer fit, CFI = 0.737, RMSEA = 0.241, 90% [0.202, 0.282], $\Delta\ \chi^2 = 60.75$, $p < 0.001$, thus lending further support to the hierarchical structure.

Using the same approach as Study 1B, we then specified a model adding PR. Once again, we found that treating RES and PR as separate constructs provided an excellent fit for the data, CFI = 0.987, RMSEA = 0.052, 90% [0.00, 0.10]. A model in which RES and PR were forced to be perfectly correlated provided a significantly poorer fit, CFI = 0.952, RMSEA = 0.10, 90% [0.06, 0.13], $\Delta\ \chi^2 = 8.48$, $p < 0.004$, thereby providing further evidence that they are separate constructs.

Predictive and Discriminant Validity Results

Having established the construct validity of RES, an important next step was to determine the predictive validity and discriminant validity of RES. To do so, we examined the effects of RES on support outcomes and compared its effects to the effects of PR.

Bayesian Estimation

As described in Part 1, for all predictive models, we analyzed data using Bayesian estimation with the *brms* package for R (Burkner, 2017). In addition to mean estimates from the posterior distribution, standard errors, and 95% credibility intervals, in Part 2 we also present directional posterior probabilities. Here, directional posterior probabilities refer to the number of posterior draws from the distribution (i.e., possible parameter values) falling above (or below) 0 divided by the total number of posterior values. Due to our use of noninformative priors, models assume an equal probability that a parameter value is above 0 or below 0 (i.e., prior to seeing the data, there is assumed to be a .50 probability of a positive effect). Directional posterior probabilities indicate the percentage of posterior values that are consistent with the hypothesized direction of an effect and can be interpreted as the probability in favor of the hypothesized direction after seeing the data. For instance, assuming an effect was hypothesized to be positive, a posterior probability of .90 indicates there is a .90 probability of an effect greater than 0 having seen the data, compared to a .50 prior probability before having seen the data. Note that these posterior probabilities can also be used to compute the odds in favor of (vs. against) an hypothesized direction; for example, a posterior probability of .90 gives an evidence ratio of .90/.10, or 9 to 1 odds in favor of the hypothesized direction. This is contrasted with prior odds of .50/.50, or 1 to 1 odds, before having seen the data.

As noted above, posterior probabilities presented in Part 2 are in reference to the hypothesized direction of the effect. We hypothesized negative effects of RES and PR on negative mood, and positive effects of RES and PR on all other outcomes. We hypothesized that there would be larger effects (in absolute value terms) of RES compared to PR on all self-regulation relevant outcomes, reflected by negative differences for negative mood and positive differences for the remaining self-regulation relevant outcomes. We hypothesized that there would be smaller effects of RES compared to PR on relational outcomes, reflected by negative differences for relational relevant outcomes.

Analytic Approach

To assess the predictive and discriminant validity of RES, we entered RES and PR as simultaneous predictors into a regression model. In the analyses for Study 2 and all subsequent studies, we tested (a) whether the effects of PR and RES were significantly different from 0 and (b) whether they were significantly different *from each other* (Gelman & Stern, 2006; Shrout & Yip-Bannicq, 2016). This allowed us to directly test our hypothesis that RES would more strongly predict self-regulation relevant variables compared to PR and that PR would more strongly predict relational variables compared to RES. For Studies 2-7, results from additional analyses examining effects of RES and PR in separate models can be acccessed in the Supplemental Materials of Zee et al. (2020). Unstandardized regression coefficients, standard errors, 95% credibility intervals, and directional posterior probabilities are provided in Table 3 (regression results) and Table 4 (tests of differences in coefficients). Results are also displayed in Figure 2.

Negative Mood

As expected, there was a significant main effect of RES, such that as RES increased, negative mood decreased, b = -0.37, 95% CI [-0.54, -0.18]. PR was also related to lower negative mood, b = -0.15, 95% CI [-0.37, 0.06], and although zero could not be excluded as a plausible value, there was relatively strong evidence in favor of a negative effect. The effect of RES on negative mood was stronger than the effect of PR on negative mood, b = -0.21, 95% CI [-0.56, 0.15]. The posterior probability for this difference (0.88) suggested the difference was most likely negative, indicating a stronger effect of RES than PR on lower negative mood.

Positive Mood

We found that both RES and PR both predicted higher positive mood, RES: b = 0.56, 95% CI [0.34, 0.79]; PR: b = 0.41, 95% CI [0.14, 0.67]. The effect of RES on positive mood was stronger than the effect of PR, $b = 0.15$, 95% CI [-0.29, 0.60], and the posterior probability for this difference (0.75) suggested evidence in favor of a larger RES effect.

Inclusion of the Other in the Self

There was a positive effect of RES on IOS, $b = 0.15$, 95% CI [-0.04, 0.33]. As hypothesized, there was a positive effect of PR on IOS, $b = 0.60$, 95% CI [0.37, 0.81]. Moreover, the effect of PR on IOS was stronger than the effect of RES on IOS, $b = -0.45$, 95% CI [-0.81, -0.08].

Table 3: Summary of results from Study 2, with unstandardized coefficients

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj
Negative Mood	Intercept	1.71	0.07	1.57	1.84	-	181
Negative Mood	RES	-0.37	0.09	-0.54	-0.18	1.00	181
Negative Mood	PR	-0.15	0.11	-0.37	0.06	0.92	181
Positive Mood	Intercept	5.03	0.08	4.87	5.19	-	181
Positive Mood	RES	0.56	0.11	0.34	0.79	1.00	181
Positive Mood	PR	0.41	0.14	0.14	0.67	1.00	181
IOS	Intercept	6.00	0.07	5.86	6.13	-	181
IOS	RES	0.15	0.09	-0.04	0.33	0.95	181
IOS	PR	0.60	0.11	0.37	0.81	1.00	181

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. N_Subj = Number of subjects in analysis. Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 4: Summary of differences in effects of RES and PR, Study 2

DV	RES-PR	SE	Lower	Upper	Post_Prob
Negative Mood	-0.21	0.18	-0.56	0.15	0.88
Positive Mood	0.15	0.23	-0.29	0.60	0.75
IOS	-0.45	0.19	-0.81	-0.08	0.99

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

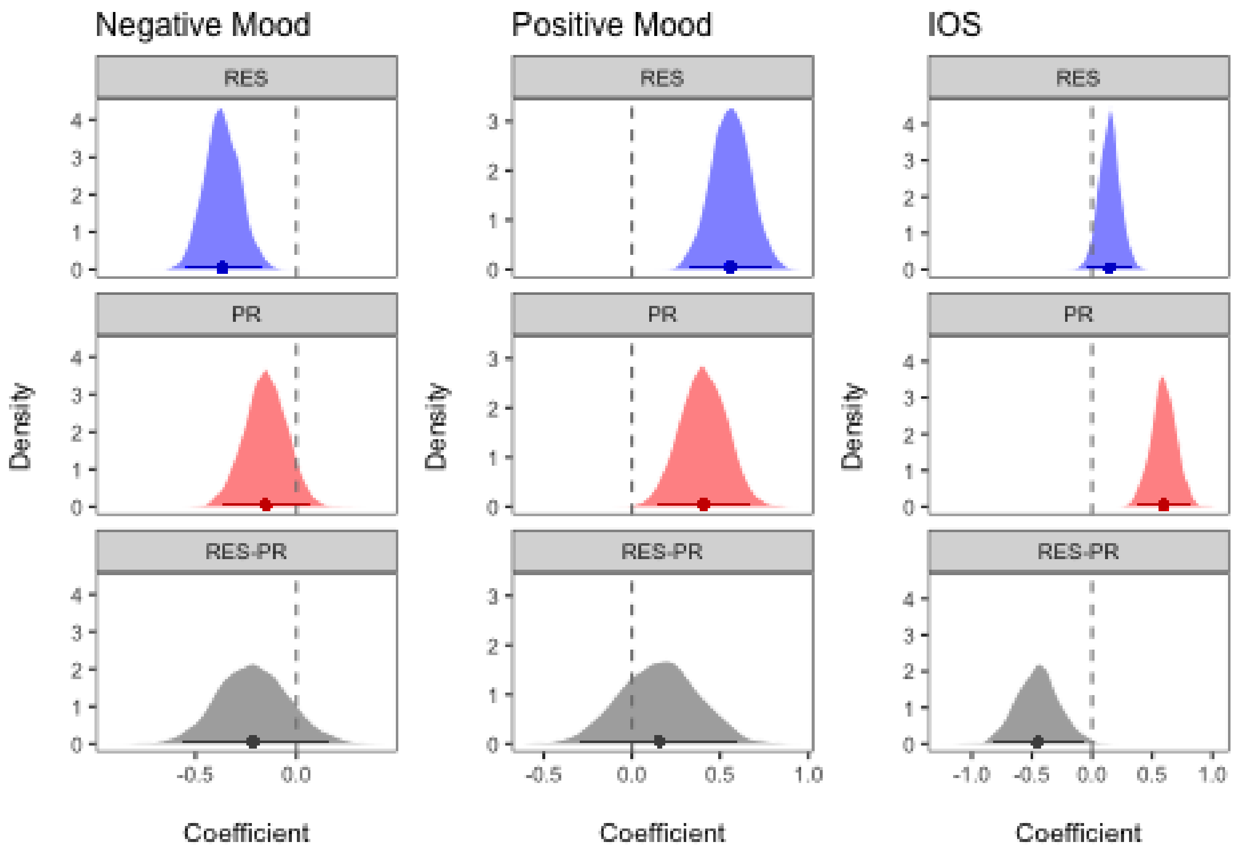

Figure 2: Posterior distributions of within-person effects of regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 2. IOS = Inclusion of Other in the Self.

Discussion

Study 2 replicated earlier findings regarding the structure of RES and showed that RES predicted lower negative mood and greater positive mood following social support interactions. These results were found even when controlling for PR. We also found that PR predicted higher IOS, and did so to a stronger degree than RES. For the difference in the effects of RES and PR on negative mood and positive mood, results pointed in the expected direction, with RES predicting lower negative mood and higher positive mood than PR. One limitation of Study 2 is that because participants were asked to recall a prior social support attempt from their partner, their reports might have have been influenced by retrospective bias. In addition, Study 2 only included mood and IOS as outcomes. Although feeling less negative and more positive can be an indication that recipients felt effective, there are other support outcomes that were also important to examine. We addressed these limitations in the subsequent studies.

Studies 3-5

The aim of Studies 3-5 was to examine the effects of RES on support outcomes in daily life. We used a daily diary design, in which participants reported on daily RES and PR in relation to support received across five days. An advantage of daily diary designs is that they allow researchers to examine psychological processes as they occur in participants' natural environments (Bolger & Laurenceau, 2013; Bolger, Davis, & Rafaeli, 2003). The diary design also helped to reduce the possibility that our results were influenced by retrospective bias. Due to the use of repeated measures, this also allowed us to examine how fluctuations in RES and PR within the same individual were related to support outcomes.

Studies 3-5 used essentially the same method and included the same measures, unless noted otherwise. Thus, the methods and results for these studies are described together. A pilot daily diary study was also conducted in connection with the present research question, the details of which can be found in the Supplemental Materials of Zee et al. (2020).

Methods

Participants

Participants were students enrolled in eligible psychology courses at Columbia University who received course credit in exchange for their participation in a five-night daily diary. Studies 3-5 were conducted in successive academic years, and the conclusion of the academic year served as our data collection stopping rule for each study.

Study 3 Participants

There were 263 who enrolled in Study 3. Because participants were drawn from an undergraduate participant pool for course credit, we were required to allow every person who signed up to participate. As such, there were some duplicate participants. There were six participants who completed this study twice—once in each semester that the study was offered—thus their second round of participation was removed from the sample. There were four participants who had previously enrolled in an earlier version of this study (the pilot diary study described above), and they were excluded from Study 3 prior to analysis. This left a sample of 253 participants.

Participants were 21 years old on average ($SD = 5$). There were 97 male participants, 144 female participants, and one participant who identified as “other”; the remaining participants did not indicate their gender. The majority of participants completed all five diary questionnaires ($n = 196$) or four out of five diary questionnaires ($n = 36$). There were six participants who did not complete any diary questionnaires, leaving a final sample of 247 participants.

Study 4 Participants

There were 210 participants who enrolled in Study 4. There were eight participants who had previously enrolled in an earlier version of this study: One person had participated in the pilot diary study, and seven people had participated in Study 3. These participants were excluded from Study 4 prior to analysis, which reduced the sample to 202 participants. There were three participants who did not nominate a target person and 10 additional participants who nominated a target but did not complete any diary questionnaires. These 13 participants were excluded also, leaving a final sample of 189 participants.

Participants were 21 years old on average ($SD = 4.1$). There were 55 male participants, 142 female participants, and 1 participant who identified as “other”; the remaining two participants did not indicate their gender. Most participants completed all five diary questionnaires ($n = 135$) or four out of five diary questionnaires ($n = 40$).

Study 5 Participants

There were 248 participants who enrolled in Study 5. Three participants had participated in a previous version of this study and were removed prior to analysis. This left a final sample of 245 participants.

Participants were 21 years old on average ($SD = 4.3$). There were 91 male participants and 152 female participants; the remaining participants did not indicate their gender. Most participants completed all five diary questionnaires ($n = 179$) or four out of five diary questionnaires ($n = 31$).

Procedure and Materials

In Studies 3-5, participants completed a five night daily diary that ran from Sunday night through Thursday night. On Sunday night, participants responded to a questionnaire consisting of individual difference measures; these measures were administered in regards to other research questions and will not be discussed further. Participants were also instructed to nominate a target person that they would be asked about for the remainder of the study. Participants were instructed to select a relationship partner whom they interacted with on a daily basis. There were 74/68/91 participants who chose a friend as their target person, 86/57/55 who chose their romantic partner, 27/23/32 who chose a parent, 4/12/10 who chose a sibling, 38/23/49 who chose a roommate, 5/4/3 who selected a different type of relationship partner, and 0/3/3 participants who did not report on the nature of their relationship with the target person in Studies 3-5, respectively. In Study 5 only, participants were also asked to identify an academic task that they would be working on over the coming days, such as a paper, problem set, or exam preparation.

Each night, participants responded to questions about social support they received from the target person that day. The average participant received support from the target person on 3 (Study 3), 3 (Study 4), or 3 (Study 5) out of the 5 diary days. They completed measures of RES, PR, and perceptions of support effectiveness, as well as outcome measures: mood, coping, and inclusion of the other in the self (IOS). We also assessed nightly sleep (Studies 4-5) as well as daily motivation and anticipated performance on the academic task that participants identified on the start of the study (Study 5).

Reliabilities for variables that were composites of two more items were estimated using procedures specified by Cranford et al. (2006) and Bolger and Laurenceau (2013) and are displayed in Table 5. These procedures provide estimates of within-person reliability, between-person reliability, and reliability of change. In particular, reliability of change is important because it assesses how well items within a composite move together over time within the same individual. Generally, reliability values across variables indicated that these composites were sensitive to both between-person differences and within-person change[7].

[7] Surprisingly, the reliability of change estimates for the truth and control facets in Study 5 were low. This was puzzling given that these facets showed strong reliability of change in the prior studies and in a pilot study. These low estimates could be due to there being only a small number of diary days used. Importantly, however, we found that despite the low reliability of change

Table 5: Within-person reliability, between-person reliability, and reliability of change, Studies 3-5

Variable	Reliability	Study 3	Study 4	Study 5
Truth	Within-person	0.87	0.88	0.90
Truth	Between-person	0.72	0.79	0.77
Truth	Reliability of change	0.88	0.89	0.17
Control	Within-person	0.87	0.86	0.88
Control	Between-person	0.69	0.82	0.79
Control	Reliability of change	0.90	0.87	0.28
RES	Within-person	0.71	0.65	0.68
RES	Between-person	0.73	0.83	0.81
RES	Reliability of change	0.76	0.73	0.74
PR	Within-person	0.84	0.84	0.85
PR	Between-person	0.84	0.83	0.82
PR	Reliability of change	0.87	0.87	0.48
Sup. Eff.	Within-person	0.59	0.52	0.50
Sup. Eff.	Between-person	0.74	0.78	0.72
Sup. Eff.	Reliability of change	0.65	0.54	0.54
Neg. Mood	Within-person	0.56	0.65	0.56
Neg. Mood	Between-person	0.79	0.79	0.77
Neg. Mood	Reliability of change	0.72	0.77	0.70
Pos. Mood	Within-person	0.75	0.69	0.72
Pos. Mood	Between-person	0.73	0.71	0.65
Pos. Mood	Reliability of change	0.82	0.81	0.81

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. Sup. Eff. = Support Effectiveness.

Regulatory Effectiveness of Support

Participants responded to the RES measure, which was the same measure used in Studies 1-2. Specifically, participants were instructed to think about support they had received from the target person that day when making their ratings. If they did not receive support from the target person that day, they checked a box next to each RES item indicating so.

Perceived Responsiveness

We administered a three-item perceived responsiveness measure (Maisel & Gable, 2009). These items have been used previously in diary studies (Maisel & Gable, 2009), and they also mapped onto key theoretical components of PR (validating, caring, and understanding). As with RES, participants were instructed to think about support they had received from the target person that day when making their ratings: *"Today, the person I nominated made me feel cared for"*, *"...valued my abilities and opinions"*, and

for the separate facets, the RES composite of truth and control showed adequate reliability of change, thereby indicating that these facets could be combined.

"... understood me" (1 = *Not at all*, 7 = *Extremely*). If they did not receive support from the target person that day, they checked a box next to each item indicating so. Reliability estimates of daily PR were generally good.

Participants were asked not to take support received from other people into account when making their ratings of RES and PR. Again, if participants did not receive any support from the target person that day, they were asked to check a box indicating so. Because RES and PR items asked about support received, only support receipt days were assessed in our analyses.

RES and PR were moderately correlated within- and between persons across studies, Study 3: $r_{Within} = 0.39$, 95% CI [0.32, 0.46], $r_{Between} = 0.64$, 95% CI [0.55, 0.72]; Study 4: $r_{Within} = 0.53$, 95% CI [0.45, 0.61], $r_{Between} = 0.66$, 95% CI [0.56, 0.74]; Study 5: $r_{Within} = 0.37$, 95% CI [0.29, 0.45], $r_{Between} = 0.54$, 95% CI [0.43, 0.63]. Within-person correlations were estimated as relationships between variables in person-specific standard deviation units using Bayesian multilevel modeling to account for repeated-measures obtained on each person. This procedure can produce somewhat different estimates compared to some other approaches for calculating within-person correlations, but was used for consistency with the predictive analyses. Correlations among remaining variables are presented in Appendix A.

Support Effectiveness

Support effectiveness was included as a measure of construct validity. Because RES is proposed to be a measure tapping support effectiveness, it should be positively associated with this variable. Each day, participants were asked to indicate how beneficial they found the emotional and practical support they received from the target person. Participants were first presented with definitions of emotional support (*e.g., offers of reassurance, expressions of concern*) and practical support (*e.g., advice, suggestions of course of action, offers of direct assistance*). They then responded to the following items: "*In general, how beneficial was the emotional help you received from this person during the past 24 hours?*" and "*In general, how beneficial was the practical help you received from this person during the past 24 hours?*" (1 = *Not at all*, 7 = *Extremely*). If participants did not receive any emotional support or any practical support from the target person, they checked a box indicating so. There was adequate reliability of emotional support effectiveness and practical support effectiveness across studies (see Table 5). Therefore, for simplicity and ease of comparison across studies, we created a composite by combining daily ratings of emotional support effectiveness and practical support effectiveness.

Mood

Participants indicated their levels of negative mood and positive mood using a scale ranging from 1 (*Not at all*) to 7 (*Extremely*). Daily negative mood was assessed with three items (*discouraged*, *sad*, *anxious*)[8], and daily positive mood were assessed with two items (*cheerful*, *lively*).

Coping

Participants also reported on their daily coping behaviors. Coping items were presented as a checklist, using items adapted from Carver et al. (1989). Similar coping checklists have been used in diary studies of daily coping in relationships (Tuskeviciute, Snyder, Stadler, & Shrout, 2018). Participants were asked to check off coping behaviors they had engaged in that day in order to deal with the primary issue for which they received support. There were nine positive coping behaviors, such as: *"I persevered"* and *"I exercised"* (checked = Yes, blank = No).

Inclusion of the Other in the Self

Inclusion of the Other in the Self (IOS), the same measure that was used in Study 2, was included as a relational outcome (1 = *No overlap*, 7 = *Near complete overlap*).

Sleep (Studies 4-5 only)

Studies 4 and 5 also included a measure of nightly sleep quality. Participants were asked to indicate how well they slept the previous night (-3 = *Very poorly*, +3 = *Very well*). To facilitate comparison with the other outcome variables measured, sleep quality was rescaled on a 1 to 7 scale. Participants also reported the time they went to sleep the night before and the time they woke up that morning (sleep duration, in hours), for use as a control variable[9].

We examined sleep quality due to growing awareness of the potential importance of social support for sleep and the possible role this link might play in accounting for the health-promoting effects of relationships (Grey, Uchino, Trettevik, Cronan, & Hogan, 2018). Sleep has also been proposed an as important antecedent of effective self-regulation, with disrupted sleep leading to self-regulation difficulties (Baumeister, 2003; Hagger, 2010). Thus, sleep was relevant to the present investigation due to its links to both social support and self-regulation.

[8] Additional mood items were measured. Items were chosen based on results of an exploratory factor analysis.

[9] Sleep duration values were the number of hours (to the nearest half hour) between participants' self-reported bed time and self-reported waking time. Negative sleep duration values or extreme sleep duration values (14 hours or more) were manually inspected and corrected if there was a clear reason for the implausible value (e.g., if a participant indicated 1 pm rather than 1 am as their bed time).

Daily Task Motivation (Study 5 only)

Each night, participants in Study 5 were presented with a reminder of the academic task they had identified in the preliminary questionnaire on the first night of the study. They were asked to indicate how motivated they felt to do well on the task that day (*How motivated are you to do well on this task/assignment?*; 1 = *Not at all*, 7 = *Extremely*). If they had already completed the task in question, they were instructed to check a box in place of providing a rating.

Daily Anticipated Task Performance (Study 5 only)

Participants in Study 5 were also asked to rate their anticipated task performance each night. They reported how well they thought they would perform on the task (*How well do you expect you will do on this task/assignment?*; 1 = *Not at all*, 7 = *Extremely*). If they had already completed the task in question, they were instructed to check a box in place of providing a rating.

Results

Analytic Approach

Results were analyzed using Bayesian multilevel modeling with the *brms* package for R. Following procedures specified by Bolger & Laurenceau (2013), we decomposed the within-person and between-person sources of variability in RES and PR. The model included fixed effect terms for RES (both within-person and between-person centered) and PR (both within-person and between-person centered), controlling for diary day (centered on the middle day of the study, which was the third day). Note that these analyses only included data from days on which participants received support.

This analysis also included subject-specific random intercepts and random slopes for RES and PR and allowed for autocorrelated residuals using an autoregressive AR(1) error structure, as is recommended for temporally ordered data with even intervals, such as daily diary data (Bolger & Laurenceau, 2013). An AR(1) error structure takes into account that the residuals of adjacent observations are often more highly correlated with each other than the residuals of observations that are not adjacent (Bolger & Laurenceau, 2013).

Results are displayed in Figures 3, 4, and 5 (within-person effects) and Figures 6, 7, and 8 (between-person effects). Results for the fixed effects are also summarized in Tables 6, 7, and 8. Differences in the fixed effects of RES and PR (RES-PR) are shown in Tables 9, 10, and 11. Tables displaying random effect estimates are provided in Appendix A.

As noted above, we again used Bayesian estimation in these analyses. Bayesian models are especially useful for these data: Due to the relatively small number of days collected per subject in our daily diary studies, it can be difficult (and in some cases, impossible) to estimate the necessary random effects using traditional maximum likelihood estimation (MLE). Bayesian estimation has greater facility in handling random effects, which allowed us to estimate random slopes for both of our focal variables: Regulatory Effectiveness of Support (RES) and Perceived Responsiveness (PR).

Support Effectiveness

First, we examined effects of RES and PR on perceptions of support effectiveness as construct validity check. Results indicated that higher within-person RES was associated with higher perceptions of support effectiveness, Study 3: b = 0.45, 95% CI [0.35, 0.55]; Study 4: b = 0.45, 95% CI [0.30, 0.60]; Study 5: b = 0.39, 95% CI [0.25, 0.52]. On days when participants received support higher on RES relative to their own average, the higher their perceptions of the effectiveness of the support. Higher within-person PR was also associated with higher perceptions of support effectiveness, Study 3: b = 0.28, 95% CI [0.16, 0.39]; Study 4: b = 0.34, 95% CI [0.18, 0.49]; Study 5: b = 0.38, 95% CI [0.23, 0.52]. The effect of within-person RES on support effectiveness was generally stronger than the effect of within-person PR, Study 3: b = 0.17, 95% CI [-0.01, 0.36]; Study 4: b = 0.11, 95% CI [-0.16, 0.39]; Study 5: b = 0.01, 95% CI [-0.23, 0.25]. Posterior probabilities for these estimates were in favor of our prediction that there would be a positive difference between RES and PR, indicating a stronger effect of RES.

There was also an effect of higher between-person RES on higher perceptions of support effectiveness, Study 3: b = 0.47, 95% CI [0.33, 0.61]; Study 4: b = 0.44, 95% CI [0.30, 0.58]; Study 5: b = 0.38, 95% CI [0.27, 0.49]. Participants who experienced higher (*vs.* lower) levels of RES across the diary period tended to perceive the support they received from the target person as more effective. Higher between-person PR also predicted higher perceptions of support effectiveness, Study 3: b = 0.35, 95% CI [0.23, 0.47]; Study 4: b = 0.41, 95% CI [0.26, 0.55]; Study 5: b = 0.47, 95% CI [0.35, 0.59]. The effect of between-person RES on support effectiveness was generally stronger than the effect of between-person PR Studies 3 and 4, Study 3: b = 0.12, 95% CI [-0.12, 0.36]; Study 4: b = 0.03, 95% CI [-0.23, 0.30]. However, there was a reversal in this difference for Study 5, b = -0.09, 95% CI [-0.30, 0.11].

Negative Mood

We examined effects of RES and PR on daily negative mood. Results indicated that higher within-person RES was associated with lower negative mood, Study 3: b = -0.23, 95% CI [-0.32, -0.14]; Study

4: b = -0.12, 95% CI [-0.25, 0.009]; Study 5: b = -0.13, 95% CI [-0.24, -0.02]. On days when participants received support higher on RES relative to their own average, the lower their negative mood that day. Higher within-person PR was not consistently associated with negative mood across studies, Study 3: b = -0.02, 95% CI [-0.12, 0.09]; Study 4: b = -0.17, 95% CI [-0.30, -0.03]; Study 5: b = -0.03, 95% CI [-0.16, 0.09]. The effect of within-person RES on negative mood was generally stronger than the effect of within-person PR, although there were some inconsistencies across studies, Study 3: b = -0.21, 95% CI [-0.38, -0.04]; Study 4: b = 0.05, 95% CI [-0.19, 0.28]; Study 5: b = -0.10, 95% CI [-0.29, 0.10].

There was also an effect of higher between-person RES on lower negative mood, although zero could not be excluded as a plausible value in some studies, Study 3: b = -0.16, 95% CI [-0.33, 0.01]; Study 4: b = -0.30, 95% CI [-0.49, -0.12]; Study 5: b = -0.10, 95% CI [-0.24, 0.03]. Participants who experienced higher (*vs.* lower) levels of RES across the diary period tended to feel less negative. Higher between-person PR across the diary period was weakly linked to lower negative mood, Study 3: b = -0.08, 95% CI [-0.23, 0.08]; Study 4: b = -0.03, 95% CI [-0.22, 0.15]; Study 5: b = -0.09, 95% CI [-0.23, 0.06]. The effect of between-person RES on negative mood was generally stronger than the effect of between-person PR, with posterior probabilities in favor of this hypothesis exceeding .50 across studies, Study 3: b = -0.08, 95% CI [-0.39, 0.22]; Study 4: b = -0.27, 95% CI [-0.61, 0.06], probability of a negative effect = 0.60; Study 5: b = -0.02, 95% CI [-0.27, 0.23].

Positive Mood

Higher within-person RES was generally associated with higher positive mood, Study 3: b = 0.17, 95% CI [0.07, 0.26]; Study 4: b = 0.06, 95% CI [-0.08, 0.19]; Study 5: b = 0.11, 95% CI [-0.01, 0.24]. On days when participants received support higher on RES relative to their own average, the higher their positive mood that day. Higher within-person PR was also generally associated with positive mood, Study 3: b = 0.12, 95% CI [0.008, 0.23]; Study 4: b = 0.19, 95% CI [0.04, 0.34]; Study 5: b = 0.03, 95% CI [-0.11, 0.17]. The differences in the effects of RES and PR varied across studies, but suggested a stronger effect of RES in two out of three studies, Study 3: b = 0.05, 95% CI [-0.12, 0.23]; Study 4: b = -0.13, 95% CI [-0.39, 0.12]; Study 5: b = 0.08, 95% CI [-0.14, 0.31]

There was also an effect of higher between-person RES on higher positive mood, Study 3: b = 0.32, 95% CI [0.16, 0.48]; Study 4: b = 0.41, 95% CI [0.26, 0.57]; Study 5: b = 0.25, 95% CI [0.13, 0.37]. Participants who experienced higher (*vs.* lower) levels of RES across the diary period tended to feel more positive. However, we were unable to conclude that higher between-person PR across the diary period was reliably related to higher positive mood, Study 3: b = -0.09, 95% CI [-0.23, 0.05]; Study 4: b = -0.07, 95% CI [-0.23, 0.09]; Study 5: b = 0.08, 95% CI [-0.05, 0.22]. The effect of between-person RES on positive mood was stronger than the effect of between-person PR across studies, Study 3: $b = 0.41$, 95% CI [0.14, 0.68]; Study 4: $b = 0.48$, 95% CI [0.18, 0.77]; Study 5: $b = 0.17$, 95% CI [-0.06, 0.40], indicated by posterior probabilities in favor of a larger RES effect exceeding 0.93.

Coping

Because our measure of coping was administered as a checklist, coping was a count variable. We took the sum of the number of adaptive coping behaviors that participants engaged in each day. Then, following established practices (Fox, 2016), we square-root transformed this sum to help normalize the distribution and then rescaled the resulting values on a 1-7 scale, the same scale used to measure the other variables. This transformation was used to facilitate comparison across outcomes. We also analyzed coping data in the original metric using multilevel poisson regression, which produced a pattern of results that was consistent with the results presented below.

Higher within-person RES was associated with higher coping, Study 3: $b = 0.11$, 95% CI [0.04, 0.18]; Study 4: $b = 0.15$, 95% CI [0.04, 0.24]; Study 5: $b = 0.06$, 95% CI [-0.01, 0.14]. On days when participants received support higher on RES relative to their own average, the more coping behaviors they reported engaging in that day. Within-PR was also associated with higher coping, Study 3: $b = 0.04$, 95% CI [-0.03, 0.11]; Study 4: $b = 0.05$, 95% CI [-0.06, 0.15]; Study 5: $b = 0.11$, 95% CI [0.02, 0.20]. The effects of within-person RES on coping were larger than the effect of within-person PR in two of the three studies, Study 3: $b = 0.07$, 95% CI [-0.05, 0.19]; Study 4: $b = 0.10$, 95% CI [-0.08, 0.27]; Study 5: $b = -0.05$, 95% CI [-0.19, 0.09].

Higher between-person RES was generally related to higher coping, Study 3: $b = 0.07$, 95% CI [-0.05, 0.20]; Study 4: $b = 0.12$, 95% CI [-0.02, 0.25]; Study 5: $b = 0.14$, 95% CI [0.02, 0.25]. On average, participants who experienced higher (*vs.* lower) levels of RES across the diary period engaged in more coping behaviors. Between-person PR was also sometimes related to higher coping, Study 3: $b = 0.06$, 95% CI [-0.05, 0.17]; Study 4: $b = 0.06$, 95% CI [-0.08, 0.21]; Study 5: $b = -0.002$, 95% CI [-0.13, 0.13]. There effect of between-person RES on coping was typically stronger than the effect of between-person PR, with posterior probabilities exceeding 0.54 across studies, Study 3: $b = 0.01$, 95% CI [-0.21, 0.23]; Study 4: $b = 0.05$, 95% CI [-0.20, 0.30]; Study 5: $b = 0.14$, 95% CI [-0.09, 0.36].

IOS

We examined effects of RES and PR on daily IOS. Results indicated that higher within-person RES was associated with higher IOS, Study 3: b = 0.11, 95% CI [0.03, 0.20]; Study 4: b = 0.14, 95% CI [0.03, 0.26]; Study 5: b = 0.13, 95% CI [0.04, 0.22]. On days when participants received support higher on RES relative to their own average, the higher their IOS that day. Higher within-person PR was also associated with higher IOS across studies, Study 3: b = 0.45, 95% CI [0.36, 0.55]; Study 4: b = 0.32, 95% CI [0.20, 0.43]; Study 5: b = 0.36, 95% CI [0.24, 0.48]. The effect of within-person PR on IOS was generally stronger than the effect of within-person RES, with posterior probabilities in favor of a larger effect of PR exceeding 0.95 across studies, Study 3: b = -0.34, 95% CI [-0.49, -0.19]; Study 4: b = -0.17, 95% CI [-0.38, 0.04]; Study 5: b = -0.23, 95% CI [-0.41, -0.05]

Higher between-person RES across the diary period was also generally related to higher IOS, Study 3: b = 0.10, 95% CI [-0.10, 0.29]; Study 4: b = 0.25, 95% CI [0.07, 0.43]; Study 5: b = 0.07, 95% CI [-0.09, 0.23]. Higher between-person PR was strongly related to higher IOS, Study 3: b = 0.62, 95% CI [0.45, 0.79]; Study 4: b = 0.69, 95% CI [0.48, 0.88]; Study 5: b = 0.73, 95% CI [0.57, 0.90]. The effect of between-person PR on IOS was stronger than the effect of between-person RES, Study 3: b = -0.53, 95% CI [-0.86, -0.18]; Study 4: b = -0.43, 95% CI [-0.78, -0.07]; Study 5: b = -0.66, 95% CI [-0.95, -0.38].

Sleep (Studies 4-5 only)

We next assessed nightly sleep quality. To assess within-person effects, we used lagged within-person RES and PR values. This allowed us to ascertain whether receiving support higher (*vs.* lower) on RES and PR relative to one's own average predicted sleeping better later that night. Note that due to the need to use lagged RES and PR values, there were fewer observations available for analysis.

Higher within-person RES was associated with better sleep, Study 4: b = 0.11, 95% CI [-0.10, 0.32]; Study 5: b = 0.04, 95% CI [-0.11, 0.19]. Although zero could not be excluded as a plausible value, the posterior probabilities were in favor of a positive effect of within-person RES on nightly sleep quality. Higher within-person PR was not reliably associated with sleep quality, Study 4: b = -0.07, 95% CI [-0.29, 0.15]; Study 5: b = 0.08, 95% CI [-0.10, 0.26]. There was also inconsistency in the difference of these effects, Study 4: b = 0.18, 95% CI [-0.20, 0.57]; Study 5: b = -0.04, 95% CI [-0.32, 0.23].

Between-person RES was related to better sleep quality, Study 4: b = 0.24, 95% CI [0.01, 0.48]; Study 5: b = 0.11, 95% CI [-0.11, 0.33]. Study 4 participants who experienced higher (*vs.* lower) levels of RES across the diary period tended to report better sleep. Higher between-person PR across the diary period was not consistently related to sleep quality, Study 4: b = -0.03, 95% CI [-0.28, 0.20]; Study 5: b = 0.14, 95% CI [-0.09, 0.38]. There was also some inconsistency in the difference of these effects, Study 4: b = 0.28, 95%

CI [-0.16, 0.71]; Study 5: b = -0.03, 95% CI [-0.43, 0.37].

Task Motivation (Study 5 only)

In Study 5, participants were asked to select an academic task they planned to work on during the diary period. Each day, they were reminded of this task and reported how motivated they felt to work on it. Within-person RES predicted greater daily task motivation, b = 0.11, 95% CI [0.003, 0.22]. On days when participants received support higher (*vs.* lower) on RES relative to their own average, they felt more motivated to do well on their task. Within-person PR was not related to daily task motivation, b = 0.02, 95% CI [-0.09, 0.14]. The within-person effect of RES on daily motivation was stronger than the effect of within-person PR, b = 0.09, 95% CI [-0.09, 0.27], which corresponded to a 0.83 posterior probability in favor of a stronger effect of RES.

Between-person RES was also associated with task motivation. Participants who experienced higher (*vs.* lower) levels of RES across the diary period tended to be more motivated, b = 0.20, 95% CI [0.03, 0.37]. Between-person PR was not associated with task motivation, b = -0.007, 95% CI [-0.20, 0.18]. The between-person effect of RES on daily motivation was stronger than the effect of between-person PR, b = 0.20, 95% CI [-0.11, 0.52], which corresponded to a 0.90 posterior probability in favor of a stronger effect of RES.

Anticipated Task Performance (Study 5 only)

Study 5 also included measures of anticipated task performance (i.e., how well participants expected they would perform on their task). Neither within-person RES, b = 0.04, 95% CI [-0.04, 0.13], nor within-person PR, b = -0.01, 95% CI [-0.11, 0.09], was reliably related to daily anticipated task performance. Results suggested a stronger effect of within-person RES on anticipated performance compared to within-person PR, and although zero could not be excluded as a plausible value, b = 0.05, 95% CI [-0.10, 0.21], there was nevertheless a 0.75 probability in favor of a stronger effect of RES.

However, higher between-person RES across the diary period predicted higher anticipated task performance, b = 0.21, 95% CI [0.07, 0.35]. Participants who experienced higher (*vs.* lower) levels of RES across the diary period reported greater anticipated task performance. Between-person PR was unrelated to anticipated task performance, b = 0.001, 95% CI [-0.15, 0.15]. Results suggested a stronger effect of within-person RES on anticipated performance compared to within-person PR, and although zero could not be excluded as a plausible value, b = 0.21, 95% CI [-0.05, 0.46], there was nevertheless a 0.94 probability in favor of a stronger effect of RES.

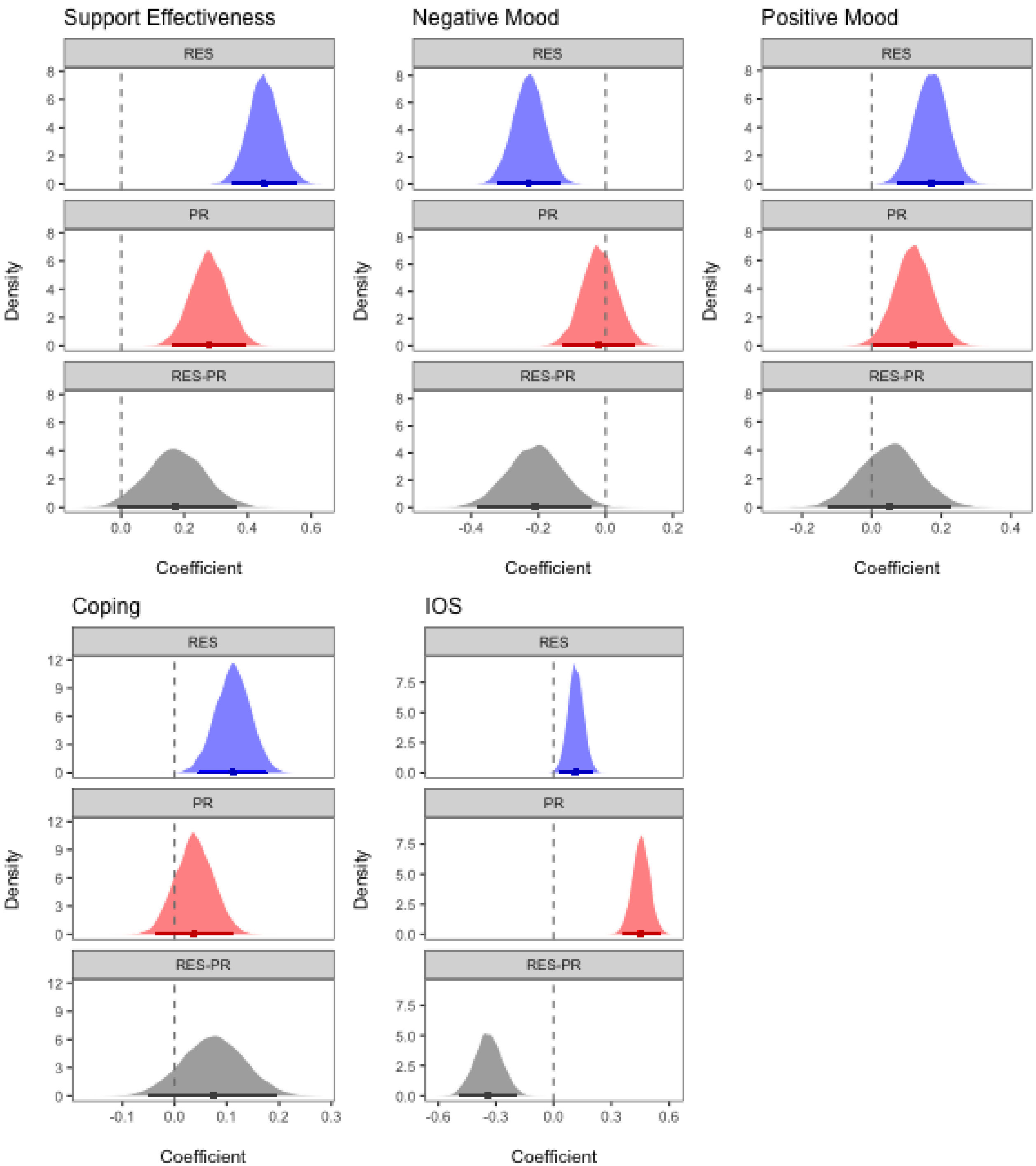

Figure 3: Posterior distributions of within-person effects of regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 3. IOS = Inclusion of Other in the Self.

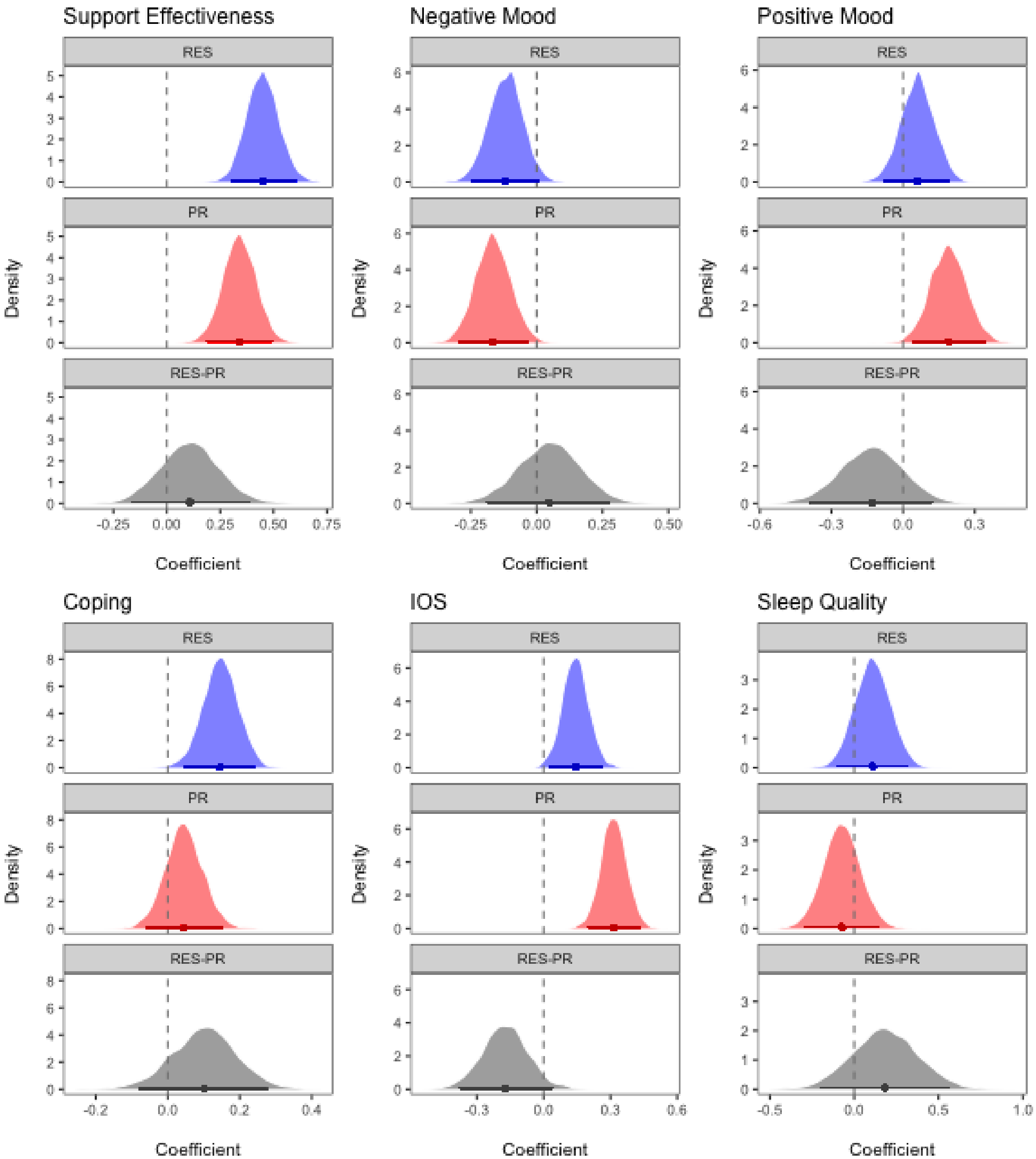

Figure 4: Posterior distributions of within-person effects of regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 4. IOS = Inclusion of Other in the Self.

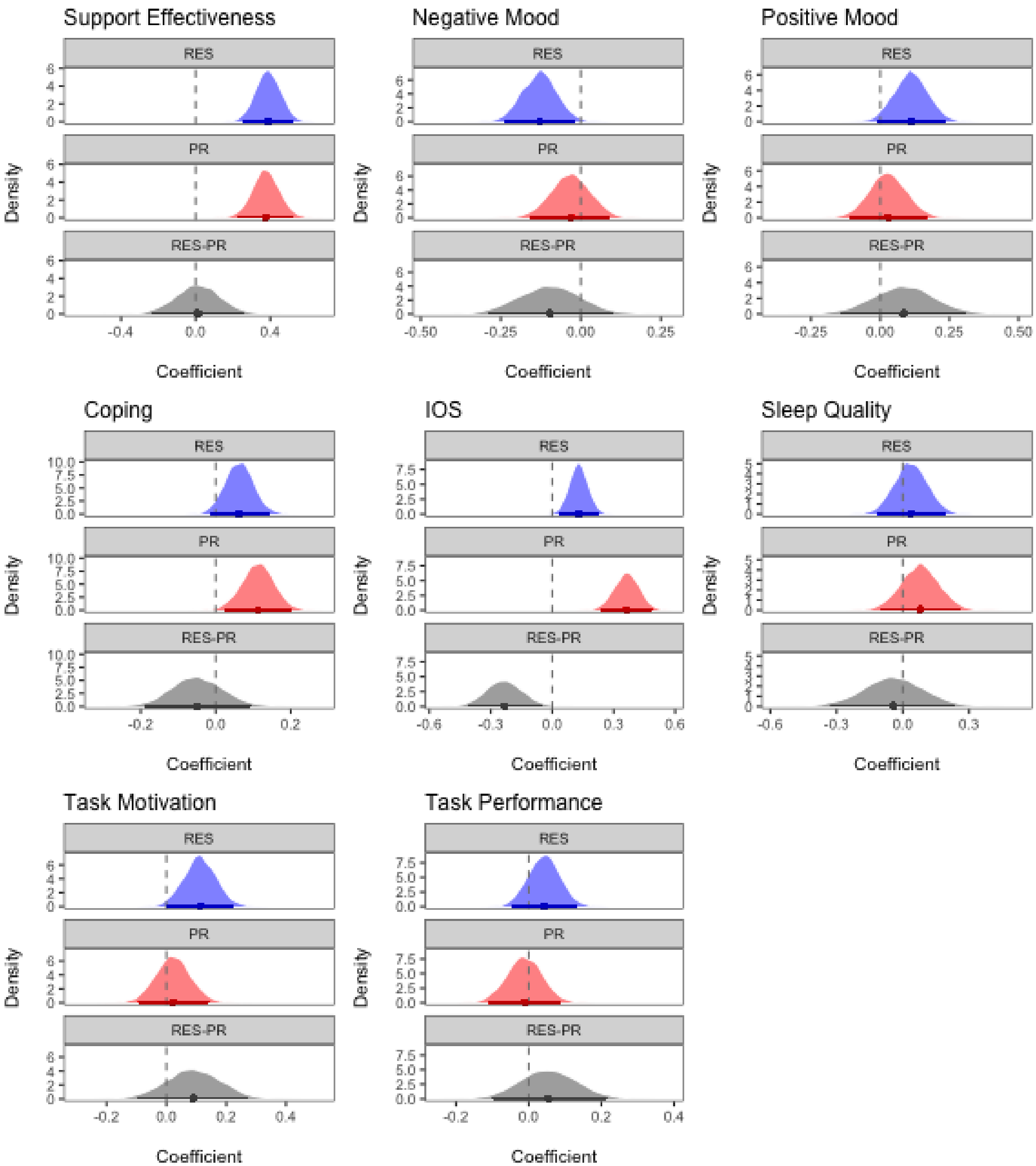

Figure 5: Posterior distributions of within-person effects of regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 5. IOS = Inclusion of Other in the Self.

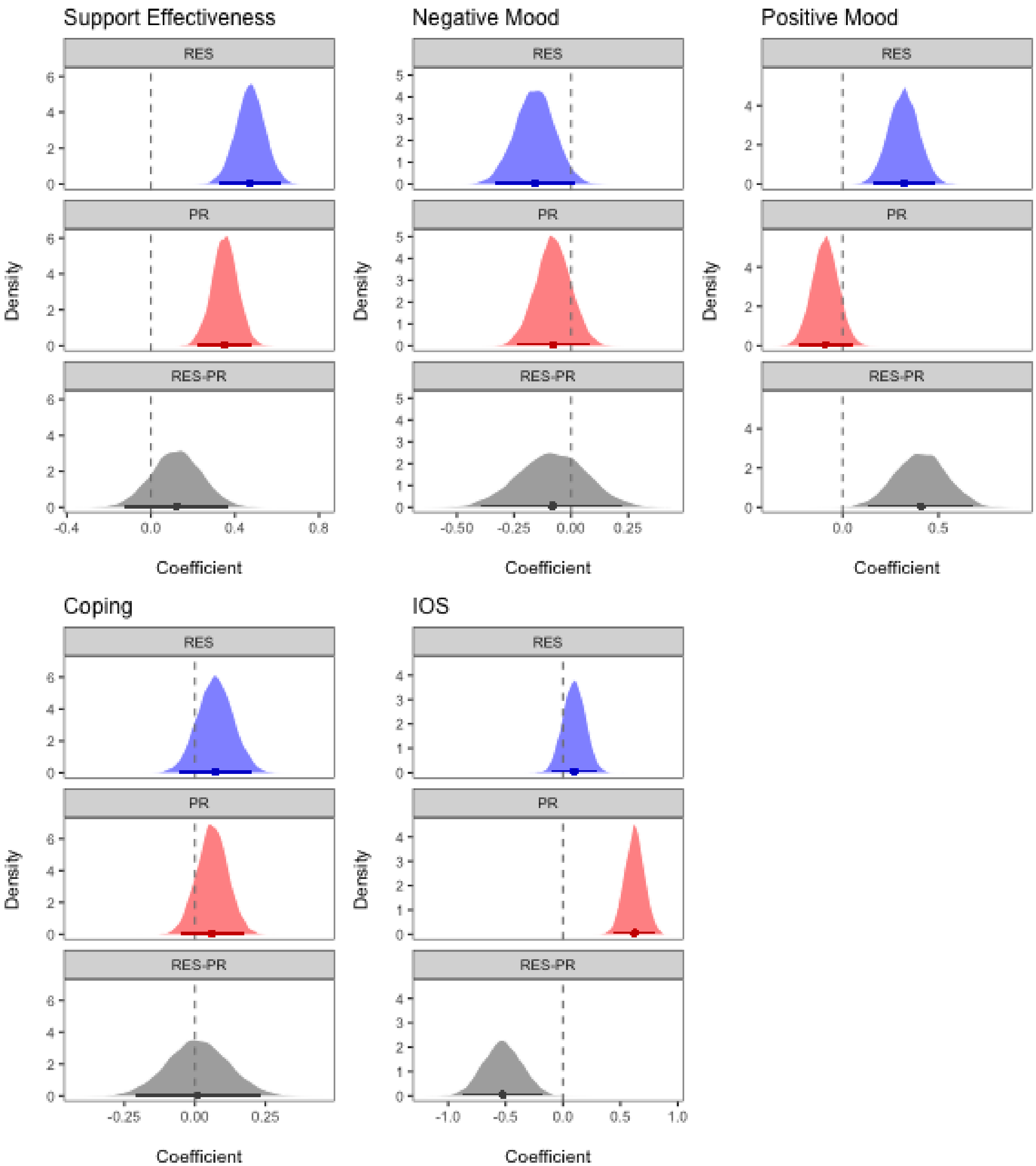

Figure 6: Posterior distributions of between-person effects of regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 3. IOS = Inclusion of Other in the Self.

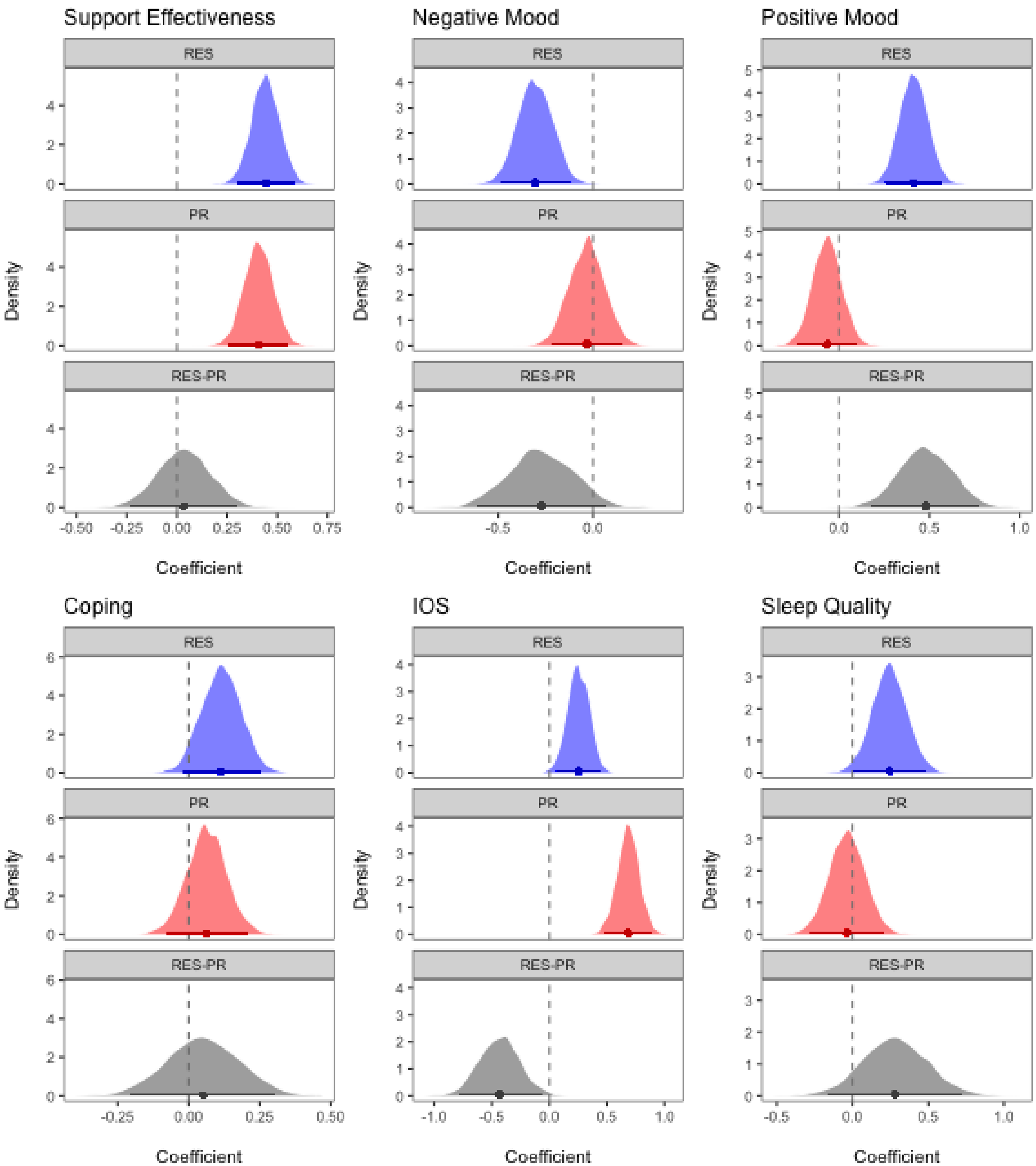

Figure 7: Posterior distributions of between-person effects of regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 4. IOS = Inclusion of Other in the Self.

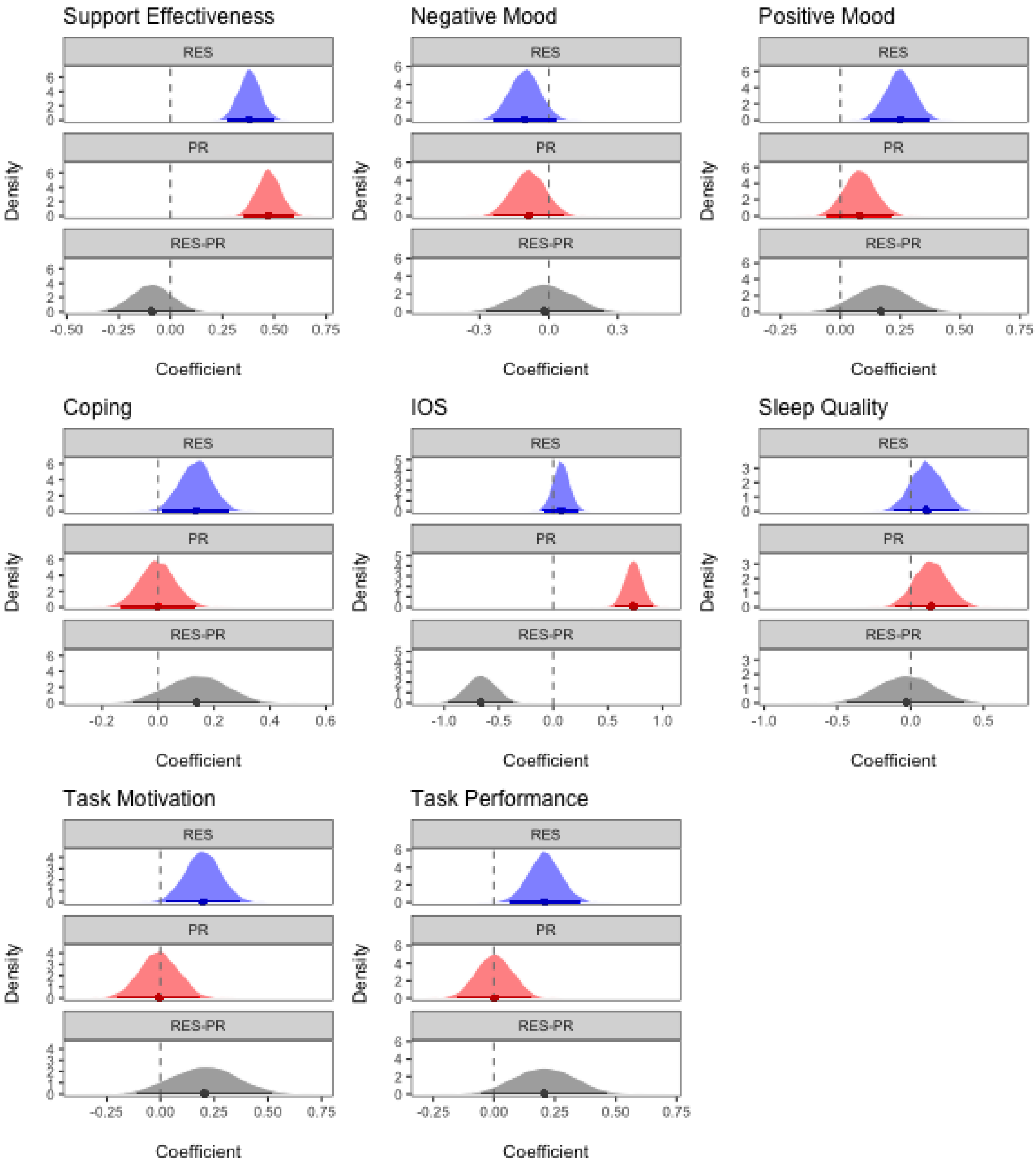

Figure 8: Posterior distributions of between-person effects of regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 5. IOS = Inclusion of Other in the Self.

Table 6: Summary of results from Study 3, with unstandardized coefficients

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Support Effectiveness	Intercept	4.31	0.06	4.20	4.43	-	222	710
Support Effectiveness	RES-within	0.45	0.05	0.35	0.55	1.00	222	710
Support Effectiveness	PR-within	0.28	0.06	0.16	0.39	1.00	222	710
Support Effectiveness	RES-between	0.47	0.07	0.33	0.61	1.00	222	710
Support Effectiveness	PR-between	0.35	0.06	0.23	0.47	1.00	222	710
Support Effectiveness	Day	-0.04	0.03	-0.11	0.02	-	222	710
Negative Mood	Intercept	2.95	0.07	2.80	3.10	-	222	717
Negative Mood	RES-within	-0.23	0.05	-0.32	-0.14	1.00	222	717
Negative Mood	PR-within	-0.02	0.05	-0.12	0.09	0.64	222	717
Negative Mood	RES-between	-0.16	0.09	-0.33	0.01	0.97	222	717
Negative Mood	PR-between	-0.08	0.08	-0.23	0.08	0.84	222	717
Negative Mood	Day	-0.14	0.03	-0.20	-0.08	-	222	717
Positive Mood	Intercept	3.68	0.07	3.54	3.81	-	222	717
Positive Mood	RES-within	0.17	0.05	0.07	0.26	1.00	222	717
Positive Mood	PR-within	0.12	0.06	0.008	0.23	0.98	222	717
Positive Mood	RES-between	0.32	0.08	0.16	0.48	1.00	222	717
Positive Mood	PR-between	-0.09	0.07	-0.23	0.05	0.10	222	717
Positive Mood	Day	0.01	0.03	-0.05	0.08	-	222	717
Coping	Intercept	4.43	0.06	4.32	4.54	-	222	717
Coping	RES-within	0.11	0.03	0.04	0.18	1.00	222	717
Coping	PR-within	0.04	0.04	-0.03	0.11	0.84	222	717
Coping	RES-between	0.07	0.07	-0.05	0.20	0.87	222	717
Coping	PR-between	0.06	0.06	-0.05	0.17	0.86	222	717
Coping	Day	-0.12	0.02	-0.17	-0.07	-	222	717
IOS	Intercept	4.26	0.08	4.09	4.42	-	222	717
IOS	RES-within	0.11	0.04	0.03	0.20	1.00	222	717
IOS	PR-within	0.45	0.05	0.36	0.55	1.00	222	717
IOS	RES-between	0.10	0.10	-0.10	0.29	0.83	222	717
IOS	PR-between	0.62	0.09	0.45	0.79	1.00	222	717
IOS	Day	0.02	0.03	-0.03	0.08	-	222	717

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. N_Subj = Number of subjects in analysis. Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 7: Summary of results from Study 4, with unstandardized coefficients

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Support Effectiveness	Intercept	4.30	0.07	4.17	4.44	-	176	533
Support Effectiveness	RES-within	0.45	0.08	0.30	0.60	1.00	176	533
Support Effectiveness	PR-within	0.34	0.08	0.18	0.49	1.00	176	533
Support Effectiveness	RES-between	0.44	0.07	0.30	0.58	1.00	176	533
Support Effectiveness	PR-between	0.41	0.07	0.26	0.55	1.00	176	533
Support Effectiveness	Day	0.007	0.04	-0.07	0.08	-	176	533
Negative Mood	Intercept	3.05	0.09	2.86	3.22	-	176	540
Negative Mood	RES-within	-0.12	0.07	-0.25	0.009	0.96	176	540
Negative Mood	PR-within	-0.17	0.07	-0.30	-0.03	0.99	176	540
Negative Mood	RES-between	-0.30	0.09	-0.49	-0.12	1.00	176	540
Negative Mood	PR-between	-0.03	0.09	-0.22	0.15	0.64	176	540
Negative Mood	Day	-0.14	0.03	-0.21	-0.08	-	176	540
Positive Mood	Intercept	3.79	0.07	3.65	3.94	-	176	540
Positive Mood	RES-within	0.06	0.07	-0.08	0.19	0.81	176	540
Positive Mood	PR-within	0.19	0.08	0.04	0.34	1.00	176	540
Positive Mood	RES-between	0.41	0.08	0.26	0.57	1.00	176	540
Positive Mood	PR-between	-0.07	0.08	-0.23	0.09	0.21	176	540
Positive Mood	Day	0.05	0.03	-0.02	0.11	-	176	540

Table 7: Summary of results from Study 4, with unstandardized coefficients *(continued)*

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Coping	Intercept	4.39	0.07	4.26	4.53	-	176	541
Coping	RES-within	0.15	0.05	0.04	0.24	1.00	176	541
Coping	PR-within	0.05	0.05	-0.06	0.15	0.81	176	541
Coping	RES-between	0.12	0.07	-0.02	0.25	0.95	176	541
Coping	PR-between	0.06	0.07	-0.08	0.21	0.82	176	541
Coping	Day	-0.17	0.03	-0.22	-0.12	-	176	541
IOS	Intercept	4.14	0.09	3.96	4.32	-	176	541
IOS	RES-within	0.14	0.06	0.03	0.26	0.99	176	541
IOS	PR-within	0.32	0.06	0.20	0.43	1.00	176	541
IOS	RES-between	0.25	0.10	0.07	0.43	1.00	176	541
IOS	PR-between	0.69	0.10	0.48	0.88	1.00	176	541
IOS	Day	-0.04	0.03	-0.10	0.02	-	176	541
Sleep Quality	Intercept	4.97	0.11	4.76	5.19	-	129	276
Sleep Quality	RES-within (lagged)	0.11	0.11	-0.10	0.32	0.85	129	276
Sleep Quality	PR-within (lagged)	-0.07	0.11	-0.29	0.15	0.25	129	276
Sleep Quality	RES-between	0.24	0.12	0.01	0.48	0.98	129	276
Sleep Quality	PR-between	-0.03	0.12	-0.28	0.20	0.39	129	276
Sleep Quality	Day	0.006	0.06	-0.12	0.13	-	129	276

Table 7: Summary of results from Study 4, with unstandardized coefficients *(continued)*

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Sleep Quality	Sleep Duration	0.24	0.06	0.13	0.36	-	129	276

Note:

RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. N_Subj = Number of subjects in analysis. Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 8: Summary of results from Study 5, with unstandardized coefficients

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Support Effectiveness	Intercept	4.55	0.06	4.43	4.67	-	228	614
Support Effectiveness	RES-within	0.39	0.07	0.25	0.52	1.00	228	614
Support Effectiveness	PR-within	0.38	0.07	0.23	0.52	1.00	228	614
Support Effectiveness	RES-between	0.38	0.06	0.27	0.49	1.00	228	614
Support Effectiveness	PR-between	0.47	0.06	0.35	0.59	1.00	228	614
Support Effectiveness	Day	0.02	0.03	-0.05	0.09	-	228	614
Negative Mood	Intercept	2.96	0.08	2.81	3.10	-	227	621
Negative Mood	RES-within	-0.13	0.06	-0.24	-0.02	0.99	227	621
Negative Mood	PR-within	-0.03	0.06	-0.16	0.09	0.70	227	621
Negative Mood	RES-between	-0.10	0.07	-0.24	0.03	0.93	227	621
Negative Mood	PR-between	-0.09	0.08	-0.23	0.06	0.87	227	621
Negative Mood	Day	-0.21	0.03	-0.27	-0.14	-	227	621
Positive Mood	Intercept	3.79	0.07	3.65	3.93	-	228	624
Positive Mood	RES-within	0.11	0.06	-0.01	0.24	0.96	228	624
Positive Mood	PR-within	0.03	0.07	-0.11	0.17	0.65	228	624
Positive Mood	RES-between	0.25	0.06	0.13	0.37	1.00	228	624
Positive Mood	PR-between	0.08	0.07	-0.05	0.22	0.87	228	624
Positive Mood	Day	0.05	0.04	-0.02	0.12	-	228	624

Table 8: Summary of results from Study 5, with unstandardized coefficients *(continued)*

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Coping	Intercept	4.47	0.07	4.33	4.60	-	228	628
Coping	RES-within	0.06	0.04	-0.01	0.14	0.95	228	628
Coping	PR-within	0.11	0.04	0.02	0.20	0.99	228	628
Coping	RES-between	0.14	0.06	0.02	0.25	0.99	228	628
Coping	PR-between	-0.002	0.07	-0.13	0.13	0.48	228	628
Coping	Day	-0.11	0.02	-0.16	-0.07	-	228	628
IOS	Intercept	4.32	0.09	4.15	4.50	-	228	628
IOS	RES-within	0.13	0.05	0.04	0.22	1.00	228	628
IOS	PR-within	0.36	0.06	0.24	0.48	1.00	228	628
IOS	RES-between	0.07	0.08	-0.09	0.23	0.82	228	628
IOS	PR-between	0.73	0.09	0.57	0.90	1.00	228	628
IOS	Day	0.03	0.03	-0.03	0.09	-	228	628
Sleep Quality	Intercept	4.88	0.12	4.65	5.11	-	142	297
Sleep Quality	RES-within (lagged)	0.04	0.08	-0.11	0.19	0.69	142	297
Sleep Quality	PR-within (lagged)	0.08	0.09	-0.10	0.26	0.82	142	297
Sleep Quality	RES-between	0.11	0.11	-0.11	0.33	0.83	142	297
Sleep Quality	PR-between	0.14	0.12	-0.09	0.38	0.88	142	297
Sleep Quality	Day	-0.03	0.06	-0.14	0.09	-	142	297

Table 8: Summary of results from Study 5, with unstandardized coefficients *(continued)*

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Sleep Quality	Sleep Duration	0.30	0.05	0.20	0.41	-	142	297
Task Motivation	Intercept	5.46	0.10	5.26	5.66	-	228	592
Task Motivation	RES-within	0.11	0.06	0.003	0.22	0.98	228	592
Task Motivation	PR-within	0.02	0.06	-0.09	0.14	0.65	228	592
Task Motivation	RES-between	0.20	0.09	0.03	0.37	0.99	228	592
Task Motivation	PR-between	-0.007	0.09	-0.20	0.18	0.47	228	592
Task Motivation	Day	-0.04	0.03	-0.11	0.03	-	228	592
Task Performance	Intercept	5.06	0.08	4.90	5.22	-	228	592
Task Performance	RES-within	0.04	0.04	-0.04	0.13	0.83	228	592
Task Performance	PR-within	-0.01	0.05	-0.11	0.09	0.41	228	592
Task Performance	RES-between	0.21	0.07	0.07	0.35	1.00	228	592
Task Performance	PR-between	0.001	0.08	-0.15	0.15	0.51	228	592
Task Performance	Day	-0.05	0.03	-0.11	0.009	-	228	592

Note:

RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. N_Subj = Number of subjects in analysis. Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 9: Summary of differences in effects of RES and PR, Study 3

Type	DV	RES-PR	SE	Lower	Upper	Post_Prob
Within	Support Effectiveness	0.17	0.09	-0.01	0.36	0.97
Within	Negative Mood	-0.21	0.09	-0.38	-0.04	0.99
Within	Positive Mood	0.05	0.09	-0.12	0.23	0.72
Within	Coping	0.07	0.06	-0.05	0.19	0.88
Within	IOS	-0.34	0.08	-0.49	-0.19	1.00
Between	Support Effectiveness	0.12	0.12	-0.12	0.36	0.84
Between	Negative Mood	-0.08	0.15	-0.39	0.22	0.69
Between	Positive Mood	0.41	0.14	0.14	0.68	1.00
Between	Coping	0.01	0.11	-0.21	0.23	0.54
Between	IOS	-0.53	0.17	-0.86	-0.18	1.00

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Type = Type of effect (within-person or between-person). Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 10: Summary of differences in effects of RES and PR, Study 4

Type	DV	RES-PR	SE	Lower	Upper	Post_Prob
Within	Support Effectiveness	0.11	0.14	-0.16	0.39	0.78
Within	Negative Mood	0.05	0.12	-0.19	0.28	0.34
Within	Positive Mood	-0.13	0.13	-0.39	0.12	0.16
Within	Coping	0.10	0.09	-0.08	0.27	0.87
Within	IOS	-0.17	0.10	-0.38	0.04	0.95
Within	Sleep Quality	0.18	0.20	-0.20	0.57	0.82
Between	Support Effectiveness	0.03	0.13	-0.23	0.30	0.60
Between	Negative Mood	-0.27	0.17	-0.61	0.06	0.94
Between	Positive Mood	0.48	0.15	0.18	0.77	1.00
Between	Coping	0.05	0.13	-0.20	0.30	0.65
Between	IOS	-0.43	0.18	-0.78	-0.07	0.99
Between	Sleep Quality	0.28	0.22	-0.16	0.71	0.90

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Type = Type of effect (within-person or between-person). Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 11: Summary of differences in effects of RES and PR, Study 5

Type	DV	RES-PR	SE	Lower	Upper	Post_Prob
Within	Support Effectiveness	0.01	0.12	-0.23	0.25	0.54
Within	Negative Mood	-0.10	0.10	-0.29	0.10	0.84
Within	Positive Mood	0.08	0.11	-0.14	0.31	0.77
Within	Coping	-0.05	0.07	-0.19	0.09	0.24
Within	IOS	-0.23	0.09	-0.41	-0.05	0.99
Within	Sleep Quality	-0.04	0.14	-0.32	0.23	0.38
Within	Task Motivation	0.09	0.09	-0.09	0.27	0.83
Within	Task Performance	0.05	0.08	-0.10	0.21	0.75
Between	Support Effectiveness	-0.09	0.10	-0.30	0.11	0.18
Between	Negative Mood	-0.02	0.13	-0.27	0.23	0.55
Between	Positive Mood	0.17	0.12	-0.06	0.40	0.93
Between	Coping	0.14	0.11	-0.09	0.36	0.88
Between	IOS	-0.66	0.15	-0.95	-0.38	1.00
Between	Sleep Quality	-0.03	0.20	-0.43	0.37	0.44
Between	Task Motivation	0.20	0.16	-0.11	0.52	0.90
Between	Task Performance	0.21	0.13	-0.05	0.46	0.94

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Type = Type of effect (within-person or between-person). Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Random Effects

In addition to generating predicted effects for the average person (fixed effects), our multilevel analysis also enabled us to obtain a distribution of subject-specific effects (random slopes; for complete summaries, see Appendix A). Although most studies of psychological processes tend to focus on fixed effects, examining subject-specific effects can provide a more complete picture of the phenomenon by revealing the degree of between-subject heterogeneity (Bolger et al., 2019). In the diary studies, we allowed each subject to have their own slopes for within-person RES and within-person PR. Because there is only one value per subject for between-person RES and PR, these values cannot be used to generate subject-specific slopes.

Using guidelines specified by Bolger et al. (2019), suggesting that heterogeneity is noteworthy if the size of the random effect (in standard deviation units) is at least 25% the size of the fixed effect, we found that there was noteworthy heterogeneity in the effects of RES and PR across all diary studies and all outcomes. In all cases, the random effects exceeded this threshold. For some variables, the size of the random effect was even larger than the size of the fixed effect. Capitalizing on our use of Bayesian models, we also generated posterior distributions corresponding to the ratio of the size of the random effect to its corresponding fixed effect as a way to further understand the degree of between-subject heterogeneity in these effects; details are provided in Appendix A for the interested reader.

Thus, there was noteworthy between-subject heterogeneity indicating that, despite the pattern of results suggested by the fixed effects, some subjects showed very strong effects of RES and PR, others showed weak effects or no effect, and some even showed reversals in these effects. This is consistent with other work demonstrating that there is widespread between-subject heterogeneity in daily support processes (Gleason et al., 2008; Shrout et al., 2010). Although beyond the aims of the present investigation, the presence of such heterogeneity suggests there may be important moderators of the effects of RES and PR, and we return to this point in the general discussion.

Discussion

Studies 3-5 examined the effects of RES in daily life. Results suggested that RES was generally related to higher perceptions of support effectiveness, lower negative mood, higher positive mood, and better coping. These effects were largely found both within-person, indicating that daily fluctuations in RES were related to support outcomes, and between-person, indicating that experiencing higher (*vs.* lower) levels of RES across the diary period was also related to support outcomes. RES was also associated with IOS across studies. In addition, and as expected, PR predicted IOS and did so to a stronger degree than RES.

Studies 4-5 also included additional outcomes relevant to effective self-regulation. Sleep quality was assessed in Studies 4 and 5, given that sleep has been proposed as an important antecedent to self-regulation (Baumeister, 2003; Hagger, 2010). However, effects of RES and PR on sleep were inconclusive. Although there were some trends suggesting that both within-person and between-person RES was related to better sleep, there was some uncertainty regarding these effects. It is important to note that fewer observations were available for our analyses of sleep due to lagging. Therefore, it could be that more observations are needed to detect potential effects of RES on sleep quality. Future research using a longer diary period to increase the precision of the estimated effects of RES would be a useful direction for future work.

Study 5 also assessed participants' goal pursuit by asking them to identify an ongoing academic task and report on their daily task motivation and anticipated performance. Both within-person and between-person RES were positively related to daily motivation. Moreover, between-person RES was also linked to better anticipated performance. Although this study did not examine actual goal attainment, the results nevertheless suggest the role of RES in predicting self-regulatory outcomes.

Although results were largely consistent across these studies, there were also some unexpected inconsistencies. First, although within-person RES was related to higher positive mood in Studies and 3, this effect in Study 4 study was small, and zero could not be ruled out as a possible value. Second, although the differences between the effects of RES and PR pointed in the anticipated direction for the most part, there were some instances in which we found reversals, with effects pointing in the opposite direction than was hypothesized.

Although we can only speculate as to the reasons for these inconsistencies, it is possible that, because these were diary studies, unmeasured variables besides the quality of support received each day influenced participants' mood, coping, feelings of self-other overlap, and sleep, making it more difficult to detect a differences between the effects of RES and PR. We attempted to reconcile these inconsistencies by meta-analyzing results across studies.

Study 6

The next step was to test RES in actual support interactions where the support environment could be better controlled. This was the aim of Study 6. Romantic partner dyads attended a laboratory session together and engaged in social support discussions.

Methods

Participants

One hundred and four romantic partner dyads participated in a laboratory session[10]. As this study was conducted to investigate multiple hypotheses, we aimed to recruit about 100 couples plus a few extra to allow for potential data loss. Power calculations performed after data collection suggested that this sample size would provide approximately 80% power to detect effects that were small-medium in size ($f^2 = .08$) or larger.

Participants were recruited via campus flyers, a university paid participant pool, and online advertisements (e.g., websites of campus organizations, Craig's List, etc.). To be eligible for the study, couples needed to have been in a romantic relationship for at least one year. They were also required to be cohabiting, which was a requirement for a different part of this study not related to the present hypotheses. Lastly, both partners were required to be proficient in English. Participants were paid $50 per couple.

There was one participant who participated twice, with a different partner each time. The two dyads containing this participant were excluded prior to analysis. There was also one dyad that withdrew their data from the study. The final sample consisted of 101 dyads ($N = 202$ individuals). There were 90 opposite-sex couples, eight same-sex couples (two male-male, six female-female), and three couples in which one member did not identify as male or female. On average, participants were 27 years old ($SD = 5.8$) and had been in a relationship for about 4 years ($SD = 3.2$).

Procedure and Materials

Upon arrival, dyad members were taken to separate testing rooms to indicate informed consent and complete individual difference and relationship measures. The partners were then reunited to complete a discussion of a shared goal. The individual difference measures and relationship measures were included to investigate hypotheses unrelated to those presented in this paper and will not be discussed further. Similarly, the goal discussion was also included to investigate a different hypothesis; as it was not designed to examine support processes and did not include measures of support, RES, or PR, it will not be discussed further.

Central to the present hypotheses, participants were next asked to complete a questionnaire in which they identified an ongoing stressful issue. They were able to choose any issue, as long as it was not related to their romantic relationship. Dyads then completed two social support discussions. One partner

[10] As a pilot, we performed secondary analyses on a dataset from a study of friend dyads' laboratory support discussions that used a paradigm similar to Study 6. However, there was a less clear pattern of results. Details are provided in Zee at al. (2020), Supplemental Materials.

was randomly assigned to be the recipient and was instructed to discuss the issue they had described in the previous questionnaire. Their partner was assigned to be the provider, and was instructed to help the recipient in any way that seemed appropriate. Dyads then had five minutes to converse about the recipient's issue. Dyads switched roles for the second support interaction, so that each person had the opportunity to both receive support for their issue and to provide support to their partner. Out of 202 total possible support discussions, participants completed 199 support discussions. All dyads completed the first support discussion, but there were three dyads that did not complete the second support discussion due to time constraints.

After each support discussion, both partners answered questions about the discussion they had just completed. Only ratings made when participants were in the role of support recipient were examined in our analyses.

Regulatory Effectiveness of Support

After each support discussion, participants were asked to respond to the RES measure, with items asked specifically in regards to the discussion they had just completed (truth: $\alpha = 0.92$; control: $\alpha = 0.88$; RES: Spearman-Brown $\rho = 0.75$).

Perceived Responsiveness

Participants also responded to a three-item measure of PR, the same one that was used in Studies 3-5. These items were also asked specifically in regards to the support discussion they had just completed ($\alpha = 0.86$).

RES and PR were moderately correlated, $r = 0.5$, 95% CI [0.39, 0.6]. Correlations among other variables are provided in Appendix A.

Support Effectiveness

Perceptions of support effectiveness were assessed with two items: *"How effective was the help you were offered by your partner?"* and *"How useful was the help you were offered by your partner?"* (1 = *Not at all*, 7 = *Extremely*; Spearman-Brown $\rho = 0.94$).

Mood

Participants indicated how negative (two items; Spearman-Brown $\rho = 0.77$)[11] and positive (four

[11] Additional mood items were measured. Items were selected based on results of an exploratory factor analysis.

items; $\alpha = 0.76$) they felt about their issue prior to the support discussions. After each support interaction, they again rated how negative (Spearman-Brown $\rho = 0.82$) and positive ($\alpha = 0.81$) they felt using the same items (1 = *Not at all*, 7 = *Extremely*).

Inclusion of the Other in the Self

IOS was again measured on a scale ranging from 1 (*No overlap*) to 7 (*Near complete overlap*). Participants were asked to make their rating based on how they felt towards their partner during the support discussion.

Closeness

Closeness was also measured as a relational outcome. Although IOS is sometimes presented as a measure of closeness, it is also related to many other relationship constructs (A. Aron et al., 1992). In this sample, IOS and closeness were only moderately correlated, $r = 0.4$, 95% CI [0.27, 0.51], suggesting that they were not empirically synonymous. For this reason, we opted to examine closeness and IOS as separate outcomes. Both at the beginning of their participation and after the support discussion in which they received support, participants responded to the item *"How close do you feel to your partner"?* (1 = *Not at all*, 7 = *Extremely*).

Observational Coding

Following data collection, four trained research assistants watched video footage of participants' support discussions and coded the degree of RES and PR observed during each discussion. Out of 199 support discussions, 191 videos were available for coding. The remaining eight videos were not coded due to corrupted video files or inadequate sound quality. Of the 191 support videos available, 92% were coded by all four coders, and 98% were coded by at least three coders.

Coders rated the degree of RES and PR observed during each discussion using the scheme described below. All ratings were made on a scale ranging from 1 (*not at all evident*) to 7 (*extremely evident*). Coders were asked to take into account the frequency, duration, and magnitude of each behavior across the whole discussion when making their ratings. Discrepancies were resolved through discussion. Coders also provided repeated-measures ratings of RES and PR in 30-second intervals. These ratings were collected to investigate a research question regarding support and temporal dynamics that is beyond the scope of this paper. As they were not analyzed for this paper, they will not be discussed further.

Inter-rater reliability for global ratings of RES and PR were assessed using an intraclass correlation. We used a two-way model to assess agreement (Shrout & Fleiss, 1979). This treats both rows of data and coders as random effects and assumes that coders are sampled from a population of possible coders. ICCs were computed using the mean composites for RES (truth and control) and PR (caring, validation, and understanding).

Coder-Rated Regulatory Effectiveness of Support

Coder-rated RES was assessed using a coding scheme developed for the present research. Coders indicated the degree of truth and control observed during each discussion. For truth, coders indicated the degree to which the provider *"helped recipient better understand the true nature of their issue/situation. Recipient gains a different perspective or changes his/her way of seeing or thinking about the situation. Helps the recipient figure things out. Provides confirmation or verification of what is truly/actually going on."* For control, coders indicated the degree to which the provider *"enabled the recipient to better manage their issue. Provider helps the recipient come up with a plan of action, think about specific steps he/she needs to take, feel more confident or competent. Provider attempts to boost recipient's sense of efficacy regarding the problem."* There was adequate inter-rater reliability for the RES composite, ICC(A, 4) = 0.85.

Coder-Rated Responsiveness

Coder-rated responsiveness was assessed using an adapted version of the global responsiveness coding scheme developed by Maisel and colleagues (2008). This coding scheme assesses responsiveness by obtaining ratings for caring, validating, and understanding. Examples of dimensions from this coding scheme included: *"Provider listens attentively, gathers information about the event"* (understanding), *"Provider expresses that he or she values and respects the recipient... validates partner's emotion"* (validation), and *"Provider expresses care and affection... expresses sympathy, and expresses empathy"* (caring). For a complete description of this coding scheme, see work by Maisel and colleagues (2008). As with the self-reported items, although both RES and PR involve understanding, RES involves altering the *recipients'* understanding of the *situation*, whereas PR involves the *provider* conveying understanding of the *recipient* and his or her thoughts and feelings. There was adequate inter-rater reliability for the PR composite, ICC(A, 4) = 0.79.

Coder-rated RES and coder-rated PR were moderately correlated, $r = 0.28$, 95% CI [0.15, 0.4].

Results

Analytic Approach

Data were analyzed using Bayesian multilevel modeling with partners nested in dyads. Generally, we did not find gender differences, nor did we have *a priori* predictions regarding differential effects for male partners and female partners. As such, we treated dyads as indistinguishable in these analyses. We examined the effects of PR and RES entered as simultaneous predictors and modeled a compound symmetry correlation structure, which assumes that residual variances are equal for partners within a dyad and estimates the residual correlation of dyad members' outcomes (D. A. Kenny, Kashy, & Cook, 2006). We then tested whether the effects of PR and RES differed from each other. Unstandardized coefficients, standard errors, credibility intervals, and posterior probabilities are displayed in Tables 12 and 13, and results are displayed in Figure 9.

Effects of Self-Reported RES and PR

Support Effectiveness

As a check on construct validity, we first examined effects of RES and PR on perceptions of support effectiveness. Both higher RES, $b = 0.68$, 95% CI [0.57, 0.79], and higher PR, $b = 0.25$, 95% CI [0.12, 0.38], predicted higher perceived support effectiveness. The effect of RES on perceptions of support effectiveness was stronger than the effect of PR, $b = 0.43$, 95% CI [0.22, 0.64].

Negative Mood

We then examined the effects of RES and PR on negative mood, controlling for baseline negative mood. There was a main effect of RES, such that as RES increased, negative mood decreased, $b = -0.30$, 95% CI [-0.47, -0.13]. There was no main effect of PR, $b = 0.000$, 95% CI [-0.20, 0.20]. The effect of RES on lower negative mood was stronger than the effect of PR, $b = -0.30$, 95% CI [-0.63, 0.02].

Positive Mood

We also examined the effects of RES and PR on positive mood, controlling for baseline positive mood. There was a main effect of RES, such that as RES increased, positive mood increased, $b = 0.32$, 95% CI [0.19, 0.45]. There was an effect suggesting that higher PR was related to higher positive mood, $b = 0.11$, 95% CI [-0.04, 0.26]. The effect of RES on higher positive mood was stronger than the effect of PR, $b = 0.21$, 95% CI [-0.04, 0.45].

IOS

Both higher RES, b = 0.31, 95% CI [0.14, 0.47], and higher PR, b = 0.48, 95% CI [0.28, 0.67], predicted higher IOS. Results suggested that the effect of PR on IOS was stronger than the effect of RES, b = -0.17, 95% CI [-0.48, 0.15], and although the credibility interval for this effect included zero, the posterior probability (0.85) suggested a negative effect, reflecting a stronger effect of PR than RES.

Closeness

We then examined closeness as an additional relational outcome, controlling for baseline closeness. We found effects of both higher RES, b = 0.10, 95% CI [0.01, 0.19], and higher PR, b = 0.37, 95% CI [0.27, 0.48], on feelings of closeness. Moreover, the effect of PR on closeness was stronger than the effect of RES, b = -0.27, 95% CI [-0.44, -0.11].

Table 12: Summary of results from Study 6, with unstandardized coefficients

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Support Effectiveness	Intercept	5.21	0.07	5.07	5.34	-	101	200
Support Effectiveness	RES	0.68	0.06	0.57	0.79	1.00	101	200
Support Effectiveness	PR	0.25	0.07	0.12	0.38	1.00	101	200
Support Effectiveness	Residual Correlation	0.09	0.07	0.004	0.24	-	101	200
Negative Mood	Intercept	2.63	0.10	2.43	2.83	-	101	199
Negative Mood	RES	-0.30	0.09	-0.47	-0.13	1.00	101	199
Negative Mood	PR	0.000	0.10	-0.20	0.20	0.50	101	199
Negative Mood	Pre Neg. Mood	0.47	0.05	0.36	0.57	-	101	199
Negative Mood	Residual Correlation	0.05	0.04	0.001	0.16	-	101	199
Positive Mood	Intercept	3.88	0.08	3.73	4.04	-	101	199
Positive Mood	RES	0.32	0.07	0.19	0.45	1.00	101	199
Positive Mood	PR	0.11	0.08	-0.04	0.26	0.93	101	199
Positive Mood	Pre Pos. Mood	0.56	0.06	0.44	0.68	-	101	199
Positive Mood	Residual Correlation	0.06	0.05	0.002	0.18	-	101	199
IOS	Intercept	4.96	0.10	4.76	5.16	-	101	200
IOS	RES	0.31	0.09	0.14	0.47	1.00	101	200
IOS	PR	0.48	0.10	0.28	0.67	1.00	101	200
IOS	Residual Correlation	0.10	0.07	0.005	0.26	-	101	200
Closeness	Intercept	6.41	0.06	6.29	6.52	-	101	200
Closeness	RES	0.10	0.05	0.01	0.19	0.98	101	200
Closeness	PR	0.37	0.05	0.27	0.48	1.00	101	200
Closeness	Pre Closeness	0.27	0.07	0.13	0.41	-	101	200
Closeness	Residual Correlation	0.18	0.10	0.009	0.39	-	101	200

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. N_Subj = Number of subjects (dyads) in analysis. N_Obs = Number of observations in analysis. Residual correlation is correlation of the residuals for partners within a dyad. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 13: Summary of differences in effects of RES and PR, Study 6

DV	RES-PR	SE	Lower	Upper	Post_Prob
Support Effectiveness	0.43	0.11	0.22	0.64	1.00
Negative Mood	-0.30	0.16	-0.63	0.02	0.97
Positive Mood	0.21	0.13	-0.04	0.45	0.95
IOS	-0.17	0.16	-0.48	0.15	0.85
Closeness	-0.27	0.08	-0.44	-0.11	1.00

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

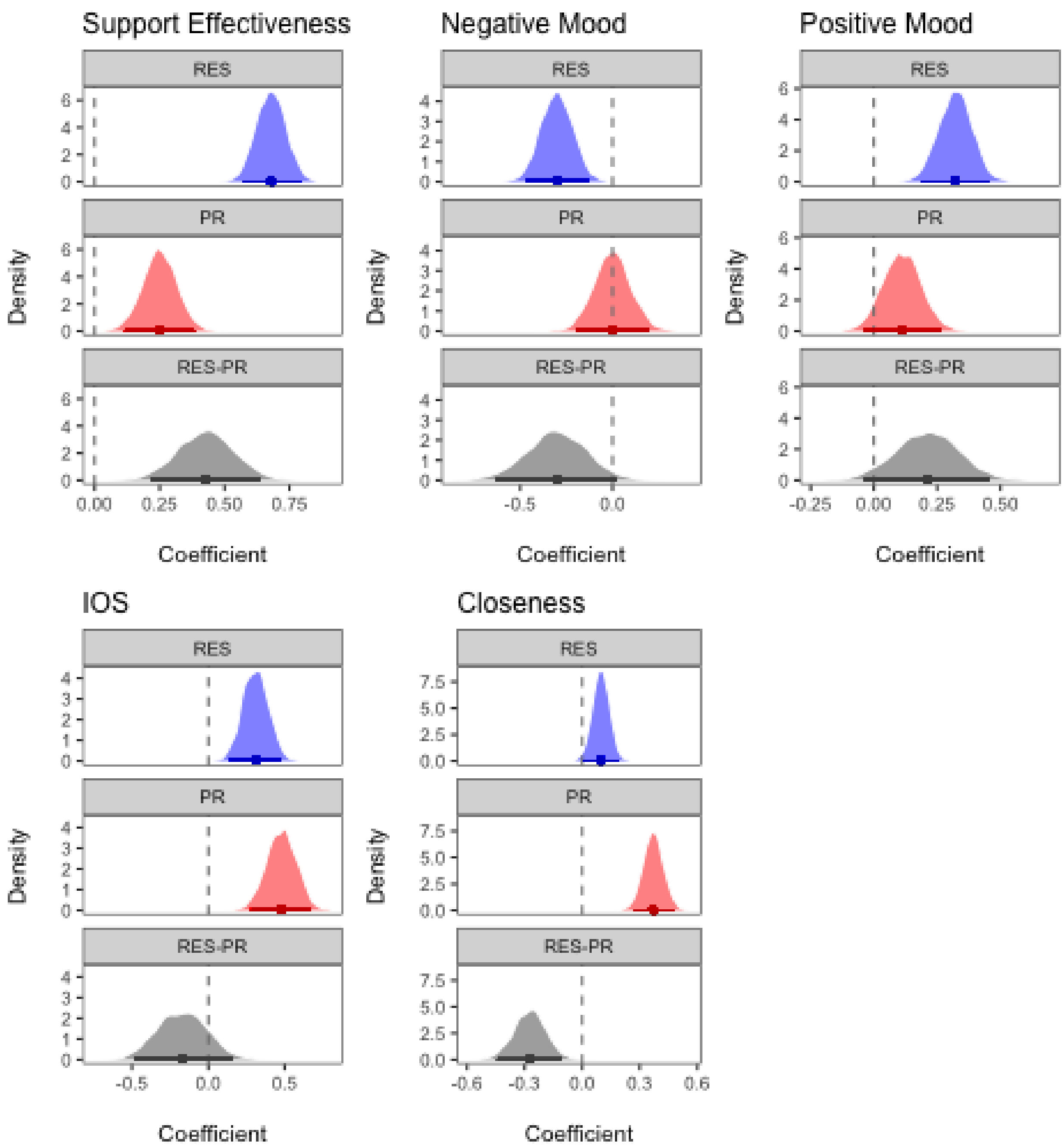

Figure 9: Posterior distributions of effects of self-reported regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 6. IOS = Inclusion of Other in the Self.

Effects of Coder-Rated RES and PR

As a next step, we performed similar analyses using coder-rated RES and PR to predict recipients' self-reported outcomes. This provided an opportunity to test whether the effects of RES and PR could be predicted using objective, observer ratings of these variables. This also helped ensure that effects of RES and PR were not due to psychological overlap between these constructs and our support outcomes. Results are summarized in Figure 10 and Tables 14 and 15

Support Effectiveness

Coder-rated RES predicted higher recipient perceptions of support effectiveness, $b = 0.55$, 95% CI [0.25, 0.86]. In contrast, coder-rated PR was only weakly associated with recipients' ratings of support effectiveness, and zero could not be excluded as a plausible value, $b = 0.07$, 95% CI [-0.26, 0.41]. Results further suggested that the effect of coder-rated RES on support effectiveness was stronger than the effect of coder-rater PR, $b = 0.48$, 95% CI [-0.01, 0.99].

Negative Mood

Higher coder-rated RES predicted lower negative mood, $b = -0.50$, 95% CI [-0.80, -0.19]. However, coder-rated PR was only weakly related to recipients' negative mood, and zero could not be excluded as a plausible value, $b = -0.07$, 95% CI [-0.43, 0.29]. The effect of coder-rated RES on negative mood was larger than the effect of coder-rated PR, $b = -0.42$, 95% CI [-0.95, 0.11], and although the credibility interval for this difference included zero, the posterior probability (0.94) pointed strongly in favor of a stronger effect of RES.

Positive Mood

High coder-rated RES predicted higher positive mood, $b = 0.26$, 95% CI [-0.003, 0.53]. Higher coder-rated PR was related to higher positive mood as well, though to a somewhat lesser degree, $b = 0.19$, 95% CI [-0.12, 0.49]. The effect of coder-rated RES on positive mood was larger than effect of coder-rated PR, but this difference was small and zero could not be excluded as a plausible value, $b = 0.07$, 95% CI [-0.38, 0.54].

IOS

Higher coder-rated RES was related to higher IOS, but zero could not be excluded as a plausible value, $b = 0.24$, 95% CI [-0.11, 0.59]. In contrast, higher coder-rated PR was related to higher IOS, $b = 0.38$, 95% CI [-0.004, 0.77]. There was a trend suggesting a stronger effect of coder-rated PR on IOS, but zero could not be excluded as a plausible value, b = -0.14, 95% CI [-0.73, 0.44].

Closeness

Coder-rated RES was not related to recipients' feelings of closeness to the support provider, b = 0.03, 95% CI [-0.16, 0.22]. In contrast, coder-rated PR was predicted greater closeness, b = 0.29, 95% CI [0.08, 0.49]. The effect of coder-rated PR on closeness was stronger than the effect of coder-rated RES, b = -0.26, 95% CI [-0.57, 0.06], with a posterior probability of 0.95 in favor of a stronger PR effect.

Table 14: Summary of results using coder-rated RES and PR, Study 6, with unstandardized coefficients

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Support Effectiveness	Intercept	5.19	0.11	4.97	5.41	-	100	191
Support Effectiveness	Coder-Rated RES	0.55	0.16	0.25	0.86	1.00	100	191
Support Effectiveness	Coder-Rated PR	0.07	0.17	-0.26	0.41	0.66	100	191
Support Effectiveness	Residual Correlation	0.21	0.11	0.01	0.42	-	100	191
Negative Mood	Intercept	2.63	0.11	2.42	2.84	-	100	190
Negative Mood	Coder-Rated RES	-0.50	0.16	-0.80	-0.19	1.00	100	190
Negative Mood	Coder-Rated PR	-0.07	0.18	-0.43	0.29	0.66	100	190
Negative Mood	Pre Neg. Mood	0.45	0.06	0.34	0.57	-	100	190
Negative Mood	Residual Correlation	0.06	0.05	0.002	0.20	-	100	190
Positive Mood	Intercept	3.88	0.09	3.71	4.05	-	100	190
Positive Mood	Coder-Rated RES	0.26	0.13	-0.003	0.53	0.97	100	190
Positive Mood	Coder-Rated PR	0.19	0.15	-0.12	0.49	0.90	100	190
Positive Mood	Pre Pos. Mood	0.64	0.06	0.52	0.77	-	100	190
Positive Mood	Residual Correlation	0.06	0.05	0.002	0.19	-	100	190
IOS	Intercept	4.95	0.12	4.72	5.20	-	100	191
IOS	Coder-Rated RES	0.24	0.18	-0.11	0.59	0.91	100	191
IOS	Coder-Rated PR	0.38	0.20	-0.004	0.77	0.97	100	191
IOS	Residual Correlation	0.13	0.09	0.005	0.32	-	100	191
Closeness	Intercept	6.42	0.07	6.27	6.56	-	100	191
Closeness	Coder-Rated RES	0.03	0.10	-0.16	0.22	0.62	100	191
Closeness	Coder-Rated PR	0.29	0.11	0.08	0.49	1.00	100	191
Closeness	Pre Closeness	0.40	0.09	0.24	0.57	-	100	191
Closeness	Residual Correlation	0.26	0.13	0.02	0.49	-	100	191

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. N_Subj = Number of subjects (dyads) in analysis. N_Obs = Number of observations in analysis. Residual correlation is correlation of the residuals for partners within a dyad. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 15: Summary of differences in effects of coder-rated RES and coder-rated PR, Study 6

DV	RES-PR	SE	Lower	Upper	Post_Prob
Support Effectiveness	0.48	0.26	-0.01	0.99	0.97
Negative Mood	-0.42	0.28	-0.95	0.11	0.94
Positive Mood	0.07	0.23	-0.38	0.54	0.64
IOS	-0.14	0.30	-0.73	0.44	0.67
Closeness	-0.26	0.16	-0.57	0.06	0.95

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

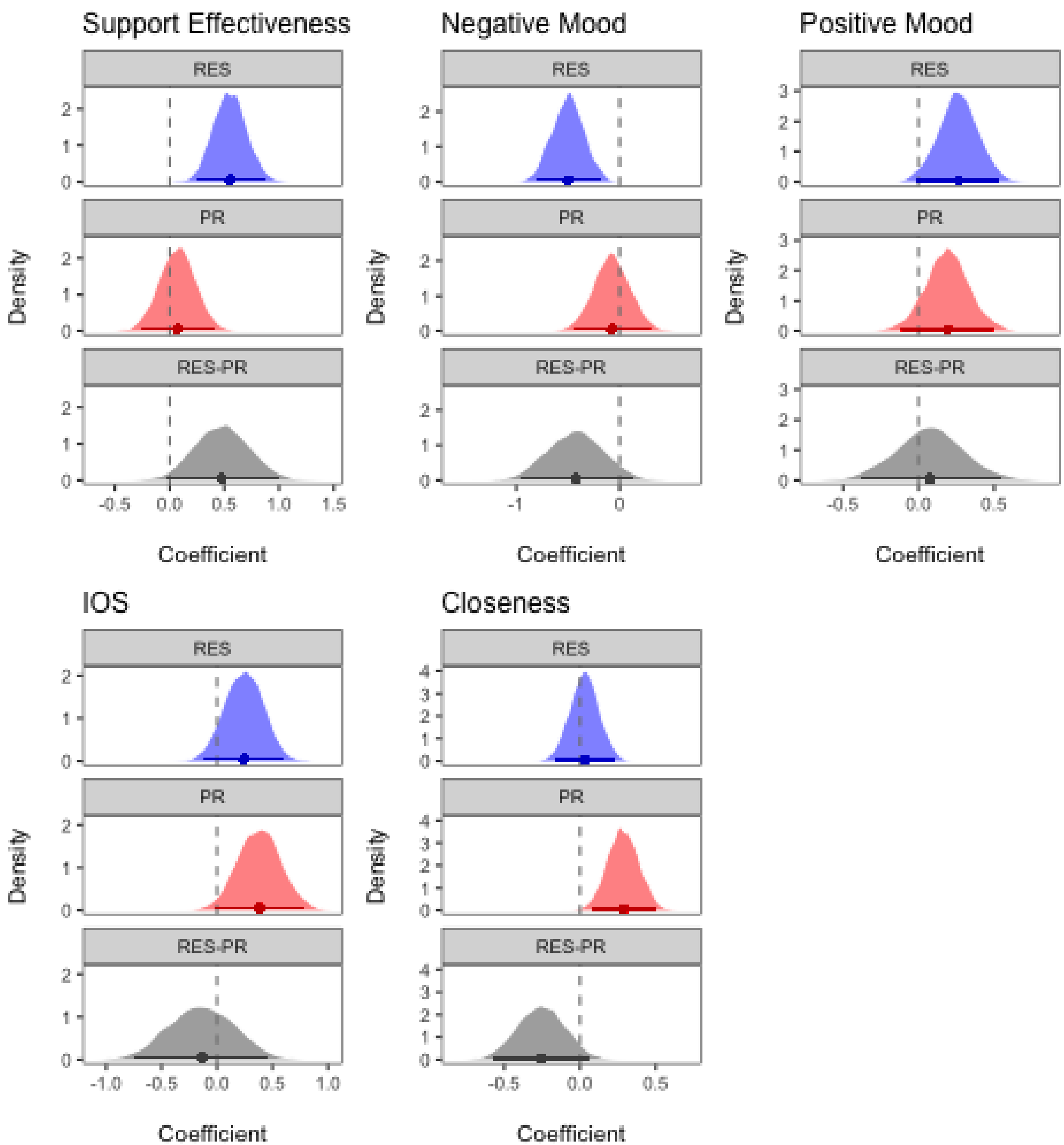

Figure 10: Posterior distributions of effects of coder-rated regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 6. IOS = Inclusion of Other in the Self.

Discussion

Study 6 allowed us to assess the effects of RES in actual support discussions in a controlled laboratory environment. The findings of Study 6 generally provided a clear pattern of main effects and a pattern of differences between the effects of RES and PR. In general, RES more strongly predicted support outcomes with implications for self-regulation, namely mood regulation, and support effectiveness, whereas PR more strongly predicted relational outcomes.

Study 6 also featured observational coding of support behaviors, which provided objective indicators of RES and PR. Results using coder-rated RES and PR generally yielded a pattern of results that was similar to the pattern of results obtained using self-reported RES and PR. By using objective RES and PR, we were able to rule out the possibility that RES and PR effects might have been due to psychological overlap with our dependent measures. Interestingly, we also found that self-reported RES and coder-rated RES, and self-reported PR and coder-rated PR, were only moderately correlated. There may be elements involved in how recipients rate RES and PR that may not be captured by objective measures. Although beyond the aims of the present investigation, examining differences in self-reported and coder-rated support perceptions would be an interesting direction for future work.

Despite this clear pattern, there were a few unexpected findings in Study 6. We hypothesized that PR would more strongly predict relational outcomes than RES, and this hypothesis was supported for closeness. However, this difference was less pronounced for IOS. We were unsure why this was the case, but given theoretical developments regarding the interdependent nature of close relationship partners' self-regulatory pursuits (Fitzsimons et al., 2015), it is possible that IOS could have reflected partners' regulatory interdependence in the Study 6 context. For example, the support received might have involved the provider offering to come up with a plan to help the recipient manage the problem, which may have increased perceptions of self-other overlap if both partners planned to work on this together. Nevertheless, we addressed this and other inconsistencies in a meta-analysis pooling results across studies.

Study 7

As the next step in this investigation, we sought to examine the effects of RES in the face of a laboratory stressor to directly test whether RES would be related to self-regulatory antecedents that would in turn benefit recipients' self-regulatory efforts. We recruited friend dyads and randomly assigned one dyad member to give a stressful speech. Dyads engaged in a support discussion in preparation for the speech, and we examined participants' self-reported support outcomes, speech performance, and cardiovascular reactivity. This study enabled us to give all participants a common goal (performing well on the speech) and assess their responses to the stressor and goal pursuit during a laboratory session. The analysis plan for this study was preregistered via the Open Science Framework (https://osf.io/c4a5g/?view_only=54e56c255f124a61bce5e164c2f1b83a), and the analyses presented were carried out in accordance with this analysis plan unless otherwise noted[12].

Methods

Participants

Friend dyads (N = 110 dyads) were recruited to participate in a study together. Participants were recruited from an undergraduate psychology participant pool, a paid university participant pool, and campus flyers. Participants received two course credits or $15 as compensation.

Power calculations were performed prior to the start of the study to determine sample size. Effect size estimates were based on results from Study 6. Results indicated that a sample of 110 dyads would provide 80% to detect effects comparable in size or larger to the average effect obtained in Study 6 (roughly equivalent to $f^2 = .08$, where $f^2 = .02$ is a small effect and $f^2 = .15$ is a medium effect; J. Cohen, 1992).

Procedure

Upon arrival, dyad members were escorted to separate testing rooms to provide informed consent. Participants then completed a questionnaire consisting of individual difference measures. As these measures were not included to address the present research question and were not included in the preregistered analysis plan, they will not be discussed further.

Participants were then fitted with physiological sensors to measure heart rate. Three electrocardiogram sensors were placed on the torso: one on the upper right torso below the collar bone, one below the lower left rib, and one below the lower right rib. Participants then rested quietly for 5 minutes as their baseline physiology was recorded.

Next, dyad members were reunited and introduced to the study task. They were informed that one dyad member (the "target") would be assigned to give an impromptu speech that would ostensibly be evaluated by an expert. They were told that it was important that they perform was well as possible on the speech. Participants were randomly assigned to role—target or partner—prior to arrival using a random

[12]Effects for all primary dependent variables described in the analysis plan are presented in the main text and Appendix A. Additional secondary analyses and exploratory analyses were also included in the preregistered analysis plan, but were not examined for the purposes of this paper and are not discussed further.

order generator. Participants then completed a brief questionnaire assessing their mood and, for targets, their motivation to perform well on the speech. Then, participants were asked to engage in a five minute support discussion leading up to the speech. Targets were instructed to share their thoughts and feelings regarding the speech, and partners were instructed to simply respond or help in any way that seemed appropriate. After the discussion, participants completed a questionnaire assessing their mood, perceptions of the support discussion (including RES and PR), and motivation to perform well on the speech.

Partners were taken to a separate room for the remainder of the study. Targets were introduced to a research assistant posing as an evaluator. They then had three minutes to deliver their speech, which was video recorded. After a brief recovery period (three minutes), targets completed a final questionnaire regarding the speech. Lastly, dyad members were reunited and were then debriefed, thanked, and paid.

Measures and Materials

Measures and materials used in Study 7 are described below. Although measures were obtained from both targets and partners, we focus exclusively on targets' (recipients') ratings given the goals of the present investigation. In addition, our analysis plan only proposed to examine targets' variables. Reliabilities and other statistics reported below refer to targets' ratings only. Unless otherwise noted, all self-reported variables were assessed between the end of the support discussion and the start of the speech.

Regulatory Effectiveness of Support

Participants responded to the RES measure, with items asked specifically in regards to the support discussion they had just completed (truth: $\alpha = 0.87$; control: $\alpha = 0.86$; RES: Spearman-Brown $\rho = 0.73$).

Perceived Responsiveness

Participants also responded to a three-item measure of the PR, the same one that was used in Studies 3-6. These items were also asked specifically in regards to the support discussion they had just completed ($\alpha = 0.86$).

RES and PR were moderately correlated, $r = 0.51$, 95% CI [0.36, 0.64]. Correlations among other variables are provided in Appendix A.

Support Effectiveness

Perceptions of support effectiveness were assessed with the same items that were used in Study 6: *"How effective was the help you were offered by your partner?"* and *"How useful was the help you were offered by your partner?"* (1 = *Not at all*, 7 = *Extremely*; Spearman-Brown $\rho = 0.93$).

Mood

In this study, mood was assessed using the Profile of Mood States (POMS) (Terry, Lane, & Fogarty, 2003). We selected this measure because it has been used previously in studies of social support and laboratory stressors with similar paradigms (Bolger & Amarel, 2007) and is known to change reliably within-persons (Cranford et al., 2006). There were eight items assessing negative mood (pre-support: $\alpha = 0.83$; post-support: $\alpha = 0.83$) and four items assessing positive mood (pre-support: $\alpha = 0.82$; post-support: $\alpha = 0.86$)[13].

Motivation for Speech

Participants' motivation to perform well on the speech was measured twice: before and after the support discussion. Motivation was assessed with one item: *"I am motivated to perform well on the speech"* (1 = *Not at all*, 7 = *Extremely*)

Inclusion of the Other in the Self

IOS was again measured on a scale ranging from 1 (*No overlap*) to 7 (*Near complete overlap*). Participants were asked to make their rating based on how they felt towards their partner during the support discussion.

Closeness

Closeness was again measured as a relational outcome. Participants indicated how close they felt to their partner both at the start of the study and then again after each support interaction. In this study, IOS and closeness were moderately correlated, $r = 0.29$, 95% CI [0.11, 0.46]. Both at the beginning of their participation and after the support discussion, participants responded to the item *"How close do you feel to your partner"?* (1 = *Not at all*, 7 = *Extremely*).

[13]There were slightly fewer observations available for analysis for the negative mood items, positive mood items, and the motivation item. This is because five participants mistakenly completed a questionnaire corresponding to another study. This other questionnaire was almost identical to the questionnaire for the present study, but it used different mood items and did not ask about motivation.

Discussion Helpfulness for Speech

After the speech, participants were asked to indicate how much they thought their discussion with their partner had helped them with their speech (1 item): *"To what extent did the discussion with your partner help you with your speech?"* (1 = *Not a all*, 7 = *Extremely*).

Observational Coding: Speech Performance

Post-data collection, three independent coders viewed and rated videos of participants' speeches. Each coder watched and rated all available speech videos. Out of 110 participants, 106 speech videos were available for analysis; the remaining four videos were not coded due to corrupted video files or inadequate sound quality.

Coders rated speech performance using the scheme described below. All ratings were made on a scale ranging from 1 (*not at all evident*) to 7 (*extremely evident*). Coders were asked to take into account the frequency, duration, and magnitude of each behavior across the whole discussion when making their ratings. Discrepancies were resolved through discussion. Coders also provided repeated-measures ratings speech performance in 60-sec intervals; these ratings were collected to investigate a research question about temporal dynamics that is beyond the scope of this paper. Therefore, they will not be discussed further.

Coder-rated speech performance was assessed using a coding scheme developed for the present research[14]. We focused on two dimensions of nonverbal speech performance. The first dimension was eye contact, indicating how much the participant looked at the evaluator while giving the speech. The second dimension was nervous movement, such as fidgeting, hair twirling, leg shaking, etc. The nervous movement dimension was reverse-scored, such that higher values corresponded to better nonverbal performance on both dimensions.

Inter-rater reliability for global ratings of speech performance was assessed using an intraclass correlation. As with the Study 6 observational coding data, we used as two-way model to assess agreement (Shrout & Fleiss, 1979). This treats both rows of data and coders as random effects and assumes that coders are sampled from a population of possible coders. ICCs were computed using the mean composites for the indicators of speech performance. There was adequate inter-rater reliability for the speech performance composite, ICC(A, 3) = 0.84.

[14]This coding scheme also included measures of verbal speech quality, such as the fluidity and persuasiveness of the speech, and emotional expressions during the speech. We opted to focus on nonverbal speech performance because we reasoned that our verbal indicator of speech performance were likely related to factors that might not be as easily influenced by a brief support discussion as nonverbal indicators, such as prior experience and comfort with public speaking. Coder-rated expressions of positive emotion and negative emotion were also assessed. However, we did not find strong evidence for effects of RES and PR on these variables. Details are provided in Appendix A.

Cardiovascular Reactivity

Prior to participation, participants were instructed to refrain from caffeine consumption and strenuous exercise for at least two hours before their visit to help ensure the validity of cardiovascular measurements. During the study, participants' cardiovascular responses were measured continuously during key phases of the study: baseline (5 minutes), support discussion (5 minutes), speech (3 minutes), and recovery (a resting period immediately following the conclusion of the speech; 3 minutes). Heart rate waveforms were sampled at 1000 Hz using Biopac's MP150 and ECG module. Data were scored in 30 second intervals using Mindware software (HRV 3.0.25).

We examined inter-beat interval (IBI) as our focal measure of cardiovascular reactivity. IBI is a time-based measure that refers to the average number of milliseconds occurring between each heart period during a specific time window. It is inversely related to heart rate (beats per minute). Leading psychophysiological guides recommend using IBI instead of heart rate because it has more desirable statistical properties (Blascovich, Mendes, Vanman, & Dickerson, 2011). Higher values indicate longer IBIs, and IBIs typically decrease during times of stress, reflecting an increase in heart rate.

Results

Manipulation Check

As a first step, we verified that participants were motivated to perform well on the speech. If so, this would establish that our intent of giving participants a goal to pursue in the laboratory context was successful. Self-reported motivation to perform well on the speech, rated prior to the support discussion, was moderate to high and exceeded the midpoint of the scale (1 = *Not at all*, 7 = *Extremely*, where 4 is the midpoint), $M = 4.49$, 95% CI [4.21, 4.77].

Analytic Approach

Analyses for Study 7 were carried out according to our preregistration, unless otherwise noted. Analyses were performed using Bayesian linear models with RES and PR entered as simultaneous predictors. We also tested whether the effects of PR and RES differed significantly from each other. Unstandardized coefficients, standard errors, credibility intervals, and posterior probabilities are displayed in Tables 16 and 17. Results are also depicted in Figure 11.

Support Effectiveness

To demonstrate construct validity, we examined the effects of RES and PR on recipients' (targets') perceptions of support effectiveness. Consistent with the results from our earlier studies, RES predicted higher perceptions of support effectiveness, b = 0.71, 95% CI [0.53, 0.89], as did PR, b = 0.24, 95% CI [0.04, 0.42]. The effect of RES on support effectiveness was stronger than the effect of PR, b = 0.47, 95% CI [0.15, 0.82].

Negative Mood

We examined the effects of RES and PR on negative mood, adjusting for negative mood measured prior to the support discussion. There was an effect of higher RES on lower negative mood, b = -0.08, 95% CI [-0.19, 0.03]; although zero could not be excluded as a plausible value for this effect, the posterior probability in favor of a negative association between RES and negative mood was 0.92. PR was weakly and not reliably associated with lower negative mood, b = -0.03, 95% CI [-0.15, 0.09]. The effect of RES on negative mood did not differ from the effect of PR, but did point in the direction consistent with earlier findings, b = -0.05, 95% CI [-0.25, 0.16].

Positive Mood

We next examined the effects of RES and PR on positive mood, adjusting for positive mood measured prior to the support discussion. There was no reliable effect of RES, b = -0.006, 95% CI [-0.17, 0.16], or PR b = 0.04, 95% CI [-0.13, 0.21], on positive mood. The effect of RES on positive mood did not differ appreciably from the effect of PR, b = -0.05, 95% CI [-0.35, 0.25].

IOS

There was an effect of higher RES on higher IOS, b = 0.26, 95% CI [0.004, 0.50]. PR also positively predicted higher IOS, b = 0.51, 95% CI [0.24, 0.79]. The effect of PR on IOS was larger than the effect of RES, b = -0.26, 95% CI [-0.73, 0.21], with a posterior probability of 0.85 in favor of a stronger PR effect.

Closeness

RES predicted greater closeness, adjusting for pre-support closeness, b = 0.19, 95% CI [0.03, 0.36]. PR also predicted greater closeness, b = 0.26, 95% CI [0.08, 0.45]. However, the difference in these effects was small, b = -0.06, 95% CI [-0.38, 0.24].

Change in Motivation

We next turned to participants' change in motivation to perform well on the speech following the support discussion, controlling for their motivation prior to the support discussion. Similar to results from Study 5, RES positively predicted increased motivation to perform well on the speech, b = 0.37, 95% CI [0.11, 0.63]. However, PR was associated with reduced motivation to perform well on the speech, b = -0.19, 95% CI [-0.47, 0.08]. The effect of RES on increased motivation was stronger than the effect of PR, b = 0.57, 95% CI [0.10, 1.04].

Discussion Helpfulness for Speech

Our next analysis examined participants' perceptions of how much the discussion with their partner had helped them with their speech, as reported after the speech. RES strongly and positively predicted greater perceived helpfulness, b = 0.69, 95% CI [0.42, 0.96]. However, PR was unrelated to helpfulness, b = -0.002, 95% CI [-0.30, 0.28]. Moreover, the effect of RES on perceived helpfulness was stronger than the effect of PR, b = 0.70, 95% CI [0.20, 1.19].

Speech Performance

RES was weakly associated with better objective speech performance, but zero could not be excluded as a plausible value, b = 0.05, 95% CI [-0.11, 0.21]. There was a trend suggesting that PR was related to poorer speech performance, b = -0.13, 95% CI [-0.31, 0.05]. The effect of RES on speech performance was stronger than the effect of PR, b = 0.18, 95% CI [-0.12, 0.48], with a posterior probability of 0.88 in favor of a positive difference.

Table 16: Summary of results from Study 7, with unstandardized coefficients

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Obs
Support Effectiveness	Intercept	5.34	0.08	5.19	5.50	-	110
Support Effectiveness	RES	0.71	0.09	0.53	0.89	1.00	110
Support Effectiveness	PR	0.24	0.10	0.04	0.42	0.99	110
Negative Mood	Intercept	2.32	0.05	2.22	2.42	-	105
Negative Mood	RES	-0.08	0.06	-0.19	0.03	0.92	105
Negative Mood	PR	-0.03	0.06	-0.15	0.09	0.71	105
Negative Mood	Pre Neg. Mood	0.69	0.05	0.59	0.78	-	105
Positive Mood	Intercept	4.17	0.07	4.03	4.31	-	105
Positive Mood	RES	-0.006	0.08	-0.17	0.16	0.47	105
Positive Mood	PR	0.04	0.09	-0.13	0.21	0.68	105
Positive Mood	Pre Pos. Mood	0.93	0.07	0.80	1.06	-	105
IOS	Intercept	5.04	0.11	4.82	5.26	-	107
IOS	RES	0.26	0.13	0.004	0.50	0.98	107
IOS	PR	0.51	0.14	0.24	0.79	1.00	107
Closeness	Intercept	5.72	0.07	5.58	5.86	-	110
Closeness	RES	0.19	0.08	0.03	0.36	0.99	110
Closeness	PR	0.26	0.09	0.08	0.45	1.00	110
Closeness	Pre Closeness	0.52	0.06	0.40	0.63	-	110
Change in Motivation	Intercept	0.36	0.12	0.14	0.59	-	105
Change in Motivation	RES	0.37	0.13	0.11	0.63	1.00	105
Change in Motivation	PR	-0.19	0.14	-0.47	0.08	0.09	105
Change in Motivation	Pre Motivation	-0.43	0.08	-0.60	-0.27	-	105
Help with Speech	Intercept	4.52	0.12	4.28	4.75	-	110
Help with Speech	RES	0.69	0.14	0.42	0.96	1.00	110
Help with Speech	PR	-0.002	0.15	-0.30	0.28	0.49	110
Speech Performance	Intercept	3.87	0.07	3.73	4.01	-	106
Speech Performance	RES	0.05	0.08	-0.11	0.21	0.71	106
Speech Performance	PR	-0.13	0.09	-0.31	0.05	0.06	106

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 17: Summary of differences in effects of RES and PR, Study 7

DV	RES-PR	SE	Lower	Upper	Post_Prob
Support Effectiveness	0.47	0.17	0.15	0.82	1.00
Negative Mood	-0.05	0.11	-0.25	0.16	0.67
Positive Mood	-0.05	0.16	-0.35	0.25	0.39
IOS	-0.26	0.24	-0.73	0.21	0.85
Closeness	-0.06	0.16	-0.38	0.24	0.65
Change in Motivation	0.57	0.24	0.10	1.04	0.99
Help with Speech	0.70	0.26	0.20	1.19	1.00
Speech Performance	0.18	0.16	-0.12	0.48	0.88

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

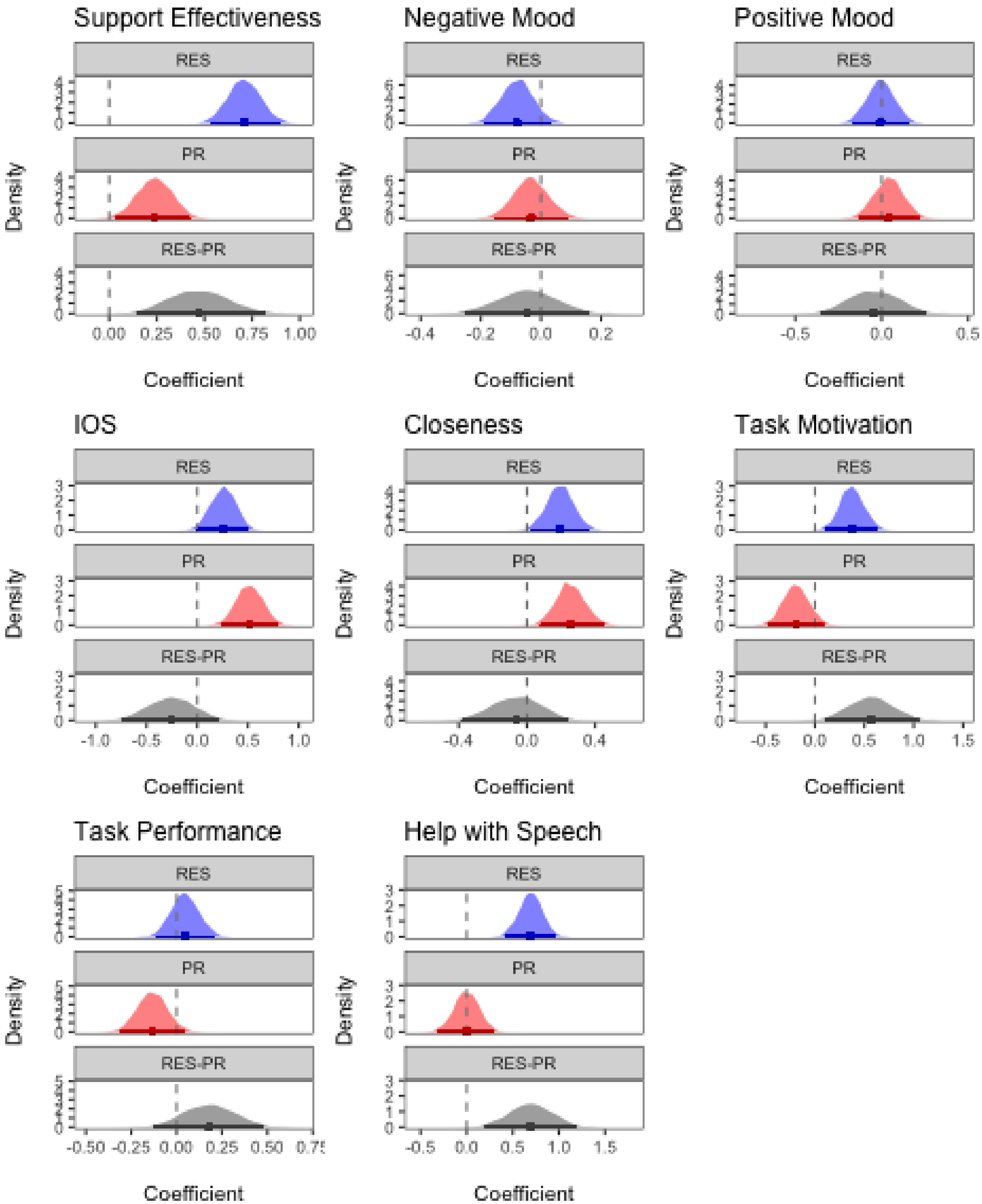

Figure 11: Posterior distributions of effects of self-reported regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR), Study 7. IOS = Inclusion of Other in the Self.

Mediation

Although we did not find conclusive evidence for an effect of RES on speech performance, we reasoned that RES might be associated with better speech performance *indirectly*. We speculated that recipients who were more (*vs.* less) motivated to perform well on the speech would in turn actually perform better. This is in line with our theorizing that RES helps to engender support benefits that in turn matter for effective self-regulation. To explore this possibility, we conducted a mediation analysis to examine whether RES would predict speech performance via increased motivation. Leading guidelines for mediation analysis specify that establishing a direct X to Y link is not a necessary prerequisite for testing for indirect effects (Shrout & Bolger, 2002). We note that although this analysis was theoretically driven, it was not included in our preregistered analysis plan.

We performed a Bayesian mediation analysis in which RES was the focal predictor, change in motivation was the mediator, and speech performance was the outcome. PR and pre-support motivation were included as covariates.

As shown in Figure 12, RES predicted increased motivation to perform well on the speech, a path: $b = 0.31$, 95% CI [0.04, 0.58], and increased motivation, in turn, predicted better speech performance, b path: $b = 0.16$, 95% CI [0.04, 0.28]. There was also an indirect effect of RES on speech performance by way of increased motivation, $b = 0.05$, 95% CI [0.003, 0.12]. This result suggested that RES had a small but reliable effect on objective speech performance via its effect on increased motivation.

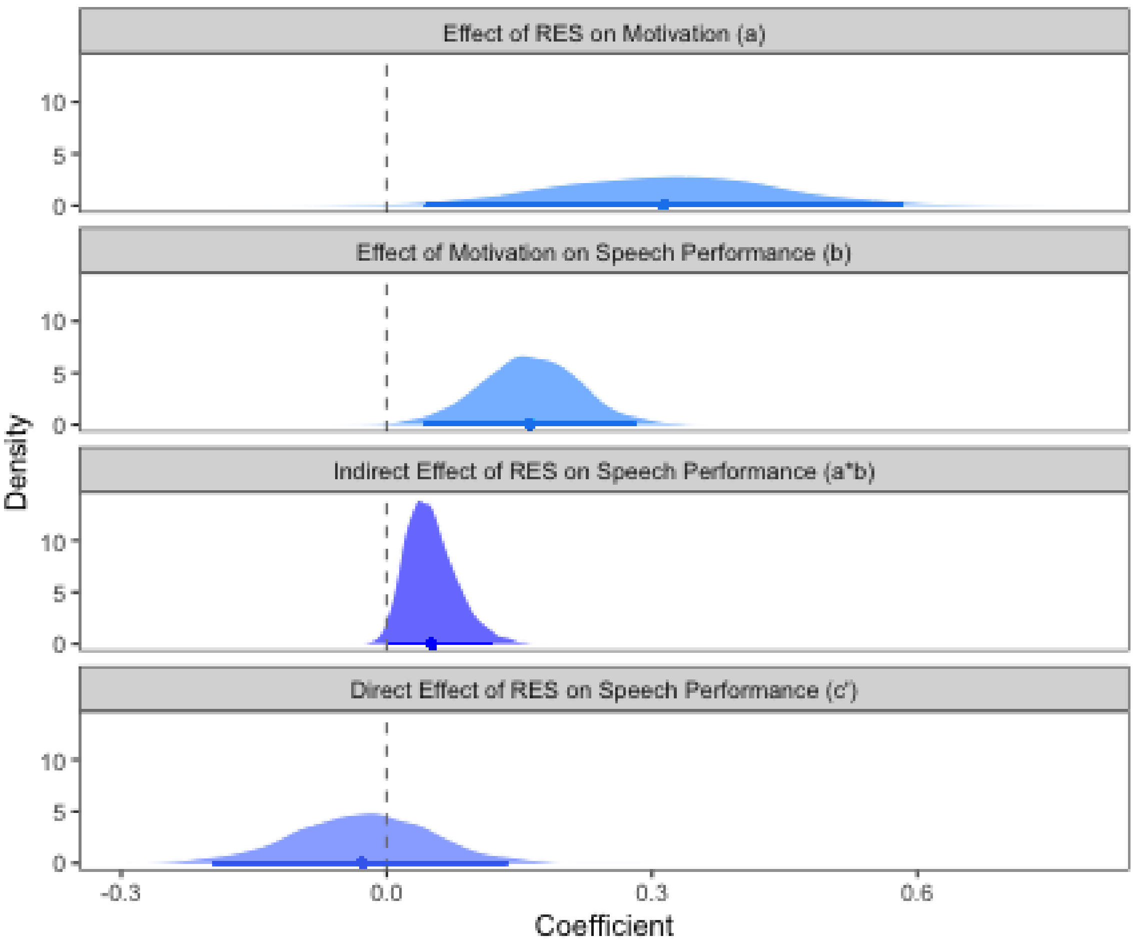

Figure 12: Posterior distributions showing the effect of regulatory effectiveness of support (RES) on coder-rated speech performance via increased motivation to perform well on speech, Study 7. The two upper panels show (a) the effect of RES on increased motivation and (b) the effect of increased motivation on speech performance. The two lower panels show the indirect effect (a*b) of RES on speech performance by way of increased motivation and the direct effect (c') of RES on speech performance adjusting for increased motivation.

Cardiovascular Reactivity

We next examined participants' cardiovascular responses[15]. Because cardiovascular (inter-beat interval; IBI) data were obtained as repeated-measures, this enabled us to examine within-person changes in IBI, as well as potential between-person differences in IBI changes as a function of RES and PR. This also allowed us to use cardiovascular data from across the study as a whole in the analysis to help increase the precision of our estimates.

In accordance with our analysis plan, IBI values falling more than 3 SD from the mean were removed prior to analysis. We fit a multilevel model to examine the effects of study phase, RES, and PR on IBI[16]. Study phase was represented by three pairs of dummy variables comparing the speech phase (reference group) to each of the other phases (Dummy 1: baseline *vs.* speech; Dummy 2: support *vs.* speech; Dummy 3: recovery *vs.* speech). Study phase, RES, PR, all two-way interactions between RES and each of the phase variables, and all two-way interactions between PR and each of the phase variables were entered as fixed effect predictors. The model also allowed for random intercepts and random slopes of study phase for each subject. Results are summarized below, and more details regarding the results of this analysis, including fixed effect estimates for the other predictors and random effect estimates, and provided in Appendix A.

Results revealed within-person differences in IBI between the speech phase and each of the other study phases, such that the average participant exhibited lower IBI during the speech relative to the baseline period, $b = 135.50$, 95% CI [115.32, 156.54], the support discussion, $b = 58.22$, 95% CI [45.77, 70.63], and the recovery period, $b = 137.24$, 95% CI [120.46, 154.12]. This is consistent with findings from the stress and psychophysiology literatures indicating that socio-evaluative stressors reliably elicit physiological stress responses (Dickerson & Kemeny, 2004), reflected by lower IBI during the speech in this case. There was substantial between-subject heterogeneity in these effects, however, with some participants showing much larger decreases in IBI across phases and others showing an increase.

We next examined whether the pattern of within-person changes in IBI depended on levels of RES

[15]In this sample, there were 3 participants who reported having a diagnosed cardiovascular condition (e.g., heart murmur, arrhythmia). However, rerunning this analysis removing these participants did not change the pattern of results appreciably.

[16]When we began analyzing our cardiovascular data, we realized that our analysis plan was not specific enough about how this multilevel analysis should be implemented. Our analysis plan proposed to analyze the cardiovascular data using a multilevel model testing for interactions of RES and PR with time, but did not indicate how time would be represented in the model. Because our goal was to assess cardiovascular reactivity during the speech (i.e., how much participants' response changed in the speech compared to the other phases), we opted for the analysis presented above so that time would be represented by the different temporal phases of the study. Using this approach meant that each of the other phases could be compared directly to the speech. Examining contrasts in this way is recommended over using an omnibus test when there is a specific comparison group in mind (Rosenthal & Rosnow, 1985). In addition, this approach, in which we entered time as experimental phases represented by dummy variables, draws directly on approaches that two authors have used previously to analyze cardiovascular data for class demonstrations. We also note that although our analysis plan did not specify an error structure, we implemented an AR(1) autoregressive error structure due to the temporal ordering of the cardiovascular measurements. Finally, rerunning the analysis with extreme values included did not change the results appreciably.

and PR. We tested for interaction effects between the contrasts comparing the speech phase to each of the other phases and RES, and between these contrasts and PR. We found that the change in IBI from the support discussion to the speech was moderated by RES, b = -11.44, 95% CI [-25.47, 2.62] (see Figure 13). This effect suggested that while the typical participant's IBI was 58.22 ms lower (faster) during the speech compared to during the support discussion (indicating an increase in heart rate during the speech), the size of this decrease in IBI was smaller for participants who received support higher on RES—that is, there was lower stress reactivity for participants higher on RES. Specifically, for participants who received support +1 SD higher on RES than average, the decrease in IBI between the support discussion and speech was only 45.56 ms. The posterior probability for this effect was 0.94, suggesting relatively strong evidence in favor of an attenuating effect of RES on physiological reactivity between the support discussion and speech. Capitalizing on our Bayesian approach, we also performed additional analyses assessing posterior probabilities of interaction effects across all study phases to gain a more holistic understanding of the implications of RES for cardiovascular reactivity; details are provided in Appendix A.

The interaction effects involving PR were all small and positive, suggesting somewhat higher stress reactivity for participants who received support higher on PR, although zero could not be excluded as a plausible value for these effects.

Discussion

Study 7 examined the effects of RES and PR as participants prepared for and underwent a controlled laboratory stressor, an impromptu speech. Results indicated that RES predicted higher perceptions of support effectiveness, increased motivation to perform well on the speech, and greater perceptions of how much the discussion had helped recipients with their speech.

Contrary to results from the prior studies, however, we were unable to confidently conclude that RES was associated with higher positive mood in this study. The effect pointed in the expected direction, but did not enable us to conclude that the effect was non-zero. This was unexpected, but there are a few possible explanations as to why the positive mood results might not have perfectly replicated those obtained in the earlier studies. One possibility is that this discrepancy is due to our having used a different measure of mood in this study compared to the other studies. It is also possible that the study context of Study 7 played a role. Study 7 was the only study that was designed to examine social support for an impending laboratory stressor with a pronounced evaluative component. Prior work has found that explicit social support offerings can be costly when evaluation concerns are salient (Zee et al., 2018). Thus, it is possible that even good

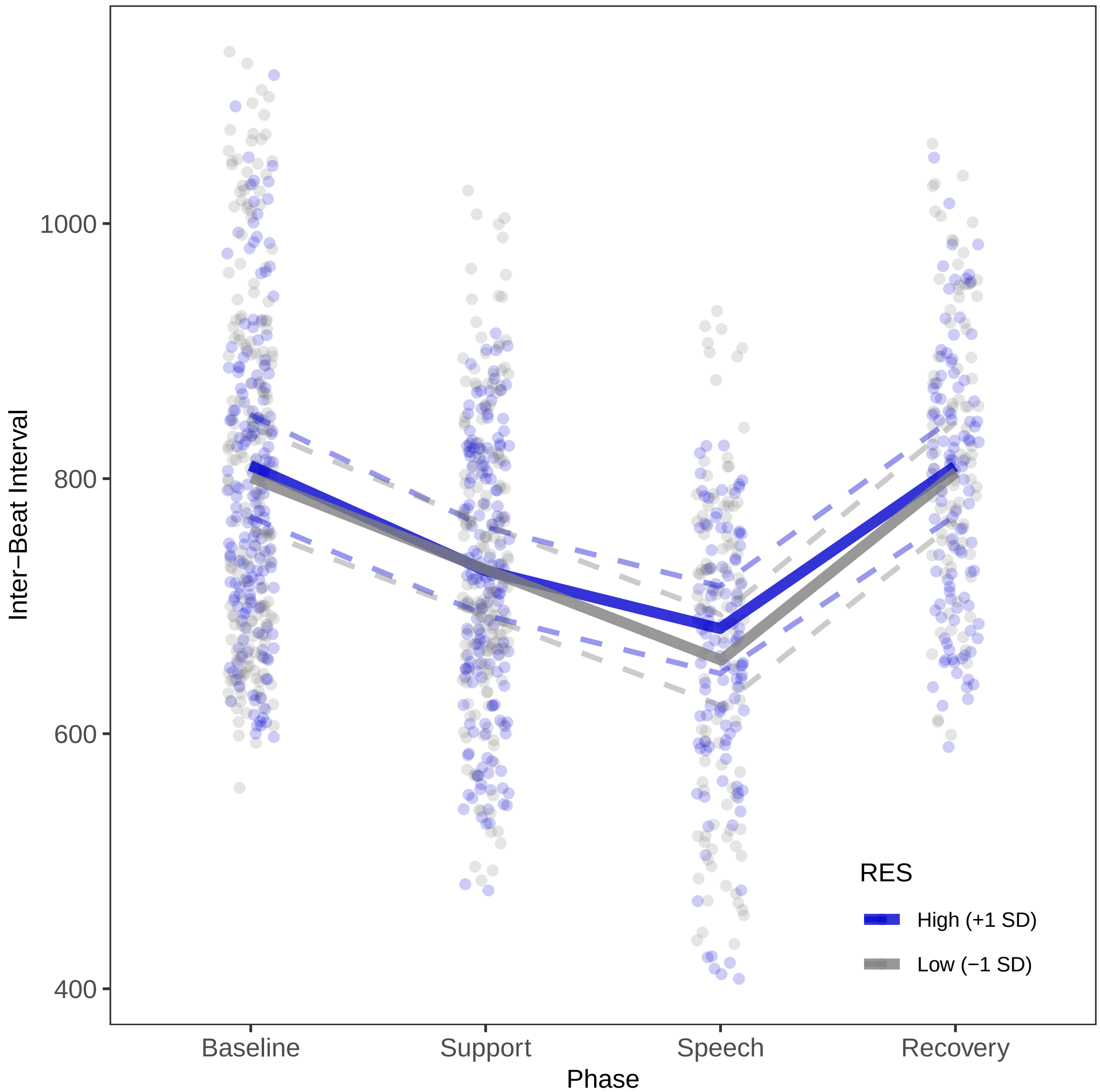

Figure 13: Predicted effects of high (+1 SD) and low (-1 SD) RES on cardiovascular reactivity across study phases, Study 7. Dark lines and points show high RES, and light lines and points show low RES. Raw data points are jittered, and points falling within +/- 1 SD from the mean are not shown for clarity of presentation. Dashed lines show 95% credibility intervals for predicted lines.

quality social support, such as support high on RES or PR, might be ineffective at lifting positive mood in this context for the average person.

Study 7 also provided an opportunity to draw new inferences regarding RES. We found some evidence for a beneficial effect of RES on speech performance. We found that RES was associated with better speech performance (as rated by independent coders) by way of increased motivation to perform well on the speech. This result is in line with our theorizing that RES plays an important role in fostering psychological outcomes, such as increased motivation, that in turn contribute to effective self-regulation, such as performance on a demanding task.

We also found preliminary evidence that RES might be related to physiological self-regulation. Although the average participant exhibited greater cardiovascular stress during the speech compared to during the support discussion (operationalized as decreases in IBI), we found an interaction effect whereby participants who received support higher (*vs.* lower) on RES showed less reactivity (i.e., smaller decreases in IBI). Although this effect was somewhat small and therefore warrants some caution, it is promising and invites additional study into the physiological and health implications of RES. Future work should aim to replicate this and other physiological effects of RES.

Meta-Analysis

Overall, results across one retrospective study, three daily diary studies, and two dyadic laboratory studies suggested that RES predicted beneficial social support outcomes, even when accounting for another construct with known implications for the effectiveness of enacted support, namely PR. Results also provided some mixed evidence for differential effects of RES and PR: Whereas in some cases RES more strongly predicted self-regulation relevant variables and PR more strongly predicted relationship relevant variables, in other cases these differences were less pronounced.

The final step in the present investigation was to meta-analyze results across studies. There were two main goals of this meta-analysis. First, as noted above, there were a few studies in which the pattern of results did not perfectly align with our hypotheses. For example, in Study 7, we did not find an association between RES and higher positive mood, despite generally finding such an association in the previous studies. Thus, meta-analyzing results across studies offered an opportunity to clarify the overall pattern of results. Second, the meta-analysis also enabled us to better gauge the size of our effects and to ascertain whether there was noteworthy effect size heterogeneity across studies and types of dependent variables. Finally, the meta-analysis provided a way to gauge the difference in effect sizes of RES and PR across studies.

Meta-Analytic Approach

Meta-analyses were performed using the *brms* package for R (Burkner, 2017). We conducted a Bayesian random effects meta-analysis that allowed effect sizes to differ across studies and across outcomes. We included crossed random effects, which allowed the model to generate specific predicted effect sizes for a particular outcome in a particular study. This approach is an extension of other work on the utility of crossed random effects (Judd, Westfall, & Kenny, 2012). Another advantage of this meta-analysis approach was that it enabled us to include nearly all of the results obtained across studies in a single meta-analysis. In addition, such an analysis assumes that studies and outcomes were drawn from a larger "population" of studies and outcomes. Doing so enabled us to generate a distribution of possible values that can be expected within this population of studies (e.g., similar types of studies) and outcomes. This can provide insight into the types of effect sizes that can be expected for different measures of outcomes used in this investigation or other similar types of outcomes that we did not examine.

Following current recommendations for Bayesian meta-analysis (D. R. Williams, Rast, & Bürkner, 2018), we used a weakly informative prior distribution, which specified a mean of 0 and a standard deviation of 3 for all parameters; for context, standard errors for coefficients from the models in Studies 2-7 correspond to the standard deviation of the posterior distribution for that coefficient, and these values typically ranged from 0.05 to 0.14 across studies. These values are well under 3.

We conducted three meta-analyses: one analysis to assess the effects of RES across studies and outcomes, a second analysis to assess the effects of PR across studies and outcomes, and a third analysis to assess the difference between RES and PR (RES-PR) across studies and outcomes. We also included variable type (1 = relational variable, 0 = non-relational variable) and level of analysis (1 = within-person effect, 0 = between-person effect) as moderators. We predicted that there would be a non-zero meta-analytic effect of RES. We also predicted that there would be a meta-analytic effect of RES-PR that would depend on the type of dependent variable. Specifically, we anticipated that the effects of RES would be stronger than the effects of PR for self-regulation relevant (non-relational) variables (e.g., mood), but that the effects of PR would be stronger than the effects of RES for relational variables (e.g., closeness). It also seemed plausible that the size of within-person effects might differ from the size of between-person effects for both RES and PR, hence our including level of analysis as an additional moderator.

We included all effects of self-reported RES, PR, and their difference in the meta-analysis.[17] Because

[17]The meta-analysis results presented in the main text included effects on perceptions of support effectiveness. We also reran our meta-analyses excluding this variable, as we had used it to help establish construct validity rather than as an outcome per se. This yielded some slightly smaller effect sizes, but did not change our conclusions. For details, please see Appendix A.

coder-rated RES and PR were only examined in one study, they were not included in the meta-analysis. Similarly, effects on cardiovascular responses were only examined in Study 7 and used a different modeling strategy to account for the repeated-measures data structure, so they were not included in the meta-analysis. Measures of effect size and error were unstandardized coefficients and standard error, respectively, which was feasible given that predictor and outcome variables were measured on the same scale. Coefficients corresponding to effects on negative mood were multiplied by -1 before being entered into the meta-analysis, so that higher numbers would indicate more beneficial effects.

Results

Fixed Effects

Based on our variable coding, intercept values correspond to the predicted between-person effect for a typical self-regulation relevant (non-relational) variable from a typical study. Figure 14 shows the posterior distributions of these meta-analytic effects for RES, PR, and their difference, and results are also displayed in Table 18. As hypothesized, there was a positive meta-analytic effect of RES for a typical non-relational variable from a typical study, $b = 0.29$, 95% CI [0.14, 0.45]. There was also a positive meta-analytic effect of PR for a typical self-regulation relevant (non-relational) variable from a typical study, but we were unable to exclude 0 as a plausible value, $b = 0.08$, 95% CI [-0.05, 0.21]. Moreover, that there was as stronger between-person effect of RES than PR for a typical self-regulation relevant (non-relational) variable from a typical study, $b = 0.16$, 95% CI [0.06, 0.28].

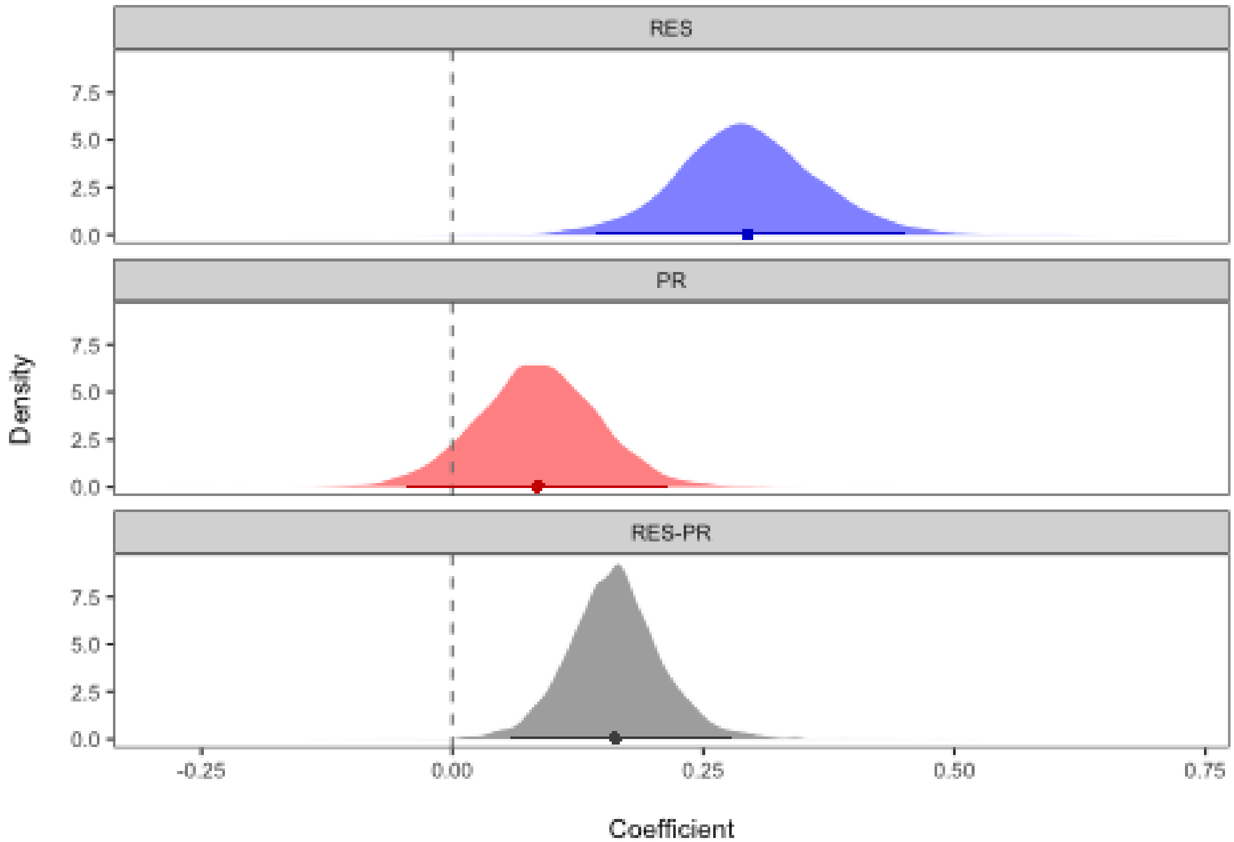

Figure 14: Posterior distributions of meta-analytic predicted effects of regulatory effectiveness of support (RES) and perceived responsiveness (PR) and the difference in their effects (RES-PR). Effects shown are predictions for a between-person effect for a typical non-relational variable in a typical study.

Table 18: Summary of meta-analysis results, fixed effects

Variable	Coefficient	Estimate	SE	Lower	Upper	N_Obs
RES	Intercept	0.29	0.08	0.14	0.45	54
RES	Relational Variable	-0.13	0.15	-0.44	0.17	54
RES	Level of Analysis	-0.07	0.03	-0.12	-0.02	54
PR	Intercept	0.08	0.07	-0.05	0.21	54
PR	Relational Variable	0.35	0.13	0.10	0.60	54
PR	Level of Analysis	-0.03	0.03	-0.08	0.03	54
RES-PR	Intercept	0.16	0.05	0.06	0.28	54
RES-PR	Relational Variable	-0.44	0.07	-0.57	-0.31	54
RES-PR	Level of Analysis	-0.04	0.04	-0.13	0.04	54

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. RES-PR = difference of RES and PR (RES minus PR). Relational Variable is coded as 1 = relational variable, 0 = non-relational variable (self-regulation relevant variable). Level of Analysis is coded as 1 = within-person effect, 0 = between-person effect.

Next, we examined whether the effect of the RES-PR difference would depend on outcome type. Results suggested that effects of RES were somewhat weaker for relational variables, but we were unable to rule out zero as a plausible value, b = -0.13, 95% CI [-0.44, 0.17]. We found an effect of outcome type for the effect of PR, such that the effect of PR was stronger for relational variables, b = -0.13, 95% CI [-0.44, 0.17]. The predicted difference in the effects of RES and PR also depended on variable type. Whereas we had found that RES was a stronger predictor of a typical non-relational outcomes than PR, this difference reversed for relational variables, indicating a stronger effect of PR for relational variables. To illustrate, Figure 15 is a strip plot showing all raw effects (open dots) and model predicted effects (solid dots) of RES-PR obtained across studies and dependent variables. This figure shows how the model predicted effects for the RES-PR difference cluster by variable type, indicating a relatively clear pattern whereby RES more strongly predicts self-regulation relevant outcomes and PR more strongly predicts relational outcomes.

We also computed directional posterior probabilities for the RES-PR difference for each type of outcome. Doing so indicated a posterior probability of 1 in favor of a stronger between-person effect of RES (vs. PR) on a typical self-regulation relevant (non-relational) variable in a typical study, and a posterior probability of 1 in favor of a stronger between-person effect of PR (vs. RES) on a typical relational variable from a typical study. There results further underscore differences in the effects of RES and PR as a function of type of outcome.

Regarding level of analysis, results generally suggested that within-person effects tended to be smaller than between-person effects.

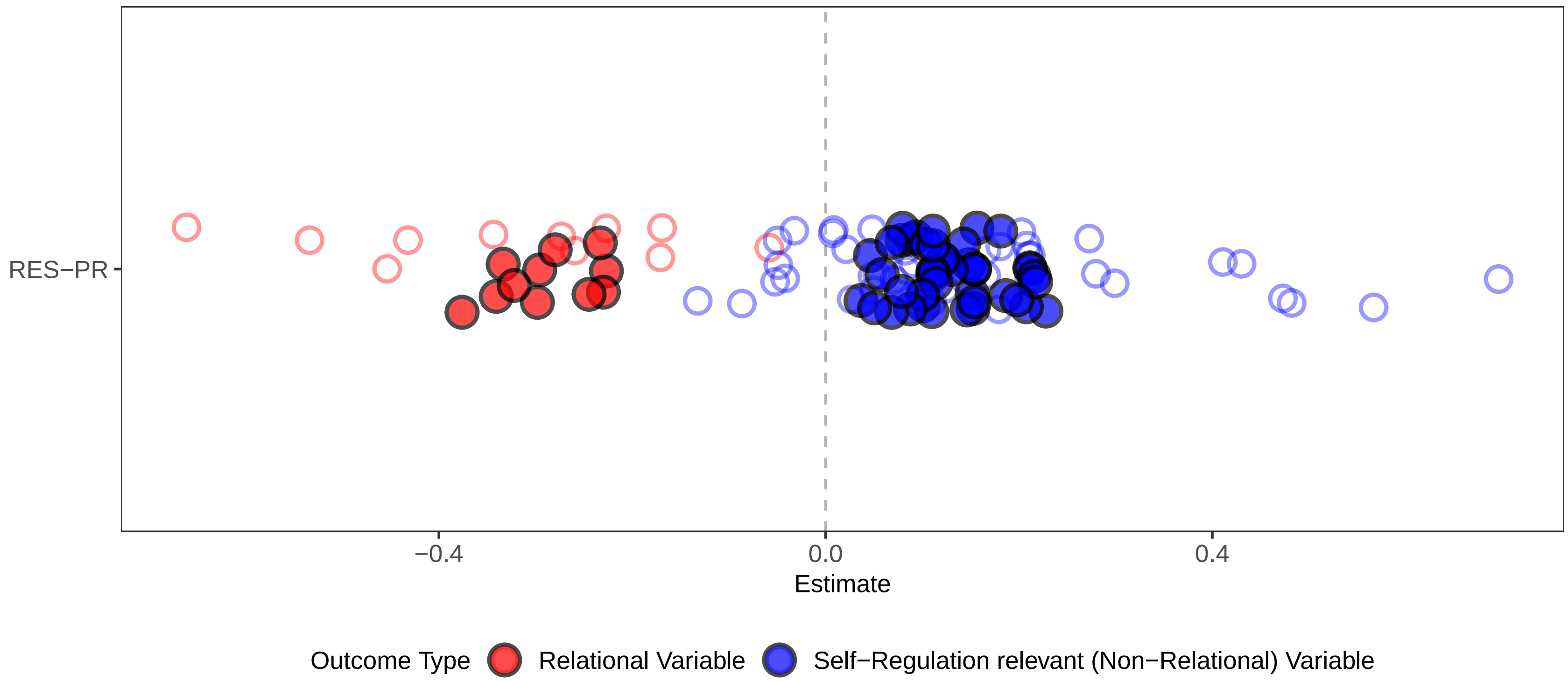

Figure 15: Strip plot displaying observed effects (open dots) and predicted effects (soild dots) for the difference between Regulatory Effectiveness of Support (RES) and Perceived Responsiveness (PR). Positive values indicate a stronger effect of RES, and negative values indicate a stronger effect of PR.

Random Effects

As discussed above, this meta-analysis included random effects that allowed estimates to vary according to study and dependent variable. This provided an opportunity to assess the degree of heterogeneity due to study and heterogeneity due to outcome.

As shown in Table 19, random effects are presented as standard deviations, which can be used to generate a distribution of effects that can be expected from the population of studies and population of outcomes from which we sampled. Using criteria proposed by Bolger and colleagues (2019), indicating that heterogeneity is noteworthy if the size of the random effect (in standard deviation units) is at least .25 the size of the corresponding fixed effect, we generally found noteworthy heterogeneity due to study and noteworthy heterogeneity due to outcome. We further assessed the sources and extent of heterogeneity by leveraging the posterior distributions generated from our Bayesian approach, and details are provided in Appendix A.

Table 19: Summary of meta-analysis results, random effects

Model	Term	Estimate	SE	Lower	Upper
RES	DV SD	0.17	0.07	0.09	0.34
RES	Study SD	0.06	0.05	0.00	0.19
RES	DV x Study SD	0.04	0.03	0.00	0.10
RES	Residual	0.04	0.02	0.00	0.09
PR	DV SD	0.14	0.05	0.08	0.27
PR	Study SD	0.06	0.05	0.00	0.18
PR	DV x Study SD	0.02	0.01	0.00	0.05
PR	Residual	0.05	0.02	0.00	0.09
RES-PR	DV SD	0.03	0.03	0.00	0.11
RES-PR	Study SD	0.08	0.06	0.00	0.23
RES-PR	DV x Study SD	0.03	0.02	0.00	0.09
RES-PR	Residual	0.06	0.03	0.00	0.12

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. RES-PR = difference of RES and PR (RES minus PR). Relational Variable is coded as 1 = relational variable, 0 = non-relational variable (self-regulation relevant variable). SD = standard deviation

General Discussion

Across eight studies and a meta-analysis, we presented evidence for the construct validity, predictive validity, and discriminant validity of a new construct: Regulatory Effectiveness of Support (RES). RES provides insight into the importance of enacted social support that addresses recipients' self-regulatory needs—–in particular, the goal pursuit process needs of truth effectiveness and control effectiveness. We found that RES was not only a reliable predictor of perceptions of support effectiveness, thus helping to establish construct validity, but it also predicted important self-regulation relevant outcomes, such as mood regulation, coping, and increased motivation. We also obtained preliminary evidence that RES is related to important downstream implications: RES predicted increased motivation, which subsequently predicted better performance on a laboratory stressor. Furthermore, the effects of RES on these outcomes were distinct from the effects of perceived responsiveness, a construct that is important for relationship quality and that has been implicated in effective enacted support (Maisel & Gable, 2009; Reis & Gable, 2015).

Together, these findings offer new insight into potential mechanisms underlying effective social support. Moreover, by distinguishing the effects of RES from PR, an existing construct with known importance during enacted support interactions, this work also highlights how different features of support attempts matter for distinct support outcomes. This could, for example, have important implications for developing relationships-based interventions to enhance relationship well-being and personal well-being. An intervention aimed at boosting relationship quality could focus on helping partners provide social support in a more responsive manner, which our results suggest could increase feelings of closeness and self-other overlap. However, an intervention aimed at boosting individuals' ability to cope effectively with stressful situations or pursue an important goal could focus on helping partners provide social support so that it addresses recipients' needs for truth effectiveness and control effectiveness.

Implications for Social Support and Close Relationships Literatures

Although much theoretical work and some empirical work has suggested the importance of support that addresses recipients' needs, most research on this topic has focused on matching support according to type or quantity. The present research advances the notion of support matching by demonstrating the importance of addressing recipients' *self-regulatory* needs. Our findings help to account for the heterogeneity of support's effects (Gleason et al., 2008; McClure et al., 2014; Rafaeli & Gleason, 2009), by revealing that individuals' support receipt outcomes might differ according to the levels of RES and PR characterizing the support. These findings also provide empirical support consistent with recent theoretical perspectives, which have emphasized the role of support in helping individuals to thrive in the face of adversity through processes involved in self-regulation, such as reframing, reconstruction, and persistence (Feeney & Collins, 2015).

Furthermore, our findings extend knowledge of perceived responsiveness by demonstrating its role in predicting relational outcomes. This is in line with results showing that experimentally manipulated responsive support (active-constructive capitalization responding) increased liking and trust of the provider (Reis et al., 2010). This also echoes work on the social sharing of emotion, which has shown that support behaviors emphasizing validation and care were associated with social outcomes more so than with adjustment outcomes (Rimé, 2009). Given that social support is one of the most important features of close relationships, PR in the context of enacted support interactions may play a critical role in fostering and sustaining relationship well-being.

Finally, RES provides a new tool for studying enacted support processes. Although several measures currently exist that assess the perceived availability of social support or assess the frequency and quantity of enacted support, there are fewer measures that were designed to assess the *quality* of enacted support (Wills & Shinar, 2000).

Implications for Self-Regulation Literature

Dyadic aspects of self-regulation have begun to receive increased attention (Fitzsimons & Finkel, 2010; Fitzsimons et al., 2015; Lakey & Orehek, 2011; Orehek & Forest, 2016; Reeck et al., 2016; Zaki & Williams, 2013), and further theoretical and empirical research on these topics seems promising. The present work contributes to the self-regulation literature by specifying that social support is a key channel through which interpersonal regulation occurs and by providing empirical evidence for the proposed theoretical model of RES.

This work also advances the self-regulation literature by specifying what types of outcomes might stem from dyadic regulation processes. Although RES was developed to predict self-regulation relevant outcomes, we found that it also predicted relational outcomes. This builds on work that has identified links between self-regulation and relationship processes (Hofmann, Finkel, & Fitzsimons, 2015; Righetti & Finkenauer, 2011; Vohs, Finkenauer, & Baumeister, 2010). Together, these findings invite additional research on the intersection of the self-regulation and relationships literatures.

Open Questions and Future Directions

There are limitations of the current state of this research program that need to be noted. One limitation is that all studies were correlational. Although intensive longitudinal studies, such as the daily diary studies presented in this paper, provide additional rigor by allowing examination of within-person effects (Bolger & Laurenceau, 2013), causal effects of RES have yet to be established. One challenge will be developing methods of manipulating RES without altering other features of the support process, such as PR, and vice versa. Nevertheless, such manipulations could have important implications for developing social support interventions.

Although beyond the scope of the present paper, individual differences could moderate the effects of RES and PR. Indeed, we found evidence of noteworthy between-subject heterogeneity in the effects of RES and PR in the diary studies, suggesting that individuals differ in the extent to which they benefit from support higher on RES and higher on PR. To illustrate, we consider two examples. First, it seems plausible that attachment might moderate the effects of RES and PR. Individuals high on attachment anxiety worry about being abandoned by their partner, which augments their distress (Simpson & Rholes, 2017). Because PR conveys caring, understanding, and validation, it may be more effective at lessening the distress of highly anxious individuals. Because RES less strongly conveys care and acceptance than PR, it may fail to adequately address their need for reassurance. Second, developmental context could moderate these effects, such that the beneficial effects of RES might be even stronger among older adults compared to younger adults. Older adults become more reactive to stressors, which in turn threatens their health (Charles, 2010). Support high on RES could play a role in helping older adults regulate their stress responses and prevent health declines.

Another open question concerns potential effects of RES in the context of social support for positive events (i.e., capitalization support; Gable & Reis, 2010). It the effects of RES and PR likely differ in this context compared to stressful contexts. When dealing with stressors, self-regulation needs are arguably more pressing, because the recipient needs help returning to baseline. However, when a good event occurs, there is not a need to return to baseline. In fact, if the good event has enhanced positive mood, returning to baseline may even be undesirable. When responding to good events, it is plausible that PR would predict both relational outcomes (e.g., trust, liking; Reis et al., 2010) and up-regulation of positive mood (Gable & Reis, 2010; Gable et al., 2012) more strongly than RES. However, although possibly weaker in its effects in this context, RES might still matter. For example, RES could help recipients understand additional positive implications of their good event that they had not yet considered (e.g., *"Have you realized that for this new* *job you will get to travel more? You love traveling, so that's really great!"*).

Finally, we propose that both facets of RES—truth and control—are integral to successful support interactions, and this was demonstrated empirically in our studies. However, there may be contexts in which the relative importance of these facets shifts (Cavallo et al., 2016; Higgins, 2012). For example, the truth facet might be especially important if individuals are facing an uncontrollable stressor, as they might be less capable of changing their feelings of efficacy (control). Examining potential differences in the need for truth and control in support contexts could offer an interesting future direction.

Concluding Remarks

This work is among the first to develop a construct to capture and assess the effects of receiving social support that addresses recipients' self-regulatory needs to understand their situation (truth) and to feel capable of managing their situation (control). We found evidence in favor of the hypothesis that support that addresses these self-regulatory needs predicts feeling effective, as indicated by support outcomes such as better mood and increased motivation, and that this, in turn, can have implications for successful goal pursuit, such as task performance. These findings enhance the field's understanding of what it means for social support to be beneficial and suggest a novel strategy for tailoring support to address recipients' needs. Ultimately, these findings could help relationship partners more effectively address each other's self-regulatory needs when giving social support and foster better health and well-being over time.

Chapter 3: Social Support and Dyadic Coregulation

Abstract

Close relationships are proposed to function as dynamic regulatory systems, whereby partners jointly regulate each other's emotions and physiology to maintain an equilibrium level of responding——a process known as coregulation. Coregulation is proposed to contribute to well-being, yet little is known regarding when coregulation emerges. We hypothesized that because social support interactions involve explicit interpersonal emotion regulation attempts, they might be especially likely to engender stabilizing and calming patterns of coregulation. We conducted a dyadic laboratory experiment in which romantic couples completed social support and control discussions as cardiovascular responses were measured. To assess physiological self-regulation and dyadic coregulation, we used dynamical systems modeling with Bayesian estimation, which captures the frequency of oscillations around an equilibrium level and changes in amplitudes over time. Results indicated the presence of coregulation across discusisons as a whole, as well as differences in coregulation by discussion type and gender. Self-regulatory and coregulatory dynamics—indicated by patterns of regular oscillations and dcreases in amplitudes as the discussions progressed—were more pronounced during social support (vs. control) discussions, especially when the male partner received support. There was also substantial between-dyad heterogeneity in self- and coregulation, suggesting that some dyads showed pronounced regulatory dynamics whereas other did not. Overall, this work suggests the role of social support as a coregulatory context and offers novel insights into emotional dynamics linking relationships and health[18].

[18] A version of this chapter is currently under review for publication. This chapter draws on content that was published in Zee, K. S. & Bolger, N. (2020b). Using Coupled Oscillators to Examine Physiological Coregulation during Social Support Interactions. *Multivariate Behavioral Research, 55*, 157-158. This chapter also draws on data used in Study 6, Chapter 2 of this dissertation.

Introduction

Social relationships are among the strongest predictors of health and well-being across the lifespan. Being socially integrated and involved in close relationships has been linked to better physical health, mental health, and longevity, and the absence of such relationships poses significant threats to well-being (Holt-Lunstad, 2018; Holt-Lunstad et al., 2010; House, Landis, & Umberson, 1988). A key open question concerns *how* and *why* relationships confer these benefits. In response to this question, theories have proposed that relationships can be beneficial because they function as dynamic regulatory systems, whereby partners' emotional and physiological responses become linked and exert bidirectional influence on each other (Butler, 2011). This intermingling of emotions and physiology—a process known as *coregulation*—is believed to enable individuals to draw on their partner's state as a way of maintaining or restoring an equilibrium level of responding, thereby increasing their regulatory efficiency and effectiveness (Butler, 2011; Butler & Randall, 2013; Sbarra & Hazan, 2008).

Despite the proposed importance of coregulation as a possible explanatory mechanism underlying the beneficial effects of relationships, important questions about coregulation have yet to be answered. As prior work has generally concluded that coregulation is a highly context-sensitive process (Palumbo et al., 2017; Timmons, Margolin, & Saxbe, 2015), one of the most pressing of such questions concerns *when* coregulation emerges.

To address this question, this Chapter investigates physiological self-regulation and dyadic coregulation in couples during different types of dyadic interaction. We examine whether social support interactions might be especially likely to engender stabilizing patterns of coregulation (defined by regular patterns of oscillations around an equilibrium and decreasing amplitudes over time, with responses convering towards equilibrium), as social support typically occurs when people are dealing with stressful events and is characterized by partners' explicit attempts to bring each other back to equilibrium. We further explore possible gender differences in coregulation, as prior research has suggested that men and women in heterosexual relationships differ in the effectiveness of the support they provide to their partners (Bodenmann et al., 2015; Neff & Karney, 2005). Finally, we examine and quantify between-dyad heterogeneity——that is, how couples differ in their patterns of coregulation. Overall, this Chapter addresses critical knowledge gaps by revealing the role of social support in engendering physiological coregulation. In doing so, this research offers new insights into potential mechanisms underlying the benefits of close relationships.

Physiological Linkage in Close Relationships

For decades, interdependence has been considered a defining feature of close relationships, in which partners come to share and mutually influence each other's cognitions, behaviors, emotions, goals, and more (Fitzsimons et al., 2015; Kelley & Thibaut, 1978; Van Lange & Rusbult, 2012). A growing body of research has further suggested that such interdependence can even be observed at the level of emotions and physiology, as manifested through associations in partners' responses over time (Butler, 2011; Palumbo et al., 2017). Broadly, this phenomenon is known as *physiological linkage* (Thorson, West, & Mendes, 2017; Timmons et al., 2015). Although physiological linkage has sometimes been documented in strangers, it is proposed to be most prevalent and consequential in the context of attachment relationships, such as parent-child relationships and adult romantic relationships, which are typically characterized by an emotionally meaningful bond and the expectation of care, comfort, and security (Sbarra & Hazan, 2008).

To date, physiological linkage has been examined in a variety of interpersonal contexts using a diverse range of physiological measures (for reviews, see Timmons et al. 2015 and Palumbo et al. 2017). This has led to the conclusion that physiological linkage can take many forms, which in turn reflect distinct types of psychosocial processes and interpersonal influence (Butler, 2011). For example, linkage may reflect *stress contagion,* whereby physiological responses triggered when one individual experiences a stressor are then transmitted to a partner who did not experience the stressor directly (B. J. Peters & Jamieson, 2016; Waters, West, & Mendes, 2014), or may manifest as concurrent associations in partners' responses to a common stimulus even when they are not presently interacting with each other (Parkinson, Kleinbaum, & Wheatley, 2018), which can be considered a type of *synchrony.*

Coregulation

Coregulation is a particular form of physiological linkage. Coregulation has been defined as "bidirectional linkage of oscillating emotional channels between partners, which contributes to the emotional and physiological stability for both partners in a close relationship" (Butler & Randall, 2013). As this definition suggests, coregulation can be distinguished from some other forms of emotional or physiological linkage in several respects. It differs from processes such as stress transmission or contagion, in that it allows for the possibility of bidirectional[19], as opposed to unidirectional, influence: Partner A may exert an influence on Partner B's responses, and Partner B may also exert an influence on Partner A's responses. It is also proposed to be a stationary or "morphostatic" process, meaning that partners show associations in their responses around a

[19]We note that bidirectional influence is a feature of many forms of physiological linkage and is not exclusive to coregulation.

stable level, without linear increases or decreases in the level of responding over time. In this sense, it can be considered to reflect a homeostatic process rather than an escalating or de-escalating process, as might be observed in other patterns of physiological linkage (e.g., reciprocal and increasing levels of blood pressure in both partners during a heated argument).

Coregulation is also distinct because it is thought to be characterized by patterns of damping oscillations over time, as responses fluctuate around and converge towards an equilibrium level. As such, coregulation is thought to be a process that serves to stabilize and calm relationship partners. This is contrasted with other forms of linkage that are operationalized by strictly linear relationships between dyad members' responses, which are not inherently "good" or "bad," and whose meaning and implications for dyadic functioning can typically only be inferred based on the context being studied (e.g., positive, linear associations in relationship partners' heart rate are likely to reflect reciprocal increases in negativity when observed during a conflict discussion, but are likely to reflect positive emotional connectedness when observed during an eye-gazing task).

Coregulation as a specific form of physiological linkage merits further study for several reasons. First, it is believed to be a uniquely defining feature of close attachment relationships, such as romantic relationships (Sbarra & Hazan, 2008). In contrast to other forms of physiological linkage that are applicable to a wider range of interpersonal interactions, including interactions among strangers, coregulation may be especially relevant to close relationships in particular. It may therefore play a role in explaining how close relationships promote well-being.

Second, despite a rich body of work on physiological linkage generally, there is a dearth of research focusing on coregulation specifically. This may be due to the fact that analyses of coregulation processes require many repeated-measures observations and the use of advanced dynamic modeling approaches to directly capture its hallmark pattern of oscillations and varying amplitudes over time, a point we return to in later sections of this Chapter Furthermore, although a number of papers have used the term *coregulation*, the processes described in most of these papers do not meet all of the current criteria for coregulation, as they did not examine bidirectional damped oscillations.

However, extant research that investigated coregulation according to the current definition (Butler & Randall, 2013) has suggested its potential importance for dyadic functioning and implications for longer-term couple and individual well-being. One study examined coregulation of heart rate and respiration in heterosexual couples as they engaged in a series of laboratory tasks, including an eye-gazing task, in which couples looked into each other's eyes, and an imitation task, in which couples were instructed to try to “mirror each other’s physiology” (Helm, Sbarra, & Ferrer, 2012). Generally, results indicated clear patterns of oscillations in both couple members, the dynamics of which were influenced by partner responding (e.g., when the typical woman’s heart rate increased, the typical man’s heart rate sped up).

Another investigation assessed coregulation of self-reported emotion as heterosexual couples discussed the importance of a healthy lifestyle and how they affected each other’s health behaviors (Reed, Barnard, & Butler, 2015). There was evidence for coregulation in couples, in which the male and female partners showed a pattern of coupled oscillations over time, but such patterns of coregulation depended on couples’ weight status (i.e., whether both partners were normal weight or overweight, vs. whether one partner was normal weight and the other was overweight). Collectively, these studies, and others, demonstrate the oscillatory nature of couples’ emotional and physiological responses across a range of tasks and reveal the potential for cross-partner influence on individuals’ regulatory dynamics.

When does coregulation emerge?

Physiological linkage is known to be context-dependent (Palumbo et al., 2017; Timmons et al., 2015), and both theory and empirical evidence speak to the context-dependent nature of coregulation as well. Theories of emotions in close relationships have posited that coregulation processes are functional: They help individuals regulate themselves more efficiently and effectively (Butler & Randall, 2013; Coan & Maresh, 2014; Sbarra & Hazan, 2008). Therefore, coregulation processes should be relatively more apparent when one partner has been perturbed away from an equilibrium level of responding and, consequently, regulation needs are heightened (Boker & Nesselroade, 2002; Butler, 2011; Butler & Barnard, 2019; Butler & Randall, 2013).

This theoretical proposition is also echoed in work on dynamical systems, a theoretical and modeling framework that is sometimes used to quantify coregulation processes (Butler, 2011; Palumbo et al., 2017). Broadly, dynamical systems models use a combination of a variable’s level and its derivatives to capture nonlinear change on a moment-to-moment basis and can be specified to examine coupled systems involving two interdependent temporal trajectories (Boker, 2012; Boker & Laurenceau, 2006; Helm, Miller, Kahle, Troxel, & Hastings, 2018). Parameters of these models index change processes such as the rate of change (velocity) and speed of change (acceleration/deceleration).

Dynamical systems approaches are useful because they are statistical translations of physical change processes, such as the damped oscillations involved in self-regulation and coregulation of biological systems, given specific starting conditions (Boker, 2012). Importantly, these dynamics are known be most apparent following a displacement from equilibrium, as responses attempt to stabilize towards an equilibrium attractor point (Boker & Laurenceau, 2006). Given this feature of dynamical systems, regulation processes among partners within a dyad should be more likely to emerge when one or both partners have been displaced from equilibrium, such as when experiencing an upsetting or stressful event.

This notion that coregulation may be most pronounced when there has been a disruption to equilibrium may also help explain some inconsistencies in the literatures on physiological linkage and affective interdependence. For example, a recent paper examining the concordance of romantic partners' emotional fluctuations in daily life and in the lab did not find evidence for emotional coregulation (Sels et al., 2019). However, this paper examined coregulation during relatively routine interactions (e.g., in discussions of health behaviors and in everyday life), which presumably did not involve the kind of disruptions that would necessitate a coregulation process; if partners were already at their equilibrium levels, there would be no need for such a process to occur to restore equilibrium. Coregulation may instead be more readily apparent when there is a need for it to occur.

Role of Social Support Discussions

Collectively, theory suggests that disruption to one's physiological equilibrium may be an important precursor to coregulation. However, changes in one partner's physiology are unlikely to directly cause changes in the other partner's physiology or to be due to a disruption to equilibrium alone. Instead, coregulation is likely driven by behaviors enacted during dyadic interaction that play a role in transferring emotional and physiological states between partners. Partners may emit cues, such as expressed emotion or verbal remarks, that are then picked up by the other partner and translate into altered physiological responses (Thorson et al., 2017). Thus, it is important to consider what kinds of interpersonal processes partners are likely to engage in that would involve attunement to each other's inner states and facilitate a return to equilibrium.

Social support discussions may be one such process. Social support discussions involve the exchange of emotional (e.g., reassurance) or practical (e.g., advice) help in response to a particular problem or situation[20]. As this description implies, social support interactions frequently occur when there has been a disruption to a person's equilibrium, triggered by events like recalling an upsetting memory or experiencing a stressor. In addition, social support discussions are frequently characterized by active interpersonal regulation attempts, whereby the support provider might assist in emotion regulation strategies like helping the recipient engage in cognitive appraisal or offering validation and care, often with the explicit goal of helping the support recipient return to a calmer state (Maisel et al., 2008; Reeck et al., 2016; Rimé, 2009; Zee et al., 2020).

[20] Note that actual support behaviors in response to a situation are known as *enacted* social support, which is distinct from another construct known as *perceived* support, which instead refers to individuals' perceptions of generally having supportive relationships (Uchino, 2009). In this Chapter, we discuss enacted support exclusively.

Despite the relevance of social support discussions to coregulation, to our knowledge, they have not been an explicit focus of prior work on coregulation specifically or physiological linkage more generally. Indeed, as noted in a recent review, of the studies examining physiological linkage (broadly defined) during laboratory tasks, most focused on linkage during conflict discussions or problem-solving tasks (Timmons et al., 2015). Although some work has assessed coregulation during discussions that may have included some support behaviors (e.g., discussions of how partners influence each others' health behaviors; Reed et al. (2015)), these discussions also involved other topics and behaviors and therefore did not permit a targeted examination of coregulation in the context of social support discussions specifically.

Nevertheless, theoretical perspectives have speculated that dyadic social support interactions might contribute to the emergence of coregulation (Butler & Randall, 2013). Some empirical work has found that processes often implicated in support interactions, such as perspective taking (Nelson, Laurent, Bernstein, & Laurent, 2016), were linked to stronger physiological linkage in couples. Other work has identified social support variables, such as quantity of support from family and friends, frequency of support, and support seeking, as predictors of changes in widows' emotional trajectories following spousal loss (Bisconti, Bergeman, & Boker, 2006). Although this study did not examine actual dyadic support behaviors, it illustrated the role of social support variables in shaping emotional self-regulation dynamics following a stressful event. Collectively, such findings invite the possibility that dyadic social support discussions might be a context that engenders stabilizing self-regulatory and coregulatory dynamics between partners.

Research Aims and Hypotheses

The present work is the first, to our knowledge, to directly examine coregulation during social support discussions. By comparing physiological processes between couples' discussions that differed in supportiveness, we were able to trace the emergence of physiological self-regulation and coregulation over time. We investigated three aims:

Aim 1: Coregulation across discussions

Our first aim was to assess coregulation across couples' discussions as a whole. We hypothesized that there would be evidence in favor of coregulation, indicated by improvements in model fit when partner effects (statistical parameters capturing the effect of one person's responses on their partner's responses, and vice versa) were modeled vs. not modeled. As these partner effects reflect cross-partner influence, they are an essential component of modeling coregulation.

Aim 2: Coregulation during social support discussions

Our second aim was to further examine differences in patterns of coregulation across discussions and test whether stabilizng patterns of coregulation would be more likely to emerge during couples' social support (vs. control) discussions. We hypothesized that there would be differences in coregulation effects across discussions, indicated by improvements in model fit when allowing such effects to vary by discussion, and that support discussions would be more likely to engender patterns of coregulation that would better help partners return to equilibrium.

We also explored potential gender differences in self- and coregulation trajectories during social support discussions. Prior work on social support among heterosexual couples has suggested that men and women differ in the support they provide to their partners, with women tending to be more effective at providing support to their partners than men (Bodenmann et al., 2015; Neff & Karney, 2005). Other work has indicated that women are more responsive to others' emotions and physiology (Doherty, Orimoto, Singelis, Hatfield, & Hebb, 1995; Scarpa et al., 2018). Thus, we speculated that patterns of coregulation might differ according to whether the male or female partner was receiving vs. providing support.

Aim 3: Between-Dyad Heterogeneity

Our third aim was to assess between-dyad heterogeneity in coregulation effects. Although there is growing recognition that dyads likely differ in the direction, magnitude, and nature of the linkage they exhibit (Butler & Barnard, 2019; Palumbo et al., 2017; Sels et al., 2019), this variability has not traditionally been a primary focus of prior research. Examining such heterogeneity can reveal important insights regarding the generalizability of coregulation patterns, appropriately reflect real-world variability that occurs in dyadic interaction, and signal the presence of important moderators to be examined in future research (Bolger & Zee, 2019a; Bolger et al., 2019). Furthermore, it is possible that heterogeneous responses can explain why there have sometimes been inconclusive or null results regarding coregulation and physiological linkage in dyads: There may have been meaningful patterns of coregulation that were present among a subset of dyads but were not reflected in the patterns found for the average dyad. Thus, documenting and probing the extent of heterogeneity in coregulation processes stands to play an important role in informing understanding of this process and guiding future work.

Dynamical Systems Modeling

Our investigation of these aims was accomplished through the use of dynamical systems modeling with Bayesian estimation. Dynamical systems modeling is a class of analytic techniques that describes how variables change over time. These techniques, which typically involve the use of differential equation models, have shown promise for describing nonlinear within-dyad change over time (Boker & Laurenceau, 2006; Butler & Barnard, 2019; Helm et al., 2012). In particular, coupled damped oscillator models are especially useful for examining within-dyad changes because they feature parameters that can more directly index self-regulation and coregulation processes. They quantify the frequency of oscillations around an equilibrium level (*cycling*) as well as changes in amplitudes and stabilization of amplitudes toward an equilibrium level over time (*damping*), both of which are considered hallmarks of dynamic regulation processes (Butler & Barnard, 2019; Butler & Randall, 2013). In addition, they can also model cross-partner influence—that is, the extent to which partners influence *each other's* patterns of cycling and damping to capture coregulation. We provide a more detailed discussion of our coupled damped oscillator model and use of Bayesian estimation in a later section.

Methods

We used an experimental design in which romantic couples completed a series of support discussions in a laboratory setting. Data from this study were previously used in work by Zee and colleagues (2020b; 2020).

Participants and Sample Size

Couples were recruited for a laboratory study about "couples' communication" via campus flyers, a university paid participant pool, and online advertisements (e.g., websites of campus organizations). Couples were prescreened according to relationship criteria (currently cohabiting and in a romantic relationship for at least one year) and English language proficiency. Participants were paid $25 each ($50 per couple) in exchange for completing a laboratory visit together.

There were 104 couples who completed the study. However, there was one participant who participated twice, with a different partner each time, and one dyad that withdrew from the study. These three dyads were excluded prior to analysis, resulting in a sample of 101 dyads ($N = 202$ individuals). There were 90 opposite-sex (heterosexual) couples, eight same-sex couples (two male-male, six female-female), and three couples in which one member did not identify as male or female. On average, participants were 27 years old

($SD = 5.80$) and had been in a relationship with their partner for about 4 years ($SD = 3.20$).

Sample size determinations were made in regards to separate hypotheses, and we note that this study was not powered *a priori* in regards to the research question discussed in this Chapter. Recent reviews of studies of linkage of autonomic nervous system variables in couples, which is the same type of measure used in the present study, found that sample sizes typically ranged in size from four to 49 dyads (Palumbo et al., 2017) and noted that in papers examining physiological linkage in couples more generally, 71% of studies including 50 or fewer couples (Timmons et al., 2015). Our sample of 101 dyads is substantially larger than the upper bounds identified in these reviews and, specifically, is 2-3 times larger than sample sizes used in prior work that implemented similar paradigms to assess coregulation in couples (Helm et al., 2012; Helm, Sbarra, & Ferrer, 2014; Reed et al., 2015; Reed, Randall, Post, & Butler, 2013).

Procedure

Participants were instructed to refrain from caffeine consumption and strenuous exercise for at least two hours prior to their laboratory visit due to the collection of physiological measures. Upon arrival, partners were escorted to separate rooms. After indicating consent, participants completed measures of health, individual difference, and relationship variables[21]. As these variables were not analyzed in regards to this Chapter, they will not be discussed further. They were then fitted with physiological sensors to measure cardiovascular responses and rested quietly for a 5-minute baseline period.

Next, couple members were reunited and engaged in a series of discussions. First, they completed a 5-minute discussion of a shared goal that they were currently pursuing as a couple. They were asked to select a goal that involved each partner taking on various activities (i.e., it could not be about a goal held by just one partner or a joint goal that only involved tasks completed by one partner). Examples of shared goals that couples discussed included planning a vacation, buying a home, or saving money. Although this discussion was originally designed to probe a separate hypothesis about goal pursuit in couples, it served as a useful control condition for the present research question, as it had several features in common with support discussions (e.g., it was a goal-directed, affiliative discussion) but did not involve clear role differences (provider vs. recipient) or help for one person's stressful issue. Furthermore, this discussion was not intended to have a disequilibrating effect on participants. The control discussion was always completed first in order to prevent any negative affect generated during the support discussions from carrying over or contaminating

[21]As part of the health questions, 11 participants indicated that they had a cardiovascular condition (e.g., high blood pressure, heart murmur, arrhythmia, mitral valve prolapse, or family history of such conditions). Because our analyses involve repeated-measures observations and within-subject comparisons, we retained these participants in our analyses.

the control discussion; similar ordering of discussions has been used in prior work on physiological linkage in couples (Helm et al., 2014).

Next, participants were asked to individually select an ongoing stressful issue. Participants could select any issue they were currently dealing with and found stressful, as long as it did not involve their relationship with their romantic partner. Examples of the issues participants discussed included looking for a job, losing weight, etc. After writing a brief description of and answering some questions about their issue, participants were randomly assigned to role—provider or recipient—via card draw. During a 5-minute support discussion, recipients were instructed to share the issue they had identified in the previous questionnaire with their partner and to talk about their thoughts and feelings regarding this issue. Providers were instructed to respond or help in any way that seemed appropriate.

After the discussion, participants responded to follow-up questions and then switched roles and repeated this procedure. Self-report measures were not analyzed in regards to the present research questions and will therefore not be discussed further. Thus, couples completed three discussions in all: a control discussion and two support discussions. As a feature of our random assignment procedures, the gender order of the two support discussions was counterbalanced, such that for some couples the female partner received support during the first support discussion ($n = 62$), whereas for others the male partner received support during the first support discussion ($n = 39$). All dyads completed at least one support discussion, but three dyads were unable to complete the second support discussion due to time constraints.

Physiological Assessments

During baseline and each discussion, participants' cardiovascular responses were measured continuously. We collected heart rate data using Biopac's MP150 and ECG module. Heart rate waveforms were sampled at 1000 Hz and were scored in 10 second intervals using Mindware software (HRV 3.0.25). This yielded 30 observations per person for each of the three discussion phases—control discussion, female recipient support discussion (F Receives), and male recipient support discussion (M Receives)—for a total of up to 90 observations per participant (180 per dyad) during the discussion phases.

Our investigation focused on inter-beat interval (IBI), which is a time-based measure that refers to the average number of milliseconds between each heartbeat during a given period of time (10 seconds in this study). IBI is inversely related to heart rate and reflects autonomic nervous system activity. Higher values indicate a longer interval (i.e., a slower heart rate), and lower values indicate a shorter interval (i.e., a faster heart rate). IBI values are known to fluctuate with strong temporal sensitivity (it responds rapidly in response to stimuli) and reliably decrease during stress.

Initial IBI Values

As a first step, we examined participants' IBI values at the start of each discussion. We had anticipated that, when they were receiving support, participants should show more pronounced perturbations away from equilibrium (reflected by larger decreases in IBI relative to baseline) at the start of the discussion, relative to the start of the control discussion. Indeed, participants' average IBI was lower (faster) at the start of the support discussion when they received support relative to the control discussion, female partners: $\mu_{diff} =$ -22.48, 95% CI [-38.63, -6.72]; male partners: $\mu_{diff} =$ -11.64, 95% CI [-27.89, 3.64]. Note that although the credibility interval for male partners' difference in IBI included zero, the Bayesian posterior distribution of possible values for this difference (i.e., the percentage of posterior samples falling below 0, as discussed in detail shortly) indicated a 0.93 probability that IBI was lower at the start of the support discussion relative to the control discussion. This provided empirical support for our assumption that prompting participants to share a stressful event as part of the social support discussions would be more disequilibrating compared to engaging in the control discussion.

Analysis Strategy

Coupled Damped Oscillator Model

We modeled physiological changes over the course of the experiment using a coupled damped oscillator model, which, as noted earlier, is ideally suited to examining self- and coregulation because it quantifies changes in the frequency and amplitude of participants' physiological responses around an equilibrium level as a function of their own responses and their partner's responses (Butler & Barnard, 2019). Our model involves two second-order differential equations (Boker & Laurenceau, 2006), one for each dyad partner, and the parameters of the model are allowed to vary randomly from dyad to dyad (to be detailed below). Each equation specifies how the acceleration/deceleration of one partner's IBI scores is a linear function of their own current level and rate of change in IBI and of the other partner's current level and rate of change in IBI.

The basic equations for each dyad partner are:

$$\ddot{x}_t = \eta_{ax} x_t + \zeta_{ax} \dot{x}_t + \eta_{px} y_t + \zeta_{px} \dot{y}_t + e_{xt}$$

$$\ddot{y}_t = \eta_{ay} y_t + \zeta_{ay} \dot{y}_t + \eta_{py} x_t + \zeta_{py} \dot{x}_t + e_{yt}$$

Here, x_t is the IBI level of the female partner, and y_t is the IBI level of the male partner at time t. x_t and y_t are weighted averages of 10 seconds of observations, and $\dot{x}_t$ and $\dot{y}_t$ are the first derivatives of x_t and y_t and index their instantaneous rate of change of IBI. The outcomes are the second derivatives, $\ddot{x}_t$ and $\ddot{y}_t$, which index the instantaneous acceleration/deceleration of IBI.

Given these predictors and outcomes, η_{ax} indicates the coefficient for cycling (frequency of oscillations) for the female partner; η_{ay} is the equivalent coefficient for the male partner. η values must be negative, and larger negative coefficients indicate faster cycling. ζ_{ax} indicates the coefficient for changes in amplitudes over time for the female partner; ζ_{ay} is the equivalent coefficient for the male partner. ζ is positive when amplitudes increase (indicating dysregulation, with larger displacements from equilibrium over time), and is negative when amplitudes decrease (indicating damping, which results in convergence and stabilization of amplitudes towards equilibrium over time). These parameters are intrinsic self-regulation effects (i.e., the model's predicted trajectory for a person's own cycling and damping, over and above any influence from the partner) and are equivalent to *actor effects* in dyadic data analysis terminology (D. A. Kenny et al., 2006), hence the use of the subscript a.

Cross-partner effects collectively capture coregulation and are indicated by subscript p. η_{px} and ζ_{px} indicate the effect of the male partner's IBI position and first derivative on the female partner's second derivative of IBI—i.e., the influence of the male partner on the female partner's cycling and damping. η_{py} and ζ_{py} are the equivalent parameters indicating the influence of the female partner on the male partner's cycling and damping. Note that this model specification allows for asymmetric coupling, such that the effects of the female partner on the male partner can differ from the effects of the male partner on the female partner (Boker, 2012). The model also allowed for correlated residuals across partners (D. A. Kenny et al., 2006).

Observations were centered on each person's average baseline IBI[22]; centering observations on baseline offered important advantages for reasons of theory and interpretation, as the 0 point in the data corresponded to a real and meaningful equilibrium level (i.e., average IBI during a baseline resting period that participants

[22] An assumption of coupled oscillator models is that the underlying time series is stationary and does not involve linear increases or decreases in level over time. We assessed the presence of linear time trends by regressing IBI values on time, allowing time trajectories to differ according to discussion type and treating all effects as random. Details of this analysis are provided in Appendix B. In brief, this analysis revealed extremely small changes in IBI from the start to the end of the discussion for the average female and male partners across discussions: female partner: μ_{diff} = 10.57, 95% CI [3.00, 18.04]; male partner: μ_{diff} = 10.27, 95% CI [3.32, 17.11]. This corresponded to a 1% change in IBI for each partner during the entire discussion period, or a difference of 1 beat per minute when converted into a heart rate metric. We therefore used baseline centered IBI values in our analysis, because this offered theoretical advantages by allowing us to assess deviations from participants' actual equilibrium (Boker, 2012).

completed prior to the discussions). IBI observations from the baseline period were then removed prior to analysis.

Derivatives were estimated using Generalized Local Linear Approximation (Boker, Deboeck, Edler, & Keel, 2010). GLLA entails creating a moving window of 3 or more observations (known as the embed dimension), which is then multiplied by a loading matrix to compute derivatives. We selected an embed dimension of 5 *a priori* following current recommendations (Boker, 2012), to balance issues of measurement error and precision of the estimates while also ensuring a large enough number of observations per phase per dyad[23]. Because cardiovascular physiology responds relatively rapidly (Berntson, Quigley, & Lozano, 2007), we set $\tau = 1$ (within each phase), where τ indicates the number of time points between successive observations to be used in the computation of derivatives. Smaller τ values are needed to capture more rapid oscillations. For more on using coupled oscillators to examine coregulation in couples, see work by Boker and Laurenceau (2006), Helm et al. (2012), and Butler and Barnard (2019).

Bayesian Multilevel Approach

The differential equations presented above can be thought of as Level 1 of a multilevel model; at Level 2, the parameters of the Level-1 equations are specified to have a multivariate normal distribution, with the mean vector being the parameter values for the typical couple (the fixed effects) and a covariance matrix with variances and covariances of between-couple differences in the parameters (the random effects).

We estimated this differential equation using multilevel modeling (Maxwell & Boker, 2007) with Bayesian estimation. Bayesian estimation offers several advantages over conventional maximum likelihood (ML) estimation for fitting multilevel models of dyadic change processes. Most notably, Bayesian estimation has greater facility in handling multiple random effects and is typically able to obtain estimates for these parameters even when models using ML fail to converge.

Furthermore, because Bayesian estimation leads to posterior probability distributions for the locations of all model parameters, it permits the analyst to draw novel probability-based inferences on these parameters that cannot be obtained using classical Frequentist approaches. In particular, we were able to use its capabilities to draw inferences about complex patterns of cross-partner influence that would not have been possible using ML estimation (more details will be provided below).

[23]We note that some perspectives have recommended selecting embed and τ dimensions that maximize variance explained on a dyad-by-dyad basis (e.g., Butler & Barnard, 2019). However, our multilevel modeling approach required that there be commonality across dyads in the procedures used to compute derivatives. For this reason, we used a common embed dimension and τ for all dyads in the sample.

We fit our model using the *brms* package for R (Burkner, 2017). *brms* is a flexible multilevel modeling program that uses Markov-chain Monte Carlo algorithms to arrive at Bayesian posterior distributions. For each set of model parameters, we ran four Markov chains for 8000 iterations each with the first 4000 treated as warm-up and discarded. This resulted in posterior distributions of parameters each based on a total of 16000 sample values. We set a weakly informative prior for all fixed effects, namely a uniform distribution in the interval [-2, 2]. For random-effect variances and covariances, we used the default priors provided by *brms*.

As described above, the model included the cycling, damping, and cross-partner parameters. It also allowed for within-couple variation in these parameters as a function of the three discussion phases. These phases were represented by dummy variables, which were coded such that the support discussion in which the female partner received support (F Receives) was compared to (a) the support discussion in which the male partner received support (M Receives) and (b) the control discussion. The model included all two-way interaction terms between each dummy variable and the parameters described above. Given that each of these effects was treated as random across couples, the resulting model allowed dyads to vary in their self-regulatory and coregulatory patterns and in differences across each of the discussions. In addition to being a key aim of this research, examining between-dyad heterogeneity in this context was also necessary given that social support processes are known to be heterogeneous (Gleason et al., 2008; Shrout et al., 2010).

As the vast majority of partners within couples were distinguishable by gender, we estimated separate effects for female partners and male partners[24]. This is the recommended approach when analyzing intensive longitudinal data of distinguishable dyads (Bolger & Laurenceau, 2013). This approach was also practically and theoretically advantageous in that it allowed us to examine the directionality of cross-partner effects and to explore gender differences in coregulation.

Results

Results are based on a final sample of 13,884 observations from 92 dyads. Five of the original 101 dyads could not be included in this analysis because of equipment failure; five dyads did not have baseline data available for at least one partner; two dyads had no data available from the discussion phases for at least one partner; and two additional dyads had no physiological data collected from the female partner due to pregnancy.

[24]Dyads were treated as distinguishable because the overwhelming majority were heterosexual and therefore distinguishable by gender. At present, clear guidelines for analyzing dyadic data involving a mix of distinguishable and nondistinguishable dyads have yet to be developed. We followed current practices in the literature: We coded one partner as male and the other as female based on the rooms couple members were taken to at the start of the study, which was random in the case of non-heterosexual couples. Unfortunately, we did not have enough non-heterosexual couples to meaningfully examine differences in coregulation as a function of couples' gender composition.

Overview of Results

Individual parameters from coupled damped oscillator models are not readily interpretable because overall trajectories depend heavily on combining all parameters and assigning start values (Butler & Barnard, 2019). For this reason, we discuss results in terms of model-predicted trajectories for the typical couple. For more details regarding the model output, including parameter estimates for fixed effects and random effects, please see Appendix B.

Figures 16 and 17 illustrate the model-predicted trajectories for the typical couple during each discussion, using the means of participants' observed initial IBI as start values. Figure 16 presents model trajectories within the allotted time for each discussion (5 minutes), and Figure 17 shows projections across a larger time span—i.e., what the model predicted for the typical couple's discussions if those discussions had continued for 15 minutes instead of 5 minutes.

As can be seen in these figures, the typical male and female partners showed clear patterns of self-regulation, indicated by regular cycling across all three discussions with oscillations around each person's baseline level of IBI and damping (amplitudes decreasing towards equilibrium) over time. These visualizations also suggest differences by type of discussion and gender. First, damping was more apparent during the support discussions, especially when the male partner received support. This is especially clear in Figure 17: Assuming the discussions had continued for an additional 10 minutes, the model predictions suggest the male partner would return to equilibrium fastest when receiving support. Figure 17 further suggests that this damping process in the context of support receipt was not observed for the typical female partner, who showed a less regular and less stable pattern of oscillations, larger amplitudes, and a smaller damping effect during the discussion when she received support compared to during the control discussion.

These figures also show that the typical male partner generally had more volatile physiological responding, indicated by larger amplitudes at the start of all three discussions. In contrast, the typical female partner had smaller amplitudes of IBI across discussions, but especially during the control discussion and the support discussion when she provided help to her partner. This could be an indication that the typical female partner had better physiological composure on the whole compared to the typical male partner.

The model-predicted trajectories also illustrate the role of partner effects. The right hand panel of Figure 17, the discussion in which the male partner received support, shows partner attunement and convergence of their oscillations over time. In contrast, the trajectories for the control discussion and female recipient support discussion do not show this kind of attunement of partners' responses over time. This is further reflected in the trajectories of the female partner during both support discussions. Rather than showing an uninterrupted pattern of cycling and damping, which would indicate no cross-partner influence, the typical female partner was sensitive to changes the male partner's dynamics, as can be seen from the alternating patterns of higher and lower amplitudes (around minute 2 of the far right panel) and irregularities in oscillations and amplitudes (around minute 5 of the middle panel). Such patterns arise from the inclusion of partner effects and indicate a coregulatory process taking place. In this case, the typical female partner's IBI changed in response to changes in the male partner's IBI.

Overall, these trajectories reveal differences in couples' physiological dynamics during the social support and control discussions. Generally, coregulatory trajectories differed by discussion, with with stabilizing patterns appearing most pronounced when the male partner received support.

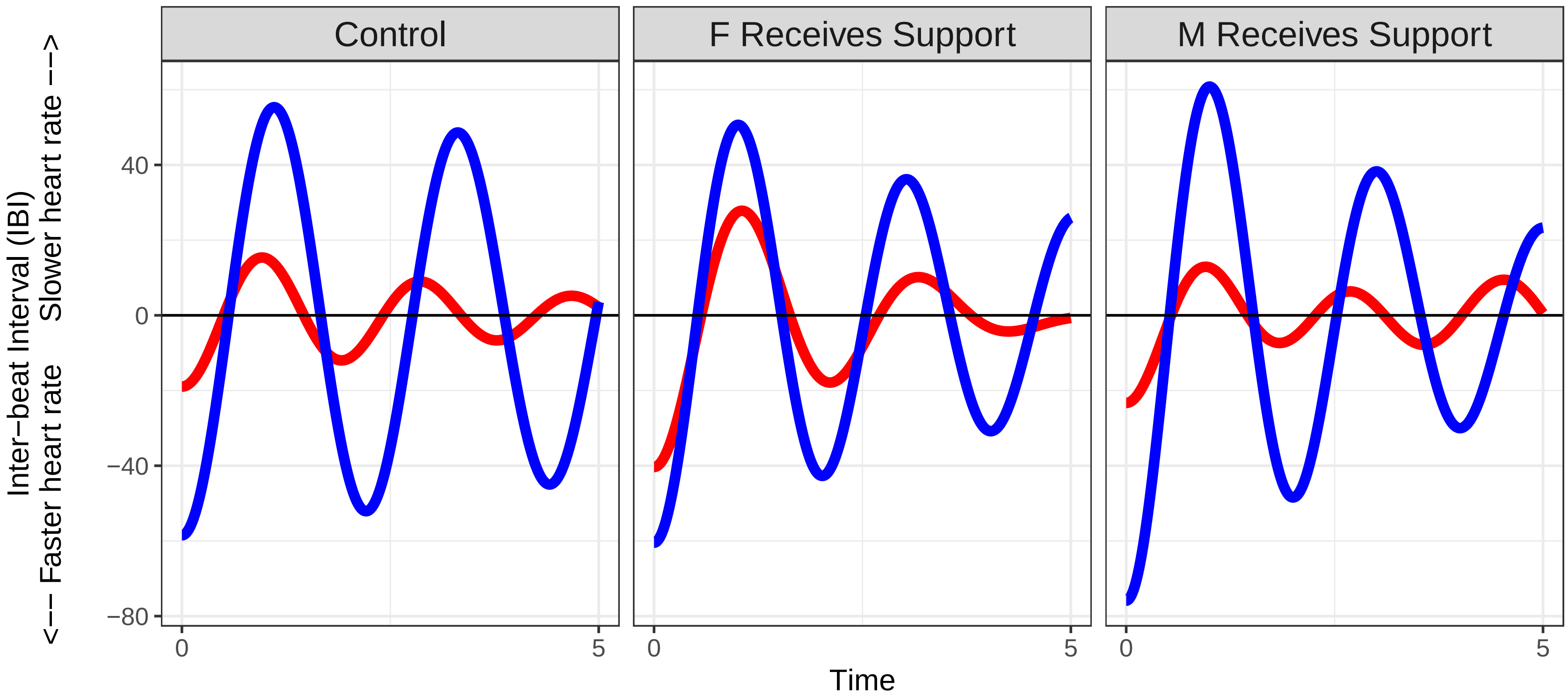

Figure 16: Results for the typical couple (fixed effects) during each 5-minute discussion. Results for the typical female partner are displayed in red, and results for the typical male partner are displayed in blue. The horizontal line at IBI = 0 indicates baseline IBI for each partner. F Receives Support = support discussion in which female partner received support. M Receives Support = support discussion in which male partner received support.

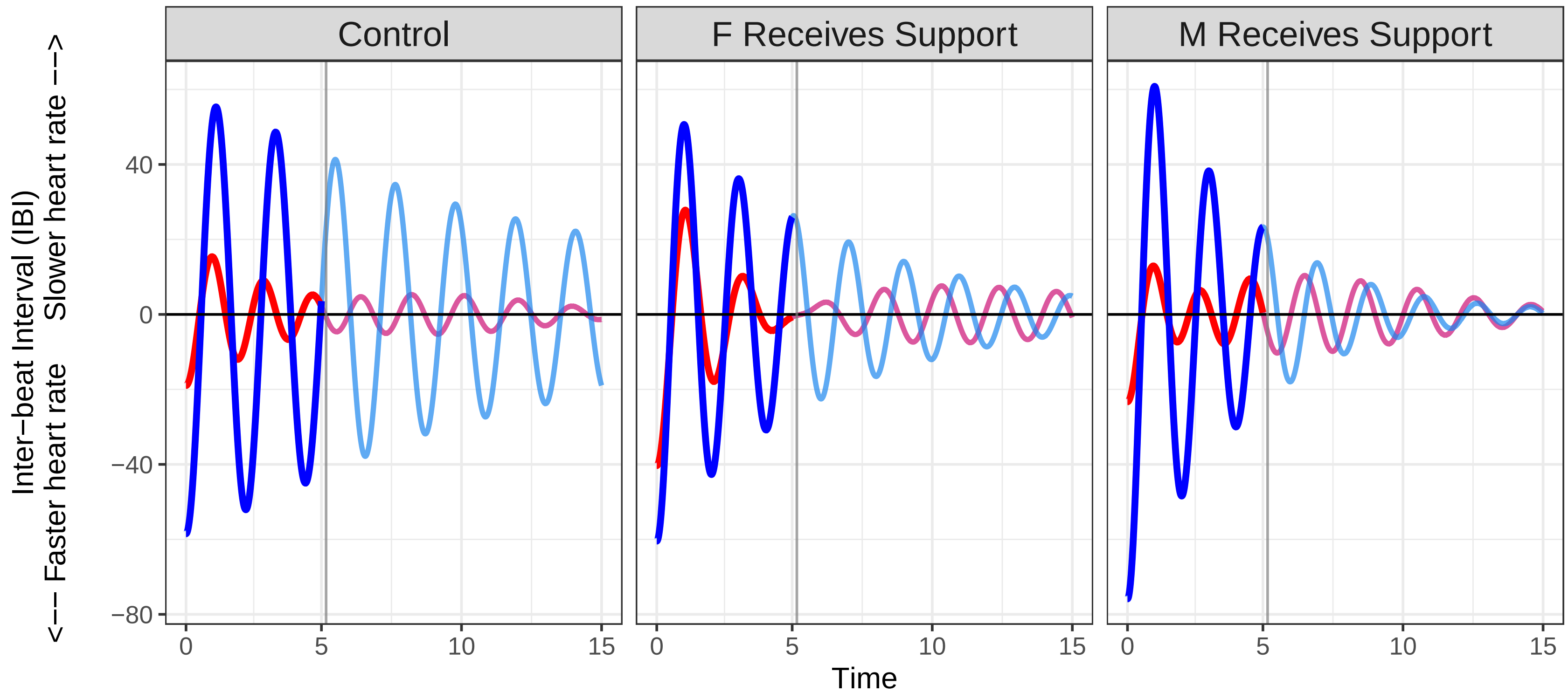

Figure 17: Results for the typical couple (fixed effects) during each discussion. Results for the typical female partner are displayed in red, and results for the typical male partner are displayed in blue. The horizontal line at IBI = 0 indicates baseline IBI for each partner. F Receives Support = support discussion in which female partner received support. M Receives Support = support discussion in which male partner received support. Darker lines up to the 5-minute mark show model predicted results during the actual discussion period, and fainter lines after the 5-minute mark show projections for the typical couple had their discussion lasted for up to 15 minutes.

Aim 1: Is there evidence of coregulation generally?

We next conducted a series of follow-up analyses to more directly investigate our aims and to probe the patterns of results suggested in Figures 16 and 17. We did so by drawing on analytic procedures that allowed us to summarize across multiple model parameters.

Our first aim was to assess whether there was coregulation generally. As noted above, it is difficult to draw firm conclusions about the presence or absence of coregulation from individual parameters alone. In light of this, we evaluated coregulation using a model comparison approach: We tested whether our original model, which included cross-partner effects (indicated by subscript p) to capture coregulation, fit the data better than a model that omitted these cross-partner effects. We reasoned that if our original model provided a better fit to the data, this would indicate that the partner effects mattered, thereby suggesting coregulation. If, however, our original model did not provide a better fit for the data compared to a model that omitted partner effects, this would indicate that the partner effects did not play a role in more accurately representing the data, thereby indicating the processes being examined purely reflected self-regulation and not coregulation.

We used a Bayesian model comparison approach called Leave-One-Out (LOO). This is a cross-validation model selection procedure that is frequently used to select a better fitting model (Vehtari, Simpson, Yao, & Gelman, 2019). The LOO approach does not assume that any of the models being compared is the "true" model, and instead is concerned with identifying the best fitting model of those considered. Practically, LOO is a procedure that involves fitting a given model to all but one data point in the dataset and generating a prediction for the omitted data point (specifically, an estimate of the expected log posterior predictive distribution), and then repeating the procedure for every data point in the dataset. The resulting errors are then aggregated as a way of evaluating the model fit. We used LOO procedures with Pareto smoothing, a technique to enhance computational efficiency and precision of estimation. Similar to other model comparison approaches, a lower LOO value indicates a relatively better model fit.

Results of this model comparison strongly indicated that our original model provided a substantially better fit for the data, in comparison to a model that omitted partner effects and only modeled self-regulation processes. This difference in the LOO metric was 1041.9 (SE = 76.4). Translated into a standardized metric, this amounted to a difference of 13.6 z-score units (1042/76). This improvement in model fit revealed that allowing for cross-partner influence more accurately reflected the data, thereby indicating there was coregulation during the discussions as a whole.

Aim 2: Is coregulation more likely during support discussions?

Our next aim was to examine whether patterns of coregulation differed according to discussion. We used two approaches: a model comparison approach, similar to the approach used for Aim 1, to assess the presence of differences in coregulation by discussion; and an approach that involved examining posterior distributions across multiple parameters and computing probabilities for combinations of effects to better understand the potential implications of these differences for couples' physiological trajectories.

Model Comparison

We first examined whether allowing discussions to differ in their coregulation effects provided a more accurate representation of the data compared to imposing common coregulation effects during all discussions. We again used LOO cross-validation. We compared the fit of our original model, which allowed all parameters to vary across discussions, to the fit of a model that did not allow for different effects by discussion (i.e., a model that assumed common self-regulation and coregulation effects across all discussions).

Results indicated that our original model that allowed effects to differ by discussion provided a substantially better fit for the data compared to a model that assumed a common process across all discussions. This difference in the LOO metric was 808.1 ($SE = 84.1$). Translated into a standardized metric, this amounted to a difference of 9.6 z-score units (808/84). This improvement in model fit indicated that there are differences in effects across discussions.

Taking this a step further, we also compared the fit of our original model to the fit of a model that allowed *self-regulation* parameters to vary across discussions, but did not allow *coregulation* (cross-partner) parameters to vary across discussions. If the original model provides a better fit for the data compared to this restricted model, this would suggest there are meaningful differences in coregulation across discussions, beyond differences in self-regulation across discussions. Consistent with this proposition, the original model fit the data better than a model that forced coregulation to be the same across discussion phases. This difference in the LOO metric was 220.1 ($SE = 32.4$). Translated into a standardized metric, this amounted to a difference of 6.8 z-score units (220/32). This improvement in model fit further suggested that coregulation effects varied across the different discussions.

Posterior Probabilities

Next, we turned to the posterior distributions for our model parameters. This provided a way to assess the probability of *combinations* of effects and, consequently, the nature of the coregulation process during the different discussions.

This second approach involved examining samples from the posterior distributions for multiple parameters. Because Bayesian estimation yields a distribution of possible parameter values, the values that make up the distribution, known as posterior samples, can be examined directly. We capitalized on this feature of Bayesian estimation to probe patterns of effects.

From a regulation standpoint, one important pattern of effects concerns the magnitude and sign of the self and partner damping parameters: Negative damping values suggest that amplitudes stabilize towards equilibrium, and larger negative values indicate more pronounced damping (i.e., better regulation). Other parameter values being equal, larger negative values across both self- and partner damping parameters would give rise to a "better" regulatory trajectory, as values stabilize and converge towards an equilibrium level. This possibility is visualized in Figure 18. The left hand panel illustrates the predicted trajectory (during the control discussion, for example) when all damping parameters are -1 SD below their mean, and the right hand panel illustrates the predicted trajectory when all damping parameters are +1 SD above their mean. In the former case, amplitudes show more of a decrease towards equilibrium, thereby indicating a more stabilizing regulation process.

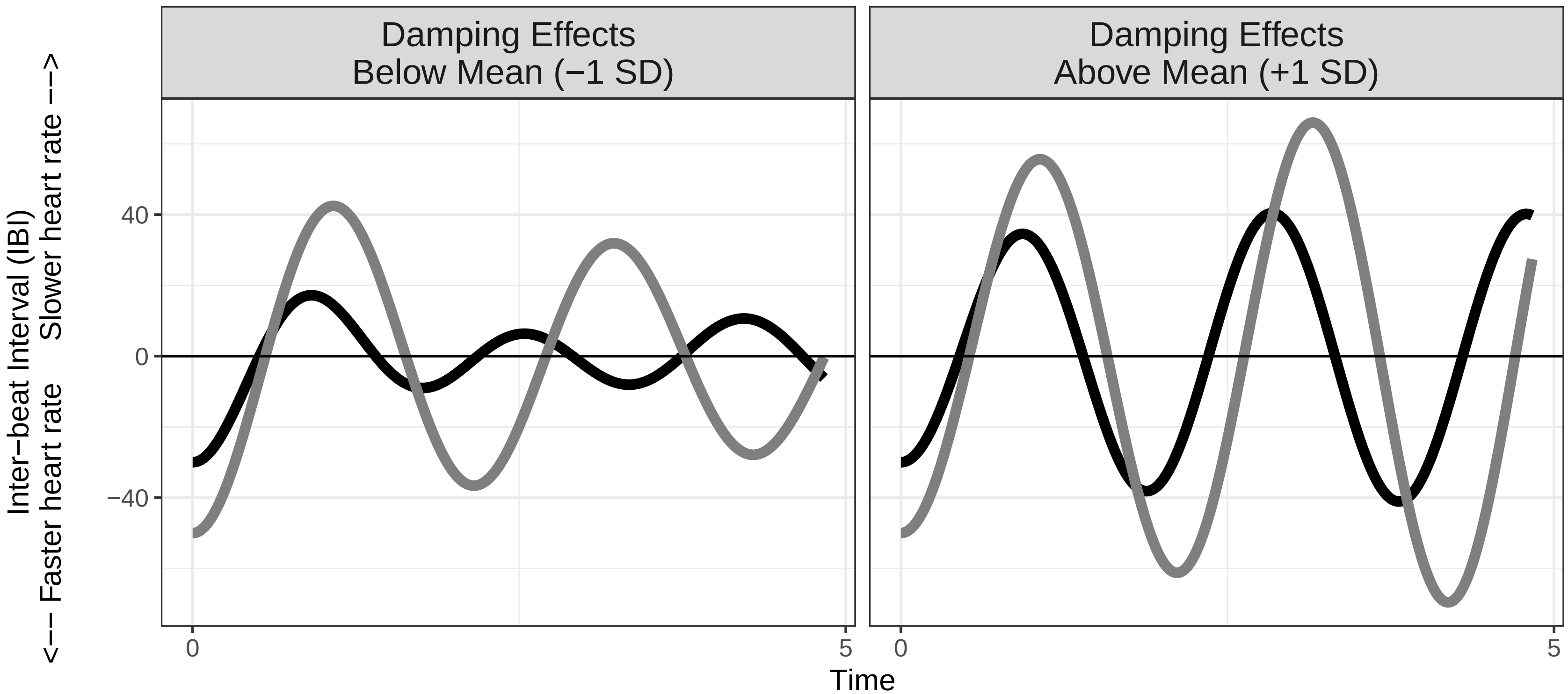

Figure 18: Simulated system trajectories when self- and partner damping effects are -1 SD below their mean (left hand panel) and +1 SD above their mean (right hand panel). Starting values are below equilibrium, holding all other coefficients at their mean values across the two plots. The horizontal line at IBI = 0 indicates baseline IBI for each partner.

Building on this notion, we reasoned that a way of understanding patterns of coregulation could be to assess the probability that at least two of the four damping parameters during each discussion showed stronger (more negative) effects[25]. First, to establish a reference point for assessing stronger (vs. weaker) damping, we computed an overall mean damping effect, which was the average of all 12 damping (ζ) parameter values across partners and discussions (for each of the three discussions, there are two self-regulatory damping effects and two partner damping effects), M_ζ = -0.032. For each posterior sample, we next coded whether each of the four damping coefficients (the two self-regulation damping effects, ζ_{ax}, ζ_{ay}, and the two partner regulation damping effects, ζ_{px}, ζ_{py}) were below this value. Then, within each discussion, we computed the probability that two of more of these parameter values fell below the overall mean damping value across discussions. We note that a potential limitation of this approach is that it does not take into account the relative size of the damping effects to each other.

Results indicated that the probability that at two or more (out of four) damping parameters per discussion were more extreme than the overall mean damping effect was 0.934 [0.930, 0.938] for the male recipient support discussion, 0.872 [0.866, 0.877] for the female recipient support discussion, and 0.415 [0.408, 0.423] for the control discussion.

Moreover, as shown in Figure 19, this probability was higher when the male (vs. female) partner received support, difference in probability = 0.062, 95% CI [0.056, 0.069]. Thus, the probability of stabilizing damping trajectories across parameters was highest during the support discussion when the male partner received support, and lower during the control discussion and female partner's support discussion. Additional analyses drawing on the posterior samples to examine patterns of effects are provided in Appendix B.

Aim 3: Do dyads differ in their coregulation effects?

With our third aim, we explicitly examined the extent to which dyads differed in their physiological dynamics across discussions. Through our use of multilevel modeling, we obtained estimates of dyad-specific effects (random effects), in addition to estimates of parameter values for the typical dyad. These random effects speak to the degree of between-dyad heterogeneity and are useful because they allow one to assess the generalizability of the results and can signal the presence of potential moderators, even if those moderators are not measured or modeled directly.

To assess the extent to which random effects are meaningfully large, we adopted Bolger et al.'s (2019) rule

[25] Probability distributions were simulated using procedures specified by Gelman (2009), which involved converting the binary distribution of "yes" and "no" codes into a single beta distribution (also see Carpenter, 2009). As noted above, this also allowed us to compute 95% intervals around the probability estimates to facilitate comparison of probabilities across phases.

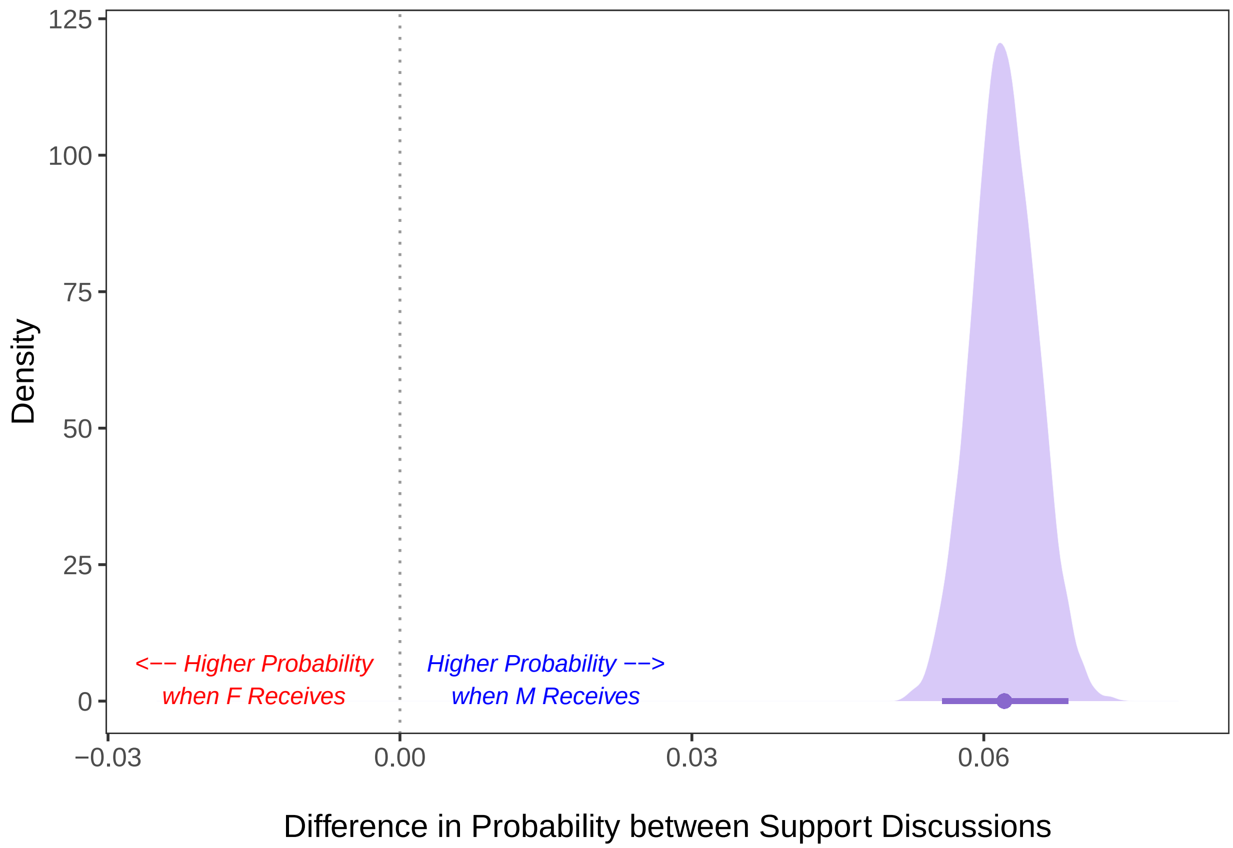

Figure 19: Difference between support discussions in probability of two or more damping parameter values falling below the overall mean damping parameter value across partners and discussions. Larger positive values indicate a higher probability of two or more stronger damping effects during the support discussion when the male (vs. female) partner received support. The solid point is the posterior mean for this probability difference, and the bar is the 95% credibility interval for this probability difference.

of thumb, which suggests that heterogeneity is noteworthy if the ratio of a random effect to its corresponding fixed effect is .25 or greater; this would indicate that, in the population, 95% of subjects could be expected show effects ranging from half the size of the average effect to 50% larger than the average effect. We computed these ratios (random / fixed) for all parameters and found that all ratios exceeded .25, thereby indicating noteworthy heterogeneity. Additional analyses quantifying the extent of between-dyad heterogeneity using directional posterior probabilities are provided in Appendix B.

Figure 20 provides an illustration of this between-dyad heterogeneity. This figure shows model-predicted trajectories for a subset of six dyads. Individual dyads are displayed along the rows, and the three discussions are displayed along the columns. Heterogeneity is apparent even in this small number of dyads. While some show patterns similar to the fixed effects (e.g., Dyad 6 during the male partner's support discussion), others show very different patterns (e.g., Dyad 3 during the female partner's support discussion), suggesting there may be important moderating processes in self- and coregulatory dynamics. Investigating the sources and implications of this heterogeneity would be an important and interesting step to explore in future studies.

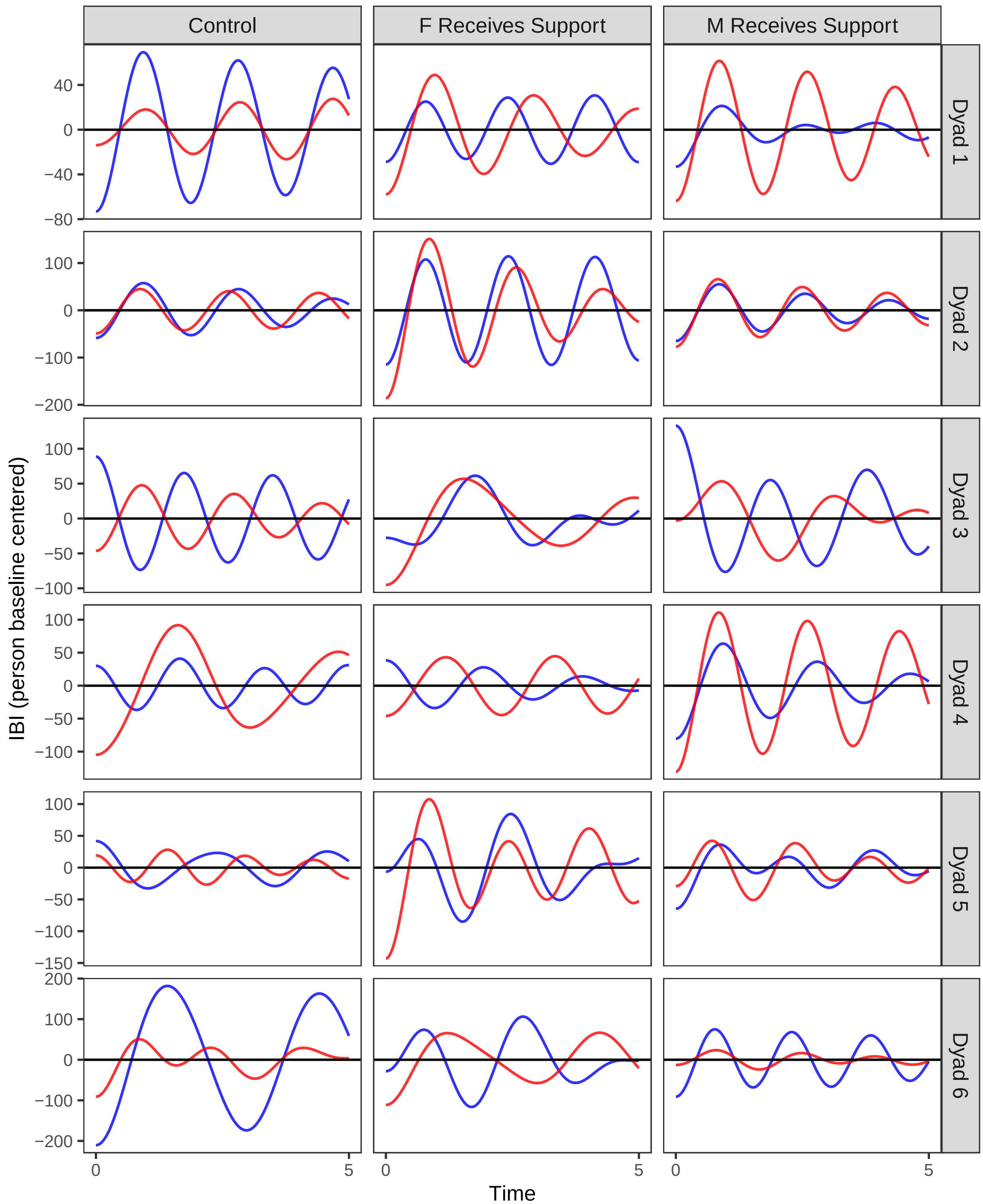

Figure 20: Panel plots illustrating model predicted trajectories for six dyads (rows), across discussion (columns). X-axes show discussion duration (5 minutes). Y-axes have been scaled on a per-dyad basis for clarity of presentation. Female partners are displayed in red, and male partners are displayed in blue. The horizontal line at IBI = 0 indicates baseline IBI for each partner. F Receives Support = support discussion in which female partner received support. M Receives Support = support discussion in which male partner received support.

General Discussion

This Chapter examined the emergence of physiological self-regulation and coregulation during couples' social support discussions. Overall, results generally found clear self-regulatory effects for the typical male and female partners, with regular cycling and damping of oscillations towards equilibrium. Results also suggested these processes differed across discussions: On average, male partners showed relatively more stabilizing trajectories during the discussion in which they received support, but this was less apparent for female partners receiving support. We also investigated three aims to gain insight into couples' coregulation effects. First, we found evidence for coregulation on the whole: Taking cross-partner effects into account provided a substantially better representation of the data relative to omitting cross-partner effects. We then examined patterns involving multiple self- and partner damping effects to better understand the nature of regulation dynamics during each discussion. These analyses indicated that there were differences by discussion, such that stabilizing patterns were more likely to occur when the male partner received support. Finally, we found widespread between-dyad heterogeneity in coregulation, suggesting that a "one-size-fits-all" view of coregulation may not be warranted.

Contributions to Emotion Literature

These results offer new insights into coregulation and into physiological and emotional linkage more broadly. This was the first investigation, to our knowledge, to explicitly examine such processes in the context of social support discussions. Although social support discussions have known importance to intrapersonal and interpersonal emotion regulation (Reeck et al., 2016; Rimé, 2009), our results speak to the role of social support in engendering dyadic coregulation between interaction partners.

Our findings also provide preliminary evidence for the possibility that coregulation processes are important, and more likely to involve stabilizing patterns of influence, when a person has experienced a disruption to equilibrium. Indeed, results generally suggested that during social support discussions, which were characterized by greater physiological displacement from equilibrium, coregulation trajectories involved decreases in responding and stabilization towards and equilibrium level, although this was more pronounced when the male partner received support. This may offer a possible explanation for some of the mixed findings in the literature regarding the presence and nature of coregulation effects: An absence of coregulation may be due to individuals already being at equilibrium and not needing coregulation to help regulate themselves, rather than due to a lack of emotional interdependence per se. Moreover, this study generally found evidence for damping during the discussions. Prior work examining physiological coregulation in couples during other types of interactions (e.g., eye-gazing, imitation) has not found such damping effects (Helm et al., 2012). Thus, social support discussions might engender regulation processes that are specific to individuals' needs in this context, namely returning to equilibrium.

This work also explicitly focused on the extent of between-dyad heterogeneity in coregulation effects. We found that although some couples showed coregulation effects similar to that of the average couple, other couples differed markedly in these effects. That coregulation processes are heterogeneous can also help explain null or inconsistent findings in prior work. Ultimately, knowledge regarding the presence and extent of between-dyad heterogeneity can help researchers plan future studies (e.g., accounting for heterogeneity has direct implications for statistical power; Bolger & Laurenceau (2013)) and develop theories about what moderating variables, such as attachment style and relationship satisfaction (Helm et al., 2012), might explain these differences in coregulation.

Contributions to Close Relationships Literature

This work also contributes to knowledge of close relationships. Separate lines of research have proposed that social support and coregulation may each play a mechanistic role in explaining the benefits of close relationships for health and well-being. The present research bridges these areas by suggesting social support and coregulation may work in tandem to benefit individual and dyadic well-being.

Our results also suggested that coregulation during social support differed according to the gender and role, such that coregulation tended to involve a stabilizing process when the average male partner received support (or when the female partner *provided* support) compared to when the average female partner received support. This may offer novel insights into known gender differences in relationships. In particular, available evidence suggests that men tend to experience greater health benefits from being involved in romantic relationships compared to women (Kiecolt-Glaser & Newton, 2001). Differential patterns of coregulation during support receipt might play a role in explaining this disparity. These results are also consistent with prior work suggesting that men and women differ in the responsiveness of the support they give to their (opposite-gender) partners (Bodenmann et al., 2015; Neff & Karney, 2005). It is possible that differential coregulation processes mediate such effects, whereby social support discussions in which female partners give support (and male partners receive it) more effectively entrain partners' physiological and emotional responses, helping dyad members come back to equilibrium more efficiently.

Limitations, Open Questions, and Future Directions

Despite the contributions of this research, it is important to note its limitations. One limitation concerns the generalizability of these findings. Specifically, this study examined mostly younger, heterosexual couples. Therefore, results may not be generalizable to other groups, cultural contexts, developmental stages, or types of relationships. Notably, our sample included some non-heterosexual couples, but there were not enough of these couples to meaningfully examine how coregulation processes might differ in heterosexual vs. non-heterosexual couples. This would be an exciting and important avenue for future research.

Another limitation was that our study asked participants to self-select an issue to talk about during the social support discussions. It is possible that men and women differed systematically in the issues they chose to discuss, e.g. in terms of the severity of the issue, the type of issue, etc. Another possibility is that men and women differ in the emotions they express when receiving vs. providing support, given earlier work that found gender differences in the degree of emotional expression during other types of couples' discussions (e.g., Carstensen, Gottman, & Levenson, 1995). Thus, the differences we found when male vs. female partners received support could be due to a host of other variables as opposed to gender per se. Future research could address this issue by having couples exchange support for a problem that is held constant across couples, such as by having one partner receive support in response to standardized laboratory stressor, and testing whether similar gender differences emerge.

Our investigation drew on dynamical systems modeling to examine self- and coregulation effects. These models offer many advantages for examining coregulation in particular, but we note some considerations and limitations. First, these models are sensitive to the size of the embed dimension—i.e, the size of the window used to compute derivatives. There are differing perspectives on how best to select an embed dimension, and in our study, we selected an embed dimension *a priori* to balance issues of measurement precision with the temporal properties of the cardiovascular process under examination. However, it is worth noting that results could differ if other embed dimensions were used. Second, the model trajectories also depend heavily on the choice of start values. That is, even if model parameters remain exactly the same, using different start values can result in markedly different trajectories (Boker & Nesselroade, 2002). We selected meaningful start values (observed IBI values at the start of each discussion) as a way to address this issue, but it is important to acknowledge that other trajectories might emerge if we were to select different start values. We note, though, that the analyses we performed on the posterior distributions and the model comparison approaches we used are not affected by start values. Nevertheless, the issue of start values is always a consideration when working with these models.

An additional open question concerns our operationalization of equilibrium. In our study, participants' average baseline responses were used to reflect equilibrium. This baseline was obtained while participants rested quietly alone. However, it could be argued that this is not equivalent to the "baseline" that people experience in their daily lives. For example, social baseline theory posits that humans (and other animals) expect to be around others, and that being with people is our "baseline" state (Coan & Maresh, 2014). Our data also do not speak to whether returning to this particular equilibrium is beneficial or desirable; future research examining what an optimal equilibrium might be in social support and other contexts could help to refine understanding of coregulation and what it means to return to an equilibrium level. Given that coregulation is conceptualized as *dyadic* process, it would be interesting to consider whether couples have a specific *dyadic* baseline as their equilibrium set point. This issue of what constitutes individuals' and dyads' "true" equilibrium is an interesting question in need of further study.

Lastly, a potential limitation involves our exclusive focus on coregulation of partners' IBI. IBI has been used as the focal measure of other studies of coregulation processes (Helm et al., 2012), but a limitation is that it is fluctuates with both sympathetic and parasympathetic nervous system activation and therefore does provide a high degree of specificity about the nature of the underlying psychological process. Future work incorporating additional physiological measures, such as respiratory sinus arrhythmia to more clearly capture parasympathetic activation and pre-ejection period to more clearly capture sympathetic activation, could provide further insights into the nature and function of coregulation in social support discussions and other contexts. Examining whether coregulation patterns are similar vs. different across physiological and emotional channels could also reveal important insights into whether coregulation is a diffuse, multi-modal process, or whether it is targeted and operates on specific emotional channels.

Conclusions

Coregulation has been proposed to play an important role in accounting for the beneficial effects of close relationships. The present work furthers this notion by demonstrating the emergence of physiological self- and coregulation during social support discussions vs. non-support discussions in couples. These results speak to the importance of considering conditions under which coregulation processes may become activated and attending to between-dyad differences in these effects. Coregulation and social support in the context of close relationships may work in tandem to help people manage their emotional and physiological responses in the face of difficulties, which in turn may contribute to better emotional well-being, physical health, and dyadic functioning over time.

Chapter 4: Social Support and Developmental Regulation

Abstract

Close relationships are essential to well-being during all life stages and become even more important in older adulthood. Theories of lifespan development have proposed that relationship partners play a central role in helping older adults' *developmental regulation* (adaptation to age-related challenges across the lifespan), and enacted social support may be a route through which this occurs. This study presents a proof-of-concept examination of social support and coregulation among older couples leading up to an acute stressor, a context in which age-related vulnerabilities are especially pronounced. We hypothesized that social support discussions might engender stabilizing patterns of coregulation in couples that would benefit individual self-regulation when facing the stressor. Older couples engaged in a control discussion and then completed a social support discussion after learning that one partner would have to deliver a stressful speech. Cardiovascular responses were monitored during the discussions and speech. Self- and coregulation were assessed with Bayesian dynamical systems modeling, to quantify the frequency of oscillations and changes in amplitudes of participants' responses. We found that couples showed *codysregulation* during the support discussion, likely due to the impending stressor; however, there was substantial heterogeneity in these effects. Exploratory analyses revealed that changes in *dyadic coregulation* between the control and support discussions predicted *individual self-regulation* during the speech: Among dyads showing smaller increases in codysregulation between discussions (indicating a more effective regulation process), individual partners showed better physiological self-regulation when facing the stressor on their own. These results demonstrate specific pathways through which relationship partners might contribute to effective developmental regulation and are among the first to suggest links between coregulation and self-regulation during this life stage.

Introduction

Close relationships are critical to psychological and physical health, and they become even more important later in life (Carstensen, Fung, & Charles, 2003; Pietromonaco, Uchino, & Dunkel Schetter, 2013; Robles et al., 2014). With age, individuals report more satisfying relationships and increasingly prioritize emotionally meaningful goals (Lang & Carstensen, 1994; Waite, Laumann, Das, & Schumm, 2009). Importantly, partners in older adulthood may do more than address relational needs: They may also play a critical role in assisting each other's efforts as they adapt to age-related challenges and opportunities.

Although theories of lifespan development have proposed that relationships contribute to healthy aging (e.g., Lang & Carstensen, 1994), relatively little is known about specific interpersonal processes through which this occurs. One possibility is that supportive interactions with a relationship partner engender patterns of dyadic coregulation——bidirectional linkage in partners' oscillations of emotional and physiological responses (Butler & Randall, 2013). Coregulation is proposed to help relationship partners maintain or restore an equilibrium level of responding when coping with difficulties (Butler & Randall, 2013; Sbarra & Hazan, 2008), and this process may be especially important for older adults given that they are more physiologically reactive to stressors (Charles, 2010; Uchino, Birmingham, & Berg, 2010; Uchino et al., 2005). Drawing on a partner's calmer state via coregulation might scaffold older adults' self-regulatory efforts, temper stress responding, and subsequently enable them to better manage stress on their own. Ultimately, this may represent one channel through which relationship partners might help older adults adapt to age-related challenges——a process known as *developmental regulation* (Haase, Heckhausen, & Wrosch, 2013; Heckhausen, 1997)

This paper presents a proof-of-concept investigation to examine the emergence of dyadic coregulation and individual self-regulation among older couples, quantify heterogeneity in these effects, and test whether dyadic coregulation might relate to individual self-regulation during a stressful task. We conducted a dyadic experiment in which older couples' physiological coregulation during a control discussion about a routine topic and during a social support discussion as one partner prepared for a laboratory stressor, an evaluative speech. To assess coregulation and self-regulation, we implemented dynamical systems modeling of physiological data, which captures oscillations of responding around an equilibrium level and changes in amplitudes over time. As heterogeneity is a hallmark of aging (P. B. Baltes & Baltes, 1990), we also assessed the extent to which dyads and individuals differed in their regulation processes. Lastly, we explored the interplay of coregulation and self-regulation—specifically, how supportive interactions might generate patterns of cross-partner influence that, in turn, predict how older adults self-regulate on their own. Overall, this research offers novel insights into specific mechanisms through which relationships might foster effective developmental regulation in older adulthood and ultimately promote healthy aging.

Importance of Relationships in Older Adulthood

Although aging is often depicted as a negative process characterized by losses in physical strength and cognitive abilities, not all aspects of life worsen in older adulthood. Indeed, a noteworthy gain is that, with age, individuals report higher quality relationships and prioritize emotionally meaningful goals (Carstensen et al., 2003; Fingerman & Charles, 2010; Lang & Carstensen, 1994; Waite et al., 2009). Although older adults prune their social networks, they are motivated to maintain their most important relationships (Carstensen et al., 2003; Lang & Carstensen, 1994; Wrzus, Hanel, Wagner, & Neyer, 2013), especially their romantic relationship (Carstensen et al., 1995; Lang & Carstensen, 1994; Levenson, Carstensen, & Gottman, 1993). Over 70% of older adults report being highly satisfied with their romantic relationship (Waite et al., 2009). Compared to their middle-aged counterparts, older couples also show more affection, less negativity, and more constructive attempts to regulate each other's emotions (Carstensen et al., 1995).

How do relationship partners help individuals manage age-related changes?

In addition to fulfilling emotional goals (Carstensen et al., 2003), relationship partners may be important in older adulthood because they play an important role in scaffolding goal pursuit and adaptation to age-related changes. Theoretical models of lifespan development reflect this possibility. For example, the Selective Optimization with Compensation (SOC) Model is a meta-theory that proposes coping strategies—selection, optimization, and compensation—that older adults can enact to counteract declines they encounter in the aging process and achieve their goals (Baltes & Carstensen, 2003; P. B. Baltes & Baltes, 1990). The SOC Model is relevant to close relationships because relationship partners may participate in all three of these goal-directed processes. Through processes like validation, joint appraisal, and age-related motivational changes, partners may influence selection (i.e., which goals individuals choose to pursue) (Baltes & Carstensen, 2003). Through processes like social support, partners may also contribute to optimization and compensation—i.e., attaining optimal goal outcomes and/or helping individuals make up for age-related declines, which might not have been possible without such support.

Another prominent theory of lifespan development is the Convoy Model of Social Relations. The Convoy Model explicitly proposes that supportive relationships help individuals move through various developmental stages across the lifespan (Antonucci, Ajrouch, & Birditt, 2014). The Convoy Model implies that relationships are not only important for health and well-being at a particular point in time, but their effects are cumulative over time, further underscoring that relationships take on increased significance with age. The Convoy Model is also distinct from many other models of lifespan development because it explicitly emphasizes the importance of considering relationship quality, function, and structure in the aging process (Uchino & Rook, 2020) and distinguishes between enacted social support (practical or emotional help given in response to a problem or situation) and perceived social support (the perception that relationship partners could be called upon for help should the need arise) (Uchino, Ong, Queen, & Kent De Grey, 2016). This perspective implies that *specific* relationship processes and behaviors need to be studied in order to reveal how relationships contribute to developmental regulation and suggests that differences among older adults could stem from different types of relationship experiences.

When do relationships matter most?

The Strength and Vulnerability Integration (SAVI) Model offers insights into contexts in which relationships may be most consequential for older adults (Charles, 2010). The SAVI Model outlines gains and losses in socioemotional functioning in aging. On the one hand, older adults experience better well-being compared to younger adults because, through age and experience, they are able to skillfully manage their socioemotional lives so as to avoid distressing situations and interpersonal interactions. However, when confronted with unavoidable stressors, older adults show more distress and poorer recovery (Kiss, De Meester, & Braeckman, 2008; Uchino et al., 2010, 2005). As relationships are proposed to play a role in buffering stressor reactivity and facilitating recovery (S. Cohen & Wills, 1985; Meuwly, Bodenmann, Germann, Bradbury, & Heinrichs, 2012), stressors may be a context in which relationship partners might play an especially important role in helping adults compensate for this vulnerability.

Relevance of Social Support for Developmental Regulation

Enacted social support involves the exchange of practical and/or emotional help in response to a particular problem, situation, or goal. Social support is a common coping strategy across the lifespan (Thoits, 1986), and it is likely a key context in which relationship partners can help each other compensate for age-related challenges in older adulthood (Uchino et al., 2016). Research has suggested the importance of partner support in older adulthood for promoting daily goal progress (Jakubiak & Feeney, 2016) and fostering self-expansion goals (i.e., goals that promote growth, broaden one's self-concept, and are new and optimally challenging) (Tomlinson, Feeney, & Peters, 2020). Furthermore, because older relationship partners have accrued more life experience and knowledge about each other, this might enhance their ability to support their partner effectively. Reflecting this possibility, one investigation found that overt (visible) practical support was more strongly related to goal progress among older adults compared to younger adults (Jakubiak, Feeney, & Ferrer, 2019).

Indeed, recent theories of self-regulation, such as Transactive Goal Dynamics Theory (Fitzsimons et al., 2015), also bear on this context. As partners become more skilled and knowledgeable of each other's needs, strengths, and weaknesses, they might increasingly participate in, or even take on, important self-regulatory tasks for their partner. This coordination of self-regulatory effort is likely to be augmented among older couples, who are likely to both have a higher degree of interdependence and rely on each other to accomplish challenging tasks.

Social support may also engender patterns of physiological coregulation that could help older adults manage their stress responses. Past work has speculated that relationships may influence healthy aging via their effects on physiological responding (specifically, autonomic nervous system activity) (Uchino & Rook, 2020). As social support frequently occurs in stressful contexts, it may provide an opportunity to draw on a partner's calmer state as a way to regulate stress (Butler & Randall, 2013; Sbarra & Hazan, 2008; Timmons et al., 2015). As older adults experience heightened stress reactivity when they are unable to avoid stressors, coregulation might serve a compensatory function that helps them return to baseline (Charles, 2010).

However, it is also possible for social support to be ineffective or detrimental for older adults (Krause, 1986). Social support can threaten recipients' sense of efficacy (Bolger & Amarel, 2007; Fisher et al., 1982) or increase feelings of indebtedness to the provider (Gleason, Iida, Bolger, & Shrout, 2003), and these concerns are likely to be heightened among older adults (Jiang, Drolet, & Kim, 2018; Martire & Schulz, 2007). The potential detrimental effects of social support for older adults might be especially pronounced in challenging or stressful contexts. Stressors may be a context in which older adults may be particularly likely to have concerns about their competence. In line with this notion, one investigation found that although older adults benefited from receiving goal-related and context-general social support from their partner in daily life, they also reported lower personal well-being when receiving social support for a *stressor* (Jakubiak et al., 2019).

Relevance of Coregulation

Engaging in dyadic coregulation with a partner may be one channel through which older adults can manage their stress reactivity. As introduced in Chapter 3, coregulation refers to "bidirectional linkage of oscillating emotional channels (subjective experience, expressive behavior, and autonomic physiology) between partners, which contributes to emotional and physiological stability for both partners in a close relationship" (Butler & Randall, 2013). Because coregulation is thought to be a stabilizing process, it may be most important when a relationship partner has been de-stabilized, such as by experiencing a stressor (Boker & Nesselroade, 2002; Butler & Barnard, 2019).

Chapter 3 demonstrated that social support interactions between partners, in which partners have experienced a disruption to their emotional equilibrium, engender coregulation to a greater degree than non-support interactions, in which there has not been a disruption to equilibrium. Thus, when facing a stressor, supportive interactions with a partner might provide an opportunity to draw on a partner's calmer state as a way to regulate stress. As older adults experience heightened stress reactivity when they are unable to avoid stressors and tend to be more oriented to relationship partners, coregulation might be especially important in older adulthood because it offers a way to compensate for this vulneratbility and help them return to an equilibrium level more efficiently (Charles, 2010).

Past work has suggested the benefits of coregulation within the context of dyadic interaction. However, we are not aware of any prior research that has examined how specific patterns of dyadic coregulation might in turn relate to individual self-regulation in older adulthood. This is an intriguing possibility that could shed light onto precise channels through which close relationships benefit health and well-being over time broadly and through which relationships facilitate healthy aging and developmental regulation specifically. In older adulthood, engaging in coregulation with a close partner would involve entraining of physiological responses; through effectively tempering their physiological responding, older adults might then be in a better position to use this as a foundation for self-regulating on their own.

Heterogeneity as a Hallmark of Aging

It is worth noting that the patterns of social behavior and stress responding found among older adults simply reflect average tendencies. Yet, people can be expected to show heterogeneity in such processes generally (Bolger & Zee, 2019b; Bolger et al., 2019), and heterogeneity is proposed to become more pronounced with age, as individuals develop over time and accrue more unique life experiences (P. B. Baltes & Baltes, 1990). Moreover, previous research, including the research presented in Chapter 3, has highlighted the heterogeneous nature of coregulation processes among younger adults (Butler & Barnard, 2019; Sels et al., 2019; Zee & Bolger, 2020b, 2020a). Thus, accounting for potential heterogeneity in how older adults coregulate with a partner and self-regulate when facing a stressor is warranted, both theoretically and empirically.

Study Overview and Aims

In sum, developmental regulation needs increase in older adulthood as people adapt to aging-related declines. Relationships can be a source of social support that might engender patterns of coregulation that scaffold older adults' self-regulatory efforts and in turn help them pursue their goals effectively.

Accordingly, this paper presents a preliminary study to investigate implications of social support for self-regulation and coregulation among older couples and to provide proof-of-concept for the utility of dynamical systems modeling for exploring links between such processes. Dyads exchanged social support as one partner prepared for an impending laboratory stressor. We focused on this stressor context due to older adults' exacerbated physiological reactivity to acute stressors (Charles, 2010; Uchino et al., 2010, 2005). Thus, this context provides an opportunity to examine how relationship partners might help older individuals manage this particular age-related vulnerability.

This investigation used intensively sampled cardiovascular measurements and implemented dynamical systems modeling with Bayesian estimation to examine self-regulatory and coregulatory trajectories within and across dyads and individuals. With this study, we investigated four Aims:

Aim 1: Dyadic Coregulation in Older Adulthood

First, we examined dyadic coregulation dynamics among older couples. Building on Chapter 3, which suggested that beneficial coregulation patterns can emerge during social support discussions to bring partners back to equilibrium, we hypothesized that couples would show more beneficial coregulation trajectories during a social support discussion compared to a control (non-support) discussion. For older couples, coregulation might be especially important due to factors such as relationship interdependence and the necessity of using coregulation as a way to cope with increased stress reactivity.

However, an important difference between the present study and the study described in Chapter 3 is the use of a stressor paradigm—namely, in this study, social support was given as one partner prepared to give a stressful speech. Because of this design, along with older adults' susceptibility to stress reactivity (Charles, 2010), we also acknowledged the possibility that couples might instead show co*dys*regulation during the support discussion as the stressor approached.

Aim 2: Individual Self-Regulation under Stress in Older Adulthood

Second, we examined self-regulatory trajectories as one partner underwent a laboratory stressor, an evaluative speech. Given older adults' reactivity to stressors, we hypothesized that older adults would show dysregulated physiological trajectories during the speech, characterized by increasing amplitudes in their physiological responses (*amplification*) as the speech progressed. Although conceptually consistent with earlier work showing linear increases in stress responses in older adults (Uchino et al., 2010, 2005), this would be the first examination, to our knowledge, to apply dynamical systems modeling of physiological data to assess dysregulation of older adults' responses during an acute stressor.

Aim 3: Heterogeneity as a Hallmark of Aging

Under Aim 3, we directly investigated the extent of between-subject heterogeneity in both coregulatory and self-regulatory processes. Examining the extent to which older people differ in their physiological trajectories during support discussions and stressors can shed light on the generalizability of these findings and pave the way for future work aimed at identifying important moderating variables. Theoretically, this focus on heterogeneity is highly relevant because heterogeneity is regarded as a hallmark of aging (P. B. Baltes & Baltes, 1990): As individuals move through the lifespan, they accrue unique life experiences that make them increasingly different from each other. As suggested by other theories of aging, such heterogeneity may stem from differences in social relationship processes (Antonucci et al., 2014).

Aim 4: Bridging Coregulation and Self-Regulation

Finally, our fourth aim was to explore links between dyadic coregulatory dynamics during the social support and control discussions and individual self-regulation dynamics during the speech. Theories of coregulation have suggested that emotional linkage between partners serves to stabilize the dyad and restore an equilibrium level of responding when encountering difficulties (Butler & Randall, 2013; Timmons et al., 2015). Thus, we predicted that beneficial coregulation during the discussions would be related to more effective self-regulation (i.e., stronger damping, or more *decreasing* amplitudes of responding) during the speech. Thus, we explored whether between-dyad differences in specific coregulation parameters might predict between-person differences in self-regulatory damping during the speech. If so, this would offer insights into specific ways in which relationships contribute to effective developmental regulation. It would also provide some of the first evidence, to our knowledge, for how heterogeneity in dyadic *coregulation* might account for variability in individual *self-regulation* in older adulthood.

Methods

A sample of older couples was recruited to participate in a laboratory study on "couples' communication." The study used a within-dyad experimental design, in which couples first completed a control discussion and then engaged in a social support discussion in preparation for a laboratory stressor.

Participants and Sample Size

Couples were recruited via neighborhood flyers, a research recruitment service (Cloud Research), and online advertisements. Couples were prescreened according to age (over 60 years of age)[26], relationship status (currently cohabiting and in a romantic relationship for at least one year), and English language proficiency. Participants were also screened for medication use: They were required to not be taking calcium channel blockers or beta-blockers, as these medications are known to affect cardiovascular responses. Participants were paid \$100 to \$150 each (\$200 to \$300 per couple) in exchange for completing a laboratory visit together[27].

There were 20 couples who completed the study. All couples were heterosexual. The mean age for female partners was 64 years (SD = 7.6), and the mean age for male partners was 67 years (SD = 8.2). 75% of couples were married or in a long-term domestic partnership, and the mean relationship length was 31 years (SD = 14.6).

We had originally planned to collect data from 60 dyads based on earlier power calculations[28] and available funding. However, the study was halted due to the COVID-19 outbreak before this sample size was reached. In light of university regulations prohibiting in-person data collection, we decided to cease data collection and proceed with the available sample of participants. The analysis plan for this project was preregistered on the Open Science Framework (https://osf.io/gy7n3/?view_only=fd7d3769c9a14968ba401cc2ee84b63f). As noted in the preregistration, no knowledge regarding the data influenced our stopping rule or analytic decisions. Nevertheless, we suggest some caution in the interpretation and generalizability of these results due to the small sample size.

[26] There was one couple who was recruited for piloting purposes, in which partners were 49 years old. Prior to analysis, we decided to include their data to maximize sample size.

[27] At the start of data collection, participants initially underwent more extensive health screenings. However, to increase feasibility of recruitment, these criteria were adjusted in consultation with psychophysiological experts, which was justifiable given our use of within-person assessments. The requirement of no medication use with cardiovascular implications (specifically, use of beta-blockers or calcium channel blockers) was retained. Compensation rates were increased to address feedback from prospective participants and to cover transportation costs to and from the lab.

[28] Power analyses were originally conducted to achieve 80% power for a between-dyad discussion manipulation (social support or control). Before data collection started, our study was redesigned to use a within-dyad approach, with dyads completing *both* a control and a support discussion. This new design was implemented to help with recruitment feasibility, increase power, and enable us to look at changes in physiological trajectories between two types of dyadic interaction within the same individuals.

Procedure

Participants were instructed to refrain from caffeine consumption and strenuous exercise for at least two hours prior to their laboratory visit due to the collection of physiological measures. Upon arrival, partners were escorted to separate rooms. After indicating consent, participants completed measures of health, individual difference, and relationship variables. As these variables were not analyzed in regard to the present hypotheses, they will not be discussed further. They were then fitted with physiological sensors to measure cardiovascular responses and rested quietly for a 5-minute baseline period.

Next, couples completed a 7-minute control discussion, in which they were instructed to discuss their upcoming schedules for the week. The purpose of this discussion was to ask couples to discuss a relatively routine topic to serve as a comparison to a support discussion. This discussion was not intended to have a disequilibrating effect on participants. Then, participants were informed that they would have another joint discussion and afterward one partner would complete an individual task. Partners were randomly assigned to role: target or provider. Targets were informed that their individual task would be to deliver an impromptu speech on a topic that was important to them that would ostensibly be evaluated by an expert. Before the speech, couples were asked to engage in a 7-minute social support discussion. Targets were instructed to share their thoughts and feelings about the upcoming speech, and providers were instructed to respond or help in any ways that seemed natural or appropriate. Because we anticipated that the introduction of the speech task and subsequent support discussion could generate stress among participants, the control discussion was always completed first to prevent carryover effects. After the support discussion, providers were taken to a separate room. Targets then delivered a 5-minute speech to a research assistant posing as an evaluator.

Physiological Assessments

During baseline, each discussion, and the speech, participants' cardiovascular responses were measured continuously. We collected heart rate data using Biopac's MP150 and ECG module. Heart rate waveforms were sampled at 1000 Hz and were scored in 10 second intervals using Mindware software (HRV 3.0.25). This yielded 42 observations per person for each of the discussion phases—control discussion and support discussion—and 30 observations per target during the speech, for a total of 114 observations per target and 84 observations per provider across these study phases. Additional physiological assessments were collected for targets during a post-stressor recovery period but were not analyzed in regard to the present research question.

As our primary measure, we focused on inter-beat interval (IBI). IBI refers to the average number of milliseconds between each heartbeat during a given period of time (10 seconds in this study). IBI is a measure of autonomic nervous system activity and is related to heart rate: Higher values indicate a longer interval (i.e., a slower heart rate), and lower values indicate a shorter interval (i.e., a faster heart rate). As such, IBI values typically decrease in the face of stressors.

Analysis Strategy

Analysis plans for this project were preregistered on the Open Science Framework (https://osf.io/gy7n3/?view_only=fd7d3769c9a14968ba401cc2ee84b63f). As described in the preregistration, some initial analyses were previously performed on a subset of 10 dyads to ensure data quality and establish the feasibility of our models. However, only dyad-specific trajectories were examined in these feasibility analyses; they had no influence on our decision about when to stop data collection, nor did they change our analysis plan.

Data Pre-Processing

Per our analysis plan, data were first separated into experimental phases by individual participant: control discussion, support discussion, and speech (for targets only). For any missing IBI data with a phase, values were imputed by taking the mean of the two preceding and two following observations within that phase. Data were detrended by fitting a linear model regressing IBI on time for each person for each phase and saving the residuals. We then detrended these data because we anticipated that the use of a stressor paradigm might product linear time trends of IBI; stationarity is an assumption of damped oscillator models, therefore linear time trends need to be removed before fitting the model. Furthermore, baseline IBI assessments were unavailable for two participants due to signal issues or computer malfunction, so using this detrending approach allowed us to include more data in our analysis.

Next, we computed derivatives of the resulting residuals using Generalized Local Linear Approximation (GLLA) (Boker et al., 2010), the same method described in Chapter 3. We again set embed dimension of a 5, whereby derivatives were computed using a moving window of five observations, and a τ value of 1, whereby successive observations were used.

Damped Oscillator Model

Data were analyzed using damped linear oscillator models. As introduced in Chapter 3, the damped oscillator is a type of dynamical systems modeling that captures the frequency of oscillations around an equilibrium level (*cycling*) and changes in amplitudes over time (this results in a pattern of *damping* when amplitudes decrease, and a pattern of *amplification* when amplitudes increase). These models can be specified to include cross-partner parameters—that is, how partners influence each others' cycling and damping.

Discussion Phase: Coupled Damped Oscillator Model

For the discussion phases of the study, we fit a coupled damped oscillator model to account for cross-partner influence. This is a version of the model used in Chapter 3.

For the present study, the basic equations for each dyad partner are:

$$\ddot{x}_t = \eta_{ax} x_t + \zeta_{ax} \dot{x}_t + \eta_{px} y_t + \zeta_{px} \dot{y}_t + e_{xt}$$

$$\ddot{y}_t = \eta_{ay} y_t + \zeta_{ay} \dot{y}_t + \eta_{py} x_t + \zeta_{py} \dot{x}_t + e_{yt}$$

Here, x_t is the IBI level of the *target* (the person giving the speech), and y_t is the IBI level of the *provider* partner at time t. x_t and y_t are weighted averages of 10 seconds of observations, and $\dot{x}_t$ and $\dot{y}_t$ are the first derivatives of x_t and y_t and index their instantaneous rate of change of IBI. The outcomes are the second derivatives, $\ddot{x}_t$ and $\ddot{y}_t$, which index the instantaneous acceleration/deceleration of IBI.

Given these predictors and outcomes, η_{ax} and η_{ay} indicate the coefficients for cycling (frequency of oscillations) for the target and the provider, respectively. η values must be negative to be interpretable, and larger negative coefficients indicate faster cycling. ζ_{ax} and ζ_{ay} indicate the coefficients for changes in amplitudes over time for the target and the provider, respectively. ζ is positive when amplitudes increase over time (indicating dysregulation, with larger perturbations away from equilibrium), and is negative when amplitudes decrease over time (indicating damping, with convergence and stabilization of amplitudes towards equilibrium). These parameters are intrinsic self-regulation effects (i.e., the model's predicted trajectory for a person's own cycling and damping, over and above any influence from the partner) and are equivalent to *actor effects* in dyadic data analysis terminology (D. A. Kenny et al., 2006), as indicated by subscript a.

Cross-partner effects collectively capture coregulation and are indicated by subscript p. η_{px} and ζ_{px} indicate the effect of the provider's IBI position and first derivative on the target's second derivative of IBI—i.e., the influence of the provider on the target's cycling and damping. η_{py} and ζ_{py} are the equivalent parameters indicating the influence of the target on the provider's cycling and damping. Note that the effects of the target on the provider can differ from the effects of the provider on the target (Boker, 2012). The model also allowed for correlated residuals across partners (D. A. Kenny et al., 2006).

Differences in these parameters by discussion type were represented by a dummy variable (0 = support, 1 = control). The model included interaction terms for all parameters, thereby allowing for differences in self- and cross-partner effects between the support and control discussions. Dyad-specific random effects were modeled for all parameters.

Stressor Phase: Non-Coupled Damped Oscillator Model

During the stressor phase, data were collected on targets only. Therefore, we fit a damped oscillator model. This model was similar to the coupled modeled, but it did not include parameters for cross-partner effects or effects of discussion phase. In other words, the model included coefficients for self-regulation effects of cycling and damping only, with these effects modeled as random for each target. The basic equation for the typical target's self-regulatory trajectory during the stressor is:

$$\ddot{x}_t = \eta_s x_t + \zeta_s \dot{x}_t + e_t$$

As with the coupled model described above, x_t is the IBI level of the target at time t during the stressor, x_t is a weighted average of 10 seconds of observations, $\dot{x}_t$ is the first derivative of x_t, and $\ddot{x}_t$ is the second derivative. η_s refers to the frequency of oscillations (cycling) and ζ_s refers to changes in amplitudes over time (damping) during the stressor. Subscript s indicates that these parameter values are specific to the stressor phase, and can differ from the targets' parameter values for cycling and damping during the dyadic discussions. As described in more detail under Aim 4, a version of this model was also fit in which both the cycling and damping effects during the speech interacted with cross-partner dynamics observed during the discussions.

Multilevel Approach with Bayesian Estimation

For both models, we again used Bayesian multilevel modeling. All parameters were modeled as random, thereby allowing dyads to differ in their effects. As described in Chapter 3, analyses were performed using the *brms* package for R. For each set of model parameters, we ran four Markov chains for 8000 iterations each, with the first 4000 treated as warm-up and discarded, yielding posterior distributions consisting of 16000 sample values for each parameter. We set a weakly informative prior for all fixed effects, namely a uniform distribution in the interval [-2, 2]. For random-effect variances and covariances, we used the default priors provided by *brms*.

Results

Analyses drew on a final sample of 2660 observations from 18 dyads for the dyadic discussions and 466 observations from targets during the speech. Of the 20 total dyads, two dyads only completed one discussion due to time restrictions and therefore could not be included in the analyses.

Aim 1: Dyadic Coregulation during Discussions

First, we examined self- and coregulatory dynamics in participants' IBI during the two discussions. As discussed in Chapter 3, individual parameters are difficult to interpret in the context of a coupled damped oscillator, because patterns of trajectories depend on combinations of both self and partner coefficients and selection of start values (Butler & Barnard, 2019). As these effects are nonlinear, the resulting combinations of effects are most easily understood through visualization. Therefore, we discuss results in terms of overall average trajectories. Individual parameter estimates are provided in Appendix C for the interested reader[29]. As start values, we took the average of the first detrended IBI value for each participant, with separate averages computed for each experimental phase.

Model-predicted trajectories for the typical couple during each discussion are displayed in Figures 21 and 22. Figure 21 shows model-predicted trajectories within the 7-minutes allotted for the discussions, and Figure 22 shows projections for couples' dynamics if their discussions had instead lasted 15 minutes. As these figures show, there were clear patterns of cycling for both partners (targets and providers) during both discussions. However, whereas the typical target and provider generally did not show marked changes in amplitudes during the control discussion (if anything, on average the target's amplitudes showed slight damping toward equilibrium over time during the 7 minute period), they both showed *increasing* amplitudes of IBI during the support discussion. This suggests that the typical couple members, and the target especially, became increasingly dysregulated during the support discussion as the stressor approached.

These trajectories also suggest cross-partner influence, or co-*dys*regulation during the support discussion leading up the stressor, indicated by the synchronization of partners' responses. Providers became increasingly

[29]As in Chapter 3, we also performed model comparisons to understand the role of cross-partner effects in this study. Surprisingly, we did not find conclusive evidence for coregulatory effects from this approach, as we could not conclude that a model with partner effects fit the data better than a model without partner effects. This may be due to the small sample size, so we hesitate to draw firm conclusions based on this result. More details are available in Appendix C.

dysregulated in responses to the target's changes in IBI. Moreover, projections for the target and provider's trajectories beyond 7-minutes indicated that while the provider was predicted to eventually show better physiological regulation (switching from increasing amplitudes to decreasing amplitudes during the latter half of the projected time period), the target's amplitudes were predicted to continue increasing. This indicates that although the impending speech was dysregulating for the dyad as a whole, this dysregulating effect was especially strong for the partner assigned to give the speech.

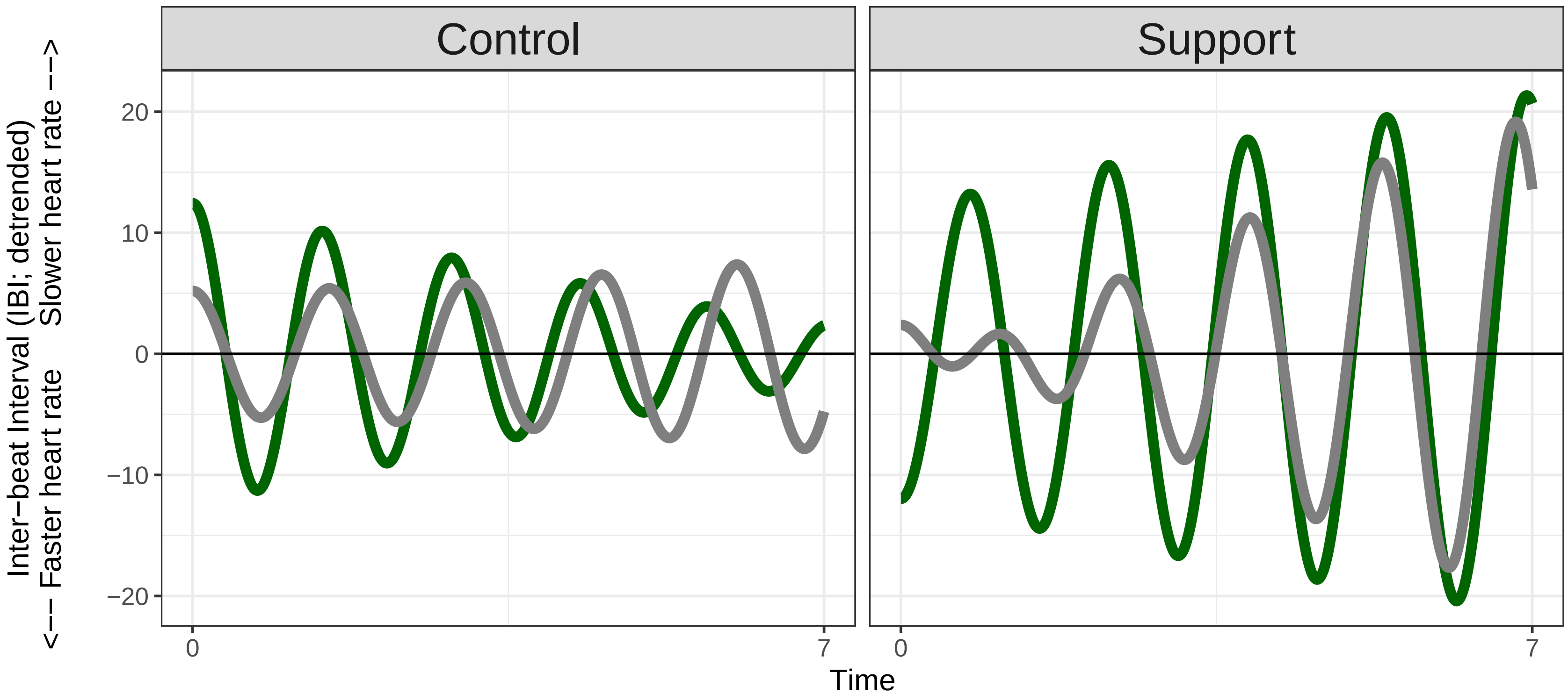

Figure 21: Results for the typical couple (fixed effects) during each 7-minute discussion. Results for the typical Target partner (partner giving speech) are displayed in green, and results for the Provider partner (partner not giving speech) are displayed in gray. The horizontal line at IBI = 0 indicates equilibrium IBI for each partner during that phase.

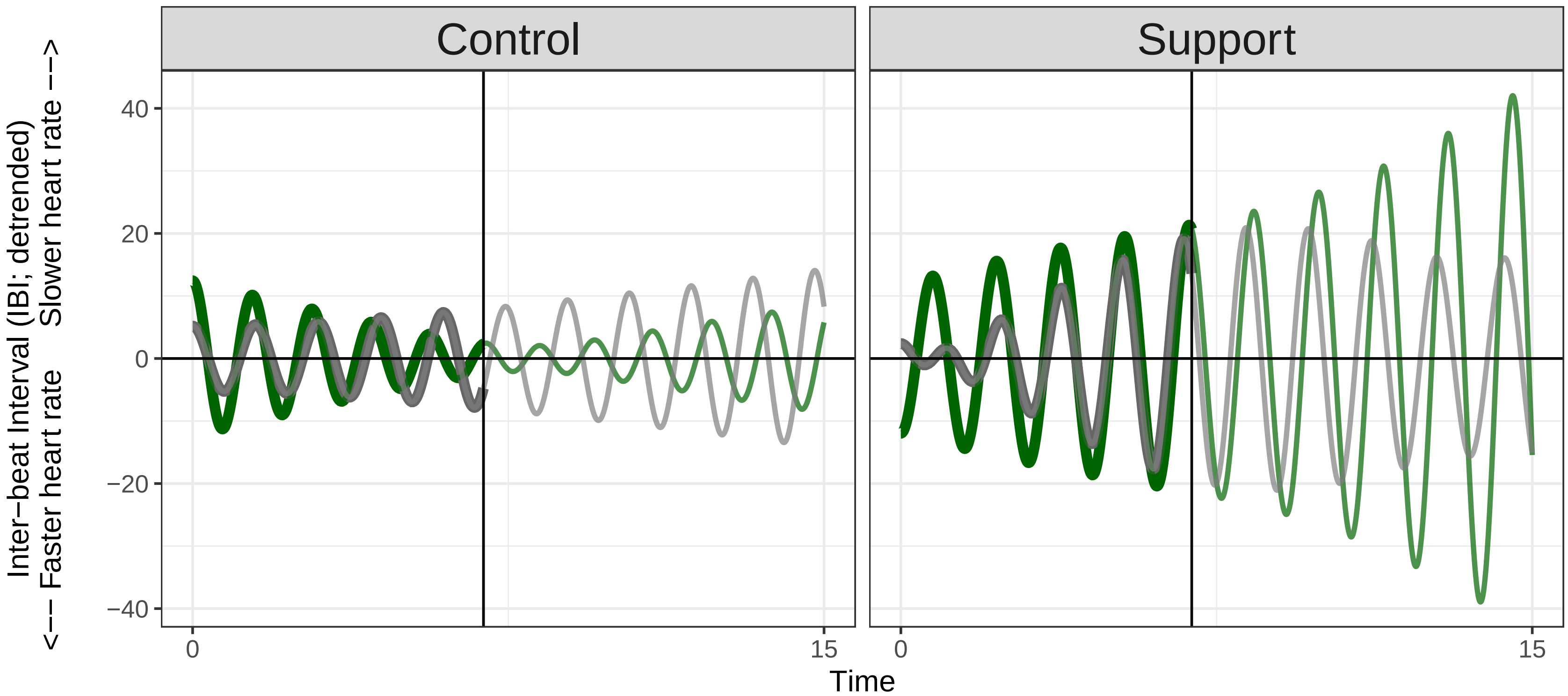

Figure 22: Results for the typical couple (fixed effects) during each 7-minute discussion. Results for the typical Target partner (partner giving speech) are displayed in green, and results for the Provider partner (partner not giving speech) are displayed in gray. The horizontal line at IBI = 0 indicates equilibrium IBI for each partner during that phase. Darker lines up to the 7-minute mark show model predicted results during the actual discussion period, and fainter lines after the 7-minute mark show projections for the typical couple had their discussion lasted for up to 15 minutes.

Aim 2: Self-Regulation during Stressor

We then examined targets' self-regulatory trajectories during the stressful speech. As noted previously, we used a damped linear oscillator model, in which targets' second derivative of IBI was modeled as a function of their IBI level (η_s, which gives the coefficient for cycling) and first derivative of IBI (ζ_s, which gives the coefficient for damping if negative and amplification if positive). Compared to the coupled version of the model, this (uncoupled) version produces coefficients that are relatively more straightforward to interpret, as there are no partner effects and the sign and magnitude of the cycling and damping effects dictate the general pattern.

As can be seen in Figure 23, the typical target showed regular cycling during the speech as well as amplification, with larger displacements from equilibrium as the speech progressed. This is consistent with earlier work suggesting that people tend to be physiologically reactive to socioevaluative stressors (Dickerson & Kemeny, 2004), as was the case for this stressor, and that older adults tend to experience greater cardiovascular reactivity to these kinds of stressors (Uchino et al., 2010, 2005). For the full model output, including individual parameter estimates and posterior distributions, see Appendix C.

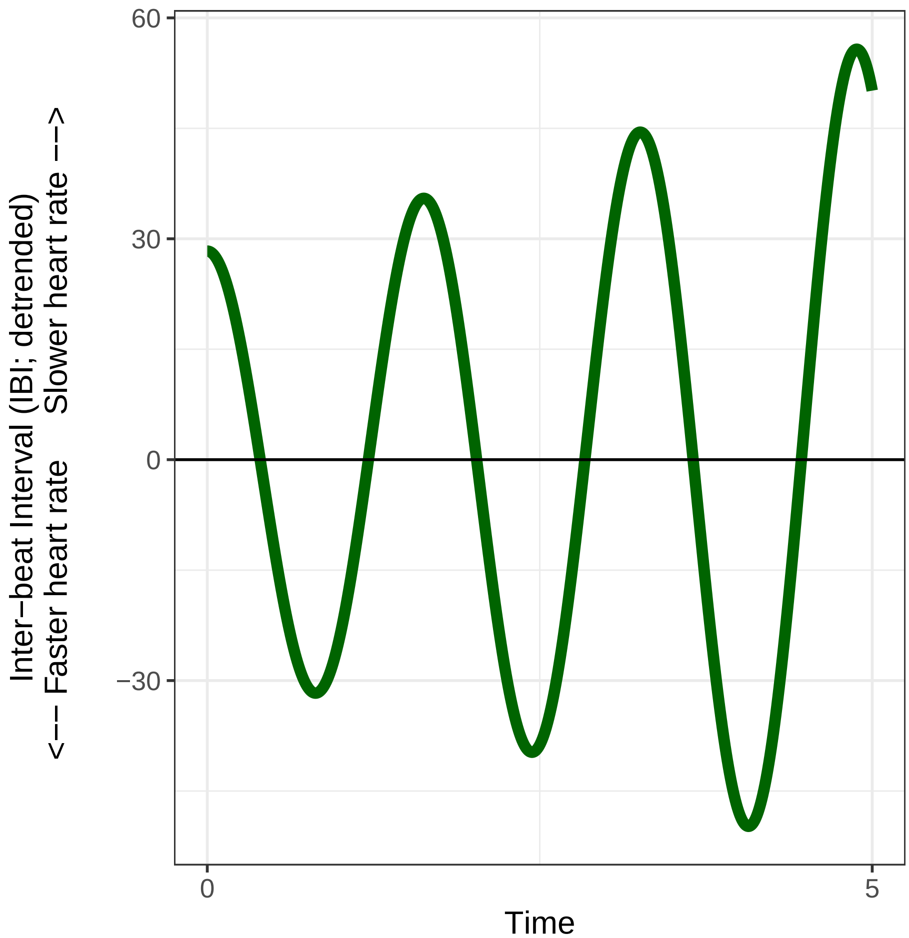

Figure 23: Results for the typical Target (fixed effects) during the 5-minute stressor. The horizontal line at IBI = 0 indicates equilibrium IBI for the Target during the stressor.

Aim 3: Between-Dyad Heterogeneity

Having revealed patterns of self-regulation and dyadic co(dys)regulation during the discussions and stressor, the next step was to assess between-dyad heterogeneity in these processes. Because the analyses presented under Aims 1 and 2 allowed dyads to vary in all parameters, we were able to generate model-predicted trajectories for each dyad.

Figure 24 presents model-predicted trajectories for a subset of dyads during the control discussion, support discussion, and speech (targets only). This figure reveals the extent of heterogeneity. For example, partners in Dyad A showed strong correspondence in their physiological trajectories during the support discussion, whereas Dyad B showed a lack of correspondence during the support discussion. Although targets from Dyads B, C, and D showed amplification during the speech, Dyad A showed a slight damping effect and Dyad E showed relatively constant amplitudes over time.

To further gauge the extent of heterogeneity in these results, we again used a technique discussed in Chapter 3. We used Bolger et al.'s (2019) rule of thumb, which proposes that heterogeneity is noteworthy if the ratio of a random effect to its corresponding fixed effect is .25 or greater. We computed these ratios (random / fixed) for all parameters across study phases and found that these ratios for all parameters exceeded this .25 threshold. For details, see Appendix C.

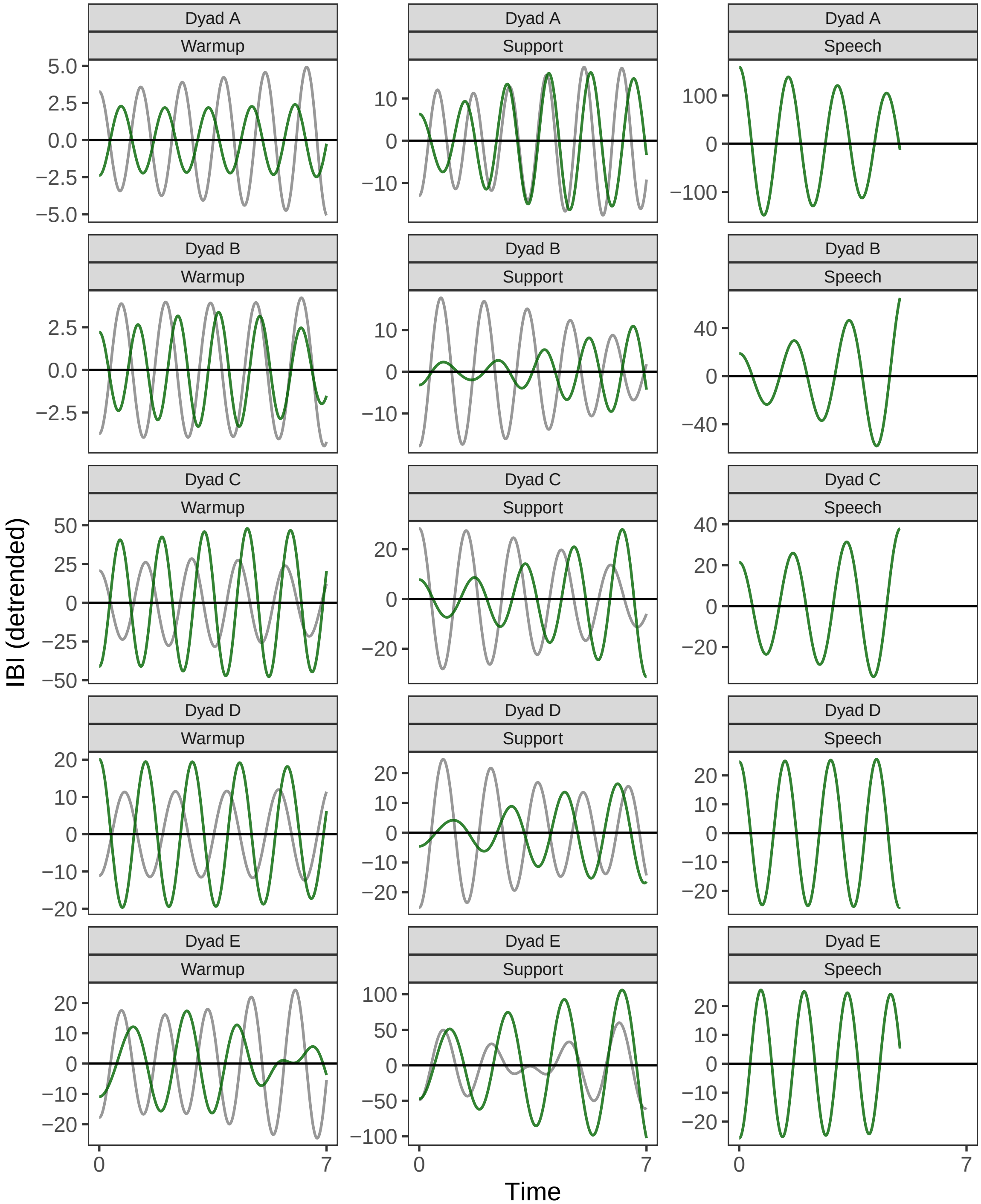

Figure 24: Panel plots illustrating model predicted trajectories for five dyads (rows), across study phases (columns). X-axes show phase duration (7 minutes for the discussions, 5 minutes for speech). Y-axes have been scaled on a per-dyad and per-phase basis for clarity of presentation. Targets are displayed in green, and providers are displayed in gray. The horizontal line at IBI = 0 indicates equilibrium IBI (detrended) for each partner during each phase.

Aim 4: Do Coregulation Dynamics Predict Self-regulation Dynamics during the Stressor?

Our final step was to test whether heterogeneity in the dyadic coregulation processes observed during the discussions might in turn be related to heterogeneity in targets' self-regulatory dynamics during the speech. We investigated this possibility in a series of exploratory analyses. We focused on associations of damping effects because, compared to cycling, damping is arguably a better indicator of effective self-regulation, with decreasing amplitudes reflecting a calming and stabilizing process.

First, we examined whether dyad-specific cross-partner damping (target's effect on provider damping and provider effect on target damping) observed during the speech were correlated with target self-regulatory damping during the speech. However, we did not find evidence for associations among these variables.

This led us to reason that *changes* in cross-partner coregulation effects between the control discussion and support discussion might be a more important predictor of targets' self-regulation. Because all dyads completed a support discussion leading up to the stressor, cross-partner effects within the support discussion alone do not differentiate between cross-partner influence that is specific to the stressor context versus general between-dyad differences in cross-partner influence. We therefore examined whether *changes* in cross-partner coregulation effects between the control and support discussions might predict targets' damping during the speech. This difference parameter more cleanly captures how partners might modulate their responding across the context of these two discussions (in other words, how partners' responding changed between a discussion about a routine topic and a support discussion).

Predicting Heterogeneity in Target Self-regulation (Damping) During Speech

We focused on changes in the effect of targets' IBI on providers' damping between the support and control discussions. Recall that ζ_{py} is the effect of the target's first derivative of IBI on the provider's second derivative of IBI for a typical dyad; thus, this moderator can be represented as $\Delta\zeta_{pyj}$, where Δ indicates the difference in this effect between discussions for dyad j. For ease of interpretation, we recoded discussions, such that for $\Delta\zeta_{pyj} = \zeta_{pyjSupport}$ - $\zeta_{pyjControl}$[30]. With this coding, when $\Delta\zeta_{pyj}$ is larger and positive, this indicates that the target had a more dysregulating effect on the provider during the support (vs. control discussion); when $\Delta\zeta_{pyj}$ is smaller, this indicates that the target had a less dysregulating effect on the provider during the support (vs. control discussion). For simplicity, we refer to this effect as *change in codysregulation* from hereon.

[30]Put differently, because discussion was represented as 1 = control, 0 = support in the coupled damped oscillator model, we multiplied resulting values for $\Delta\zeta_{pyj}$ from the coupled oscillator model by -1 to facilitate interpretation of this heterogeneity analysis.

All dyads in the sample had a change in codysregulation value that was positive in sign. However, they varied in the size of this effect (*Min* = 0.03, *Max* = 0.11). At the lower end of this range, dyads had a smaller increase in codysregulation when going from the control discussion to the support discussion; at the upper end of this range, dyads had a larger increase in codysregulation between the discussions.

Moderated Damped Oscillator Model

Thus, we examined whether targets' self-regulation dynamics (ζ_{sj}) were related to changes in dyadic coregulation across the two discussions ($\Delta\zeta_{pyj}$). We refit the damped oscillator model capturing targets' self-regulatory dynamics during the speech, this time allowing the target's cycling and damping coefficients to interact with dyad-specific change in codysregulation; change in codysregulation values were standardized prior to analysis to facilitate interpretation.

The model-predicted trajectories from this analysis are shown in Figure 25: Among dyads with larger increases in codysregulation between discussions, targets later showed more dysregulation during the speech, indicated by increasing amplitudes. However, among dyads with smaller increases in codysregulation between discussions, targets later showed better self-regulation during the speech, indicated by constant amplitudes. This result suggests that among dyads who were better able to mitigate dysregulation transferring from target to provider during the support discussion (relative to the control discussion), targets were able to regulate themselves better on their own. The full model output for this analysis, with individual parameter estimates and posterior distributions, is provided in Appendix C.

To further illustrate this effect, Figure 26 presents a scatterplot visualizing the relationship between dyad-specific changes in codysregulation and targets' damping during the speech. Targets who had a larger codysregulating effect on the provider during the support (vs. control) discussion also tended to exhibit more amplification during the speech. In contrast, targets who had a smaller codysregulating effect on the provider showed less amplification during the speech.

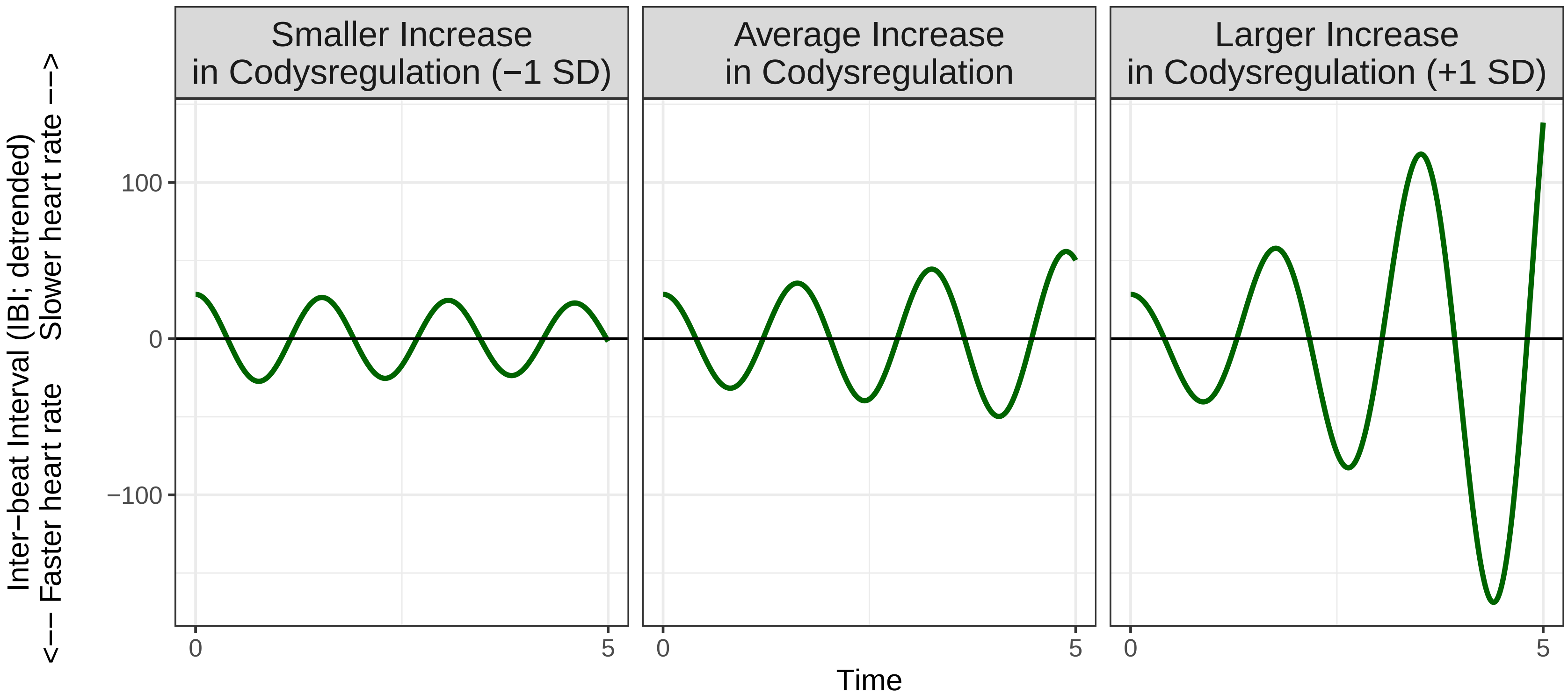

Figure 25: Model-predicted self-regulatory trajectories during the stressor for targets from dyads who showed smaller (-1 SD), average, and larger (+1 SD) changes in codysregulation between the control and support discussions. Given variable coding for this analysis, larger (positive) changes indicated greater increases in codysregulation from the control discussion to the support discussion.

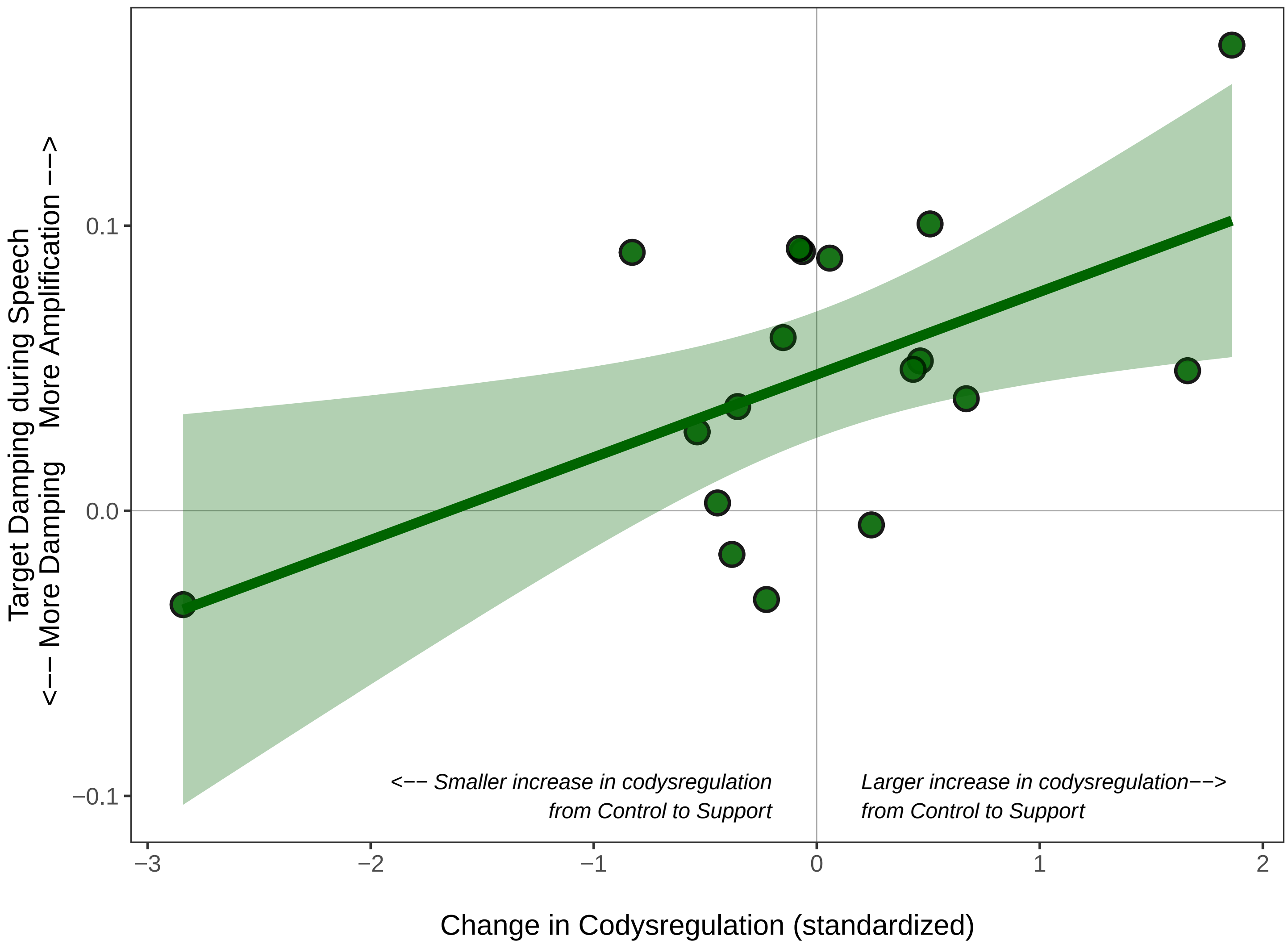

Figure 26: Scatterplot illlustrating the association between changes in codysregulation between discussions, and target's damping during the speech. Along the x-axis, larger positive values indicate an increase in codysregulation from the control to the support discussion, and lower values indicate a smaller increase in codysregulation. Along the y-axis, positive values indicate amplification (more dysregulation), and negative values indicate damping (better regulation).

Ruling Out an Alternative Explanation

Despite the promise of these findings, alternative explanations for this association might be possible. For instance, *targets' own changes* in damping between the control and support discussions could be driving this effect. This seems plausible, as targets who become more dysregulated during the support discussion leading up to the speech (compared to during the control discussion) might also show more dysregulation during the speech itself. Follow-up analyses investigating this possibility are presented in Appendix C. In brief, we fit a model that simultaneously tested for interactions involving targets' damping during the speech and (a) changes in codysregulation (our original coregulation moderator) and (b) targets' own changes in dysregulation between discussions (a self-regulation moderator); these are equivalent parameters, except that the latter reflects a self-regulation only process. However, we found that the original moderation effect remained essentially the same even when taking this potential alternative explanation into account. Moreover, further analysis revealed a 0.91 probability that the codysregulation moderator ($\Delta\zeta_{py}$) had a stronger effect than the alternative self-regulation moderator. Therefore, the evidence pointed in favor of targets' damping during the speech being linked to changes in dyadic codysregulation between discussions, over and above changes in targets' own self-regulation between discussions.

How much variability in target self-regulation is explained by codysregulation?

How much of the variability in targets' damping effects can be explained by changes in codysregulation? Drawing on approaches described in Bolger et al. (2019), we computed the total heterogeneity variance implied by the moderation model. This can be expressed as:

$$V(\zeta_s) = \delta_1^2 V(\Delta\zeta_{py}) + \sigma_\zeta^2$$

$V(\zeta_s)$ is the total heterogeneity variance in the target damping effect during the speech. $\delta_1^2 V$ is the squared regression coefficient linking the moderator—changes in codysregulation or $\Delta\zeta_{py}$—to the total heterogeneity, in standardized units. σ_ζ^2 is the residual variance in heterogeneity of the target damping effect after accounting for change in codysregulation.

The variance explained by change in codysregulation can be computed as 1-$V(\zeta_s)$, which corresponded to 1-(0.0095/0.0160). This indicated that 39% of the variability in targets' damping during the speech was explained by differences in codysregulation changes between the control and support discussions.

The role of change in codysregulation in explaining heterogeneity in targets' damping is visualized in

Figure 27. This figure presents target-specific (random effect) estimates for damping during the speech from the original model along the top row, and target-specific (random effect) estimates for damping during the speech from the model allowing for interactions with changes in codysregulation along the bottom row. Each dot represents a specific target. This figure reveals how the random effects are pulled towards the mean (known as *shrinkage*) after taking variability in coregulatory dynamics into account.

In addition to showing shrinkage of the target-specific estimates, this figure also illustrates the narrowed range of possible target damping values. The green dotted lines show the observed range containing the damping effects for 95% of targets in this *sample*. The green shaded boxes show the 95% heterogeneity interval (Bolger et al., 2019), which is the predicted range in which 95% of the *population* is estimated to fall. This interval captures true between-subject heterogeneity, which is assumed to be free of measurement error and noise; it is different from a traditional confidence interval or credibility interval, which represents the precision of a parameter estimate. Thus, although a large degree of heterogeneity in the target damping effect can be expected in the population, this degree of heterogeneity is substantially reduced by accounting for dyads' change in codysregulation. Overall, result reveals that such coregulation dynamics explain a substantial proportion of the variability in targets' self-regulation dynamics during the stressor.

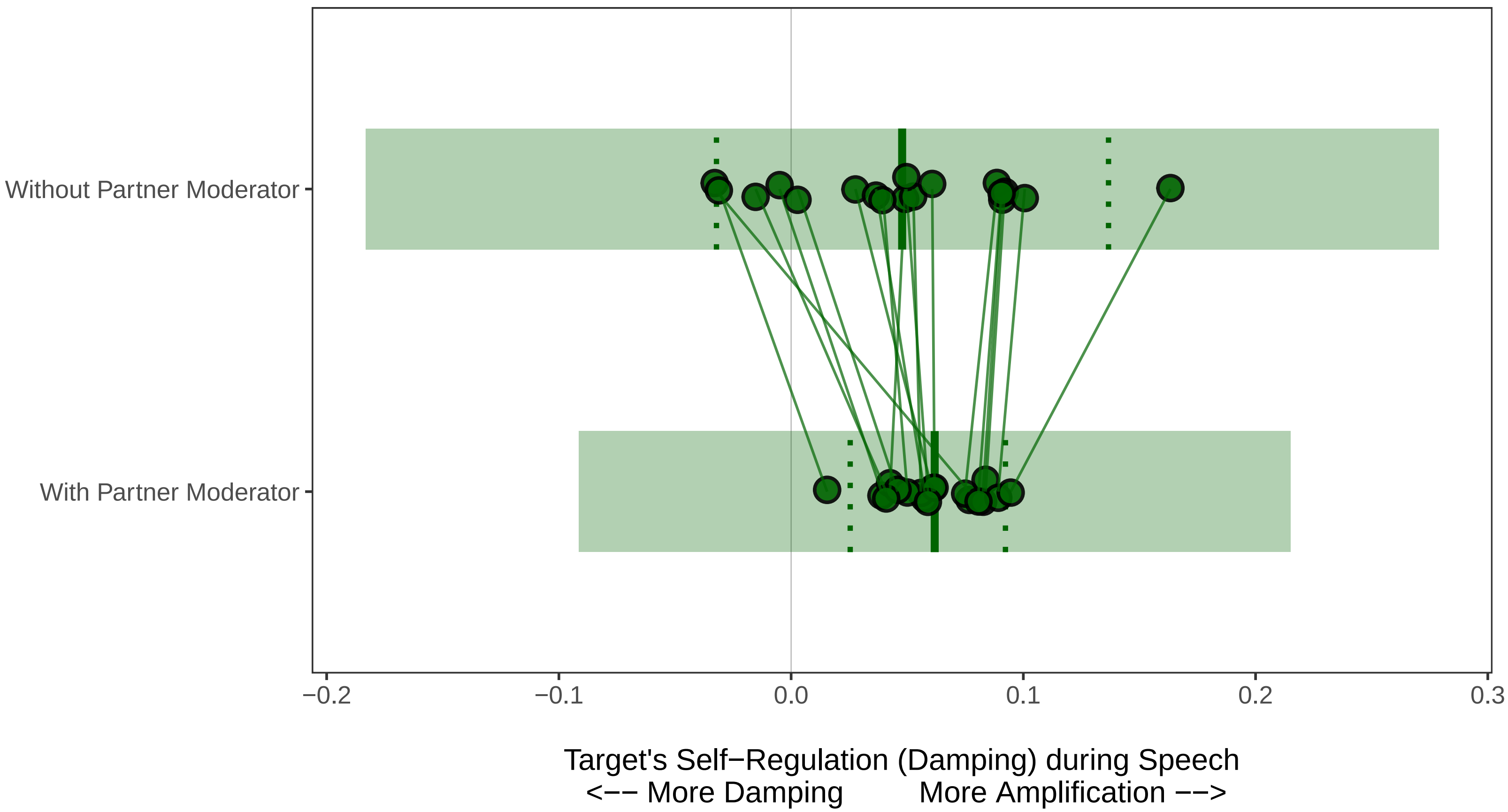

Figure 27: Strip plot displaying the target-specific (random) effects for damping during the stressor. The top panel presents damping effects from the original model, and the bottom panel presents damping effects from the model including interactions by change in codysregulation. Solid green vertical lines show the mean damping estimate, and the dashed vertical green lines show the 95-percent quantiles for the sample. The shaded green boxes are the 95-percent heterogeneity intervals, indicating the range of possible damping effects within the population. Data points are jittered for clarity of presentation.

General Discussion

Older adulthood is a critical life stage characterized by changes to interpersonal relationships, self-regulation, and physiology. This study investigated the role of relationship partners in helping older adults manage age-related challenges. Consistent with theories proposing that acute stressors are a context in which older adults experience vulnerabilities (Charles, 2010), results suggested that older couples showed dysregulation of cardiovascular responses (operationalized as increasing amplitudes) as they engaged in a support discussion in anticipation of a stressor and, for those given the speech, during the stressor itself. However, dyads showed a large degree of heterogeneity in these effects, with some dyads showing more pronounced dysregulation of their physiological trajectories, and others showing more regulatory success. We then examined this heterogeneity directly and found that heterogeneity in dyads' changes in codysregulation between the control and support discussions explain nearly 40% of the heterogeneity in targets' self-regulation during the speech. This evidence is some of the first, to our knowledge, to demonstrate the potential role of *dyadic coregulation* in predicting individual *self-regulation* in older adulthood.

Implications for Aging Literature

This work offers novel contributions to the aging literature by suggesting specific ways that relationship partners might contribute to developmental regulation and healthy aging. As described previously, although many theories of aging have proposed that relationship partners play a role in helping individuals adapt to age-related changes and challenges across the lifespan, less is known that about relationship processes or behaviors through which this might occur (Uchino et al., 2016). The present findings suggest that among older couples who showed smaller increases in codysregulation from the control discussion to the support discussion, individuals in turn exhibited better physiological regulation during a stressor. These findings are noteworthy in light of earlier work indicating that older adults tend to be more vulnerable and reactive to acute stressors (Charles, 2010; Uchino et al., 2010, 2005). Supportive interactions with a partner that engender less codysregulation may play a role in mitigating this reactivity.

This work also speaks to the importance of considering heterogeneity in an aging context. Heterogeneity is considered a hallmark feature of aging (P. B. Baltes & Baltes, 1990), as individuals become increasingly different from each other as they accrue more unique life experiences. This work highlights heterogeneity in both individual and dyadic processes. First, results reveal noteworthy heterogeneity in dyadic coregulation across both types of discussions, whereby couples differed in both their self- and cross-partner trajectories. Importantly, dyads also differed in how their trajectories *changed* from discussion to discussion. During the stressor, targets also showed heterogeneity of physiological self-regulation, with some dyads showing heightened dysregulation and others showing better regulation. Lastly, results indicate that heterogeneity in dyadic interaction accounted for nearly 40% of the variance in targets' self-regulation during the stressor. Thus, these findings invite further research examining how heterogeneity at the *dyadic* level might explain heterogeneity at the *individual* level.

This work also presents a novel application of statistical methods to understand theoretically important processes in an aging context, such as relationship influence and regulation of stress responses. We demonstrated how heterogeneity, which is a central concept in aging research, can be investigated directly using intensive longitudinal designs, and we further used innovative analyses to link heterogeneity in coregulatory dynamics to heterogeneity in individual self-regulatory dynamics. These methods could be utilized in other contexts to better understand within-person change and sources of between-person variability in such processes.

Implications for Relationships Literature

The present work also offers new insights into relationships research. Although recent theoretical advances have proposed important connections between self-regulation processes and coregulation processes of the dyad as a unit (Butler & Randall, 2013; Fitzsimons et al., 2015), this research is among the first to empirically demonstrate such links. These findings open the door to new hypotheses about the interpersonal nature of self-regulation, and how coregulating within a relationship context might confer self-regulatory benefits when individuals cope with stressors or pursue goals on their own.

The unique socioemotional and relational profile of older adulthood also offers fertile ground for further theorizing about how close relationships function during this life stage. These findings open the door to close relationships research questions, such as what relationship factors predict whether dyads will show more vs. less codysregulation to the same stressor, and how the nature of coregulation in couples might differ in younger vs. older adulthood. Further insights generated from using theories and methods from relationship science could prove valuable in better understanding determinants of healthy aging.

Caveats

Despite the promise of these results, there are caveats that are important to note. Advantages of this study include its use of real older couples recruited from the local community and use of repeated measures data with multiple experimental phases. However, a limitation is that results were derived from a small dataset of 18 couples. Although older adulthood in a period in which more pronounced responses to receiving partner support (Jakubiak et al., 2019) and acute stressors (Charles, 2010; Uchino et al., 2005) are to be expected (i.e., larger effect sizes), caution is nevertheless warranted. These results need to be replicated and extended in larger samples of couples.

There are also trade-offs to the study design and its implications for interpreting results within each discussion. An advantage of this design was its use of within-dyad comparisons to examine differences in self- and coregulation during a control discussion and a support discussion leading up to a stressor. Through capturing within-dyad change, we were able to link couple-specific differences in cross-partner influence between these discussions to individual differences in physiological self-regulation during the speech. However, a drawback of this is that it introduces difficulties in interpreting the meaning of couples' trajectories within the support discussion; specifically, it is unclear whether the patterns of dysregulation found for the typical dyad were due to ineffective support or to the stressor context. Given our earlier results indicating that social support given when a stressor is not impending can give rise to beneficial patterns of coregulation (see Chapter 3), paired with knowledge about stressor reactivity in older adulthood, it seems likely that the patterns of dysregulation might be attributable to the upcoming stressor. Yet, prior work has pointed out that the effects of social support and stressors on distress are often confounded, as stressful events can trigger support provision (Bolger, Foster, Vinokur, & Ng, 1996; Seidman, Shrout, & Bolger, 2006). This concern is relevant to the present study. Because all dyads completed a support discussion, this study does not allow us to draw inferences about whether engaging in social support is more or less beneficial than other types of partner interaction (or no partner interaction) in tempering anticipatory stress. This is an interesting research question that needs to be investigated in future work.

There are also caveats involved in our modeling strategy. To briefly summarize the main points raised in Chapter 3, results from these models depend on analytic decisions such as the size of the window used to compute derivatives and choice of start values. For this analysis, we fit models using only one window size that was determined *a priori* and preregistered, but it is possible that results could differ somewhat if we were to select a different size.

Conclusions

Older adulthood is a period of life characterized by important changes to individuals' physiology, relationships, and self-regulatory efforts. As older adults place greater emphasis on their relationships with age, relationship partners may act as a key resource for helping older adults adapt to age-related changes.

Moreover, by gaining experience coregulating in a relationship context over time, older adults may exert stronger cross-partner influence on each other. This study examineed physiological coregulation among older romantic dyads and revealed potential links between dyadic coregulatory effects and individual self-regulatory success. Coregulating effectively with a partner when receiving support for an impending stressor could play a role in enabling individuals to better manage their stress and experience better physiological self-regulation when coping with a stressor on their own. These findings invite further research into how coregulation within relationships can help older adults live longer, happier, and healthier lives.

Chapter 5: Conclusions

This dissertation research investigated how interpersonal relationships contribute to effective self-regulation, coregulation, and developmental regulation and how social support interactions are a key context in which these important regulation processes occur. Although relationships are recognized to be important for health and well-being (Holt-Lunstad, 2018), mechanisms underlying these effects have continued to be an area in need of further study. Collectively, these findings contribute to understanding of how relationships promote these benefits: Social support that addresses recipients' self-regulatory needs and creates a stabilizing coregulatory process with a close other could be integral to these effects. These concluding remarks will synthesize findings from across chapters, highlight potential avenues for future research, and summarize the contributions of this body of work to the broader literatures on relationships, self-regulation, and aging.

Synthesizing Across Chapters

Implications of RES for Coregulation and Developmental Regulation

Chapter 2 presented a new theoretical construct—Regulatory Effectiveness of Support (RES)—which proposes the importance of providing social support that addresses recipients' needs for understanding their situation (*truth*) and feeling capable of managing their situation (*control*). Across several studies and a meta-analysis, results indicated that RES predicted self-regulation relevant outcomes of support, such as better mood regulation and coping. These findings open the door to new research questions and applications in light of results from Chapters 2 and 3.

One exciting question concerns the role of RES in possibly engendering distinct patterns of dyadic coregulation during social support discussions. As RES has been linked to lower negative mood and may even temper cardiovascular stress reactivity, it seems plausible that one channel through which these effects occur is dyadic coregulation between provider and recipient. Social support interactions that are higher on RES, that address recipients' needs to understand and manage their situation to a greater degree, could engender calming patterns of dyadic coregulation, which in turn might lead recipients to experience positive support outcomes. Findings on the benefits of providing support also speak to this possibility (Inagaki & Orehek, 2017): Giving effective social support to a partner in distress may help the provider to manage their own distress. It would be interesting to consider how moment-to-moment changes in RES and other behaviors throughout a support discussion might engender real-time changes in coregulation dynamics.

Beyond RES, there may be other aspects of support quality or support behaviors that may be responsible for driving beneficial coregulation trajectories between partners. For example, factors like empathy and perspective-taking (Palumbo et al., 2017) could play a role in shaping dynamics.

Collectively, this dissertation research also invites questions about the potential role of RES in older adulthood. As alluded to in the General Discussion of Chapter 2, the effects of RES on beneficial support outcomes might be especially pronounced in older adulthood. Indeed, it is worth noting the overlap between the theoretical propositions of RES and existing theories of lifespan development, particularly the Selective Optimization and Compensation (SOC) Model (Baltes & Carstensen, 2003). The SOC Model suggests that older adults use strategies such as goal selection and compensation to optimize their goal outcomes as a way of adapting to age-related changes. The notions of selection and compensation have some overlap with the truth and control facets of RES. Enacted social support higher on RES could influence older adults' *selection* of appropriate goals and goal pursuit strategies for their capabilities through *truth effectiveness* (helping them understand their situation), and could also influence *compensation* for age-related changes through *control effectiveness* (boosting their sense of control). Further research examining how RES contributes to developmental regulation could offer a new way of understanding how relationships might promote healthy aging.

Coregulation Across Contexts and Development

Chapters 3 and 4 both investigated physiological coregulation, but did so in different psychological and developmental contexts. Chapter 3 examined coregulation among predominantly younger couples as they engaged in an affiliative non-support discussion about a joint goal (control discussion) and two support discussions about an ongoing difficulty for each partner. In contrast, Chapter 4 examined coregulation among a small sample of older couples as they completed a discussion of a routine topic (their schedules) and then a social support discussion in anticipation of an impending stressor. It is important to note that the differences in the populations and study designs used in these studies prevent direct comparison between them. However, these differences highlight potential boundary conditions and future directions to be considered in subsequent work.

First, it is interesting to note that although social support discussions in Chapter 3 generally had a stabilizing coregulatory effect, in Chapter 4 couples showed codysregulation during the support discussion. This opens up additional questions about when coregulation is calming vs. destabilizing. Chapter 3 speculated that coregulation should be most important when there has been a displacement from equilibrium and therefore a need for it to occur, but Chapter 4's findings suggest there might be a threshold or "right" amount of displacement from equilibrium for creating a beneficial coregulation process. Developmental context also merits further consideration. Because acute stressors are a context in which age-related vulnerabilities are revealed (Charles, 2010; Uchino et al., 2005), the codysregulation effect observed in Chapter 4 might have been attributable to this developmental change. Further research could clarify whether younger couples also show codysregulating effects when stressors are imminent, compared to more distal or ongoing.

Chapter 4 showed promising results about the potential links between dyadic coregulation and individual self-regulation. These are some of the first results to suggest that dyadic coregulation might give rise to individual self-regulation in adulthood. However, this study was a preliminary investigation with a small sample, and these effects need to be replicated in larger samples. Nevertheless, these results suggest broader questions about how and when coregulation helps or hinders effective self-regulation. Such questions could have critical implications for the field's understanding of the function of coregulation, what factors enable individuals to self-regulate effectively, and the importance of social context in self-regulation processes.

Contributions to Relationships Literature

This work contributes to the field's understanding of interpersonal relationships in several ways. First, each chapter integrated theories from the self-regulation literature to better understand social support and relationship process. This research expands on a burgeoning sector within relationships science focusing on the intersection of relationships and self-regulation (e.g., Feeney & Collins, 2015; Fitzsimons et al., 2015; Rusbult et al., 2009). This work is also novel, from a relationships science perspective, due to its integration with theories of aging and lifespan development. Past research, for example, has largely focused on relationships among younger couples or has been theoretically silent about how relationships function and change in older adulthood (with some notable exceptions). This research provides an example of new and exciting directions relationships research can explore by incorporating findings and theories from other areas.

Methodologically, this work highlighted the importance of treating the dyad as the unit of analysis, particularly in Chapters 3 and 4. The notion of the dyad as an entity that is distinct from two individuals is consistent with the interdependence tradition within close relationships work (Rusbult & Van Lange, 2003) and established practices in dyadic data analysis (D. A. Kenny et al., 2006). This work also went beyond the types of dyadic analyses typically encountered in relationships research through the use of dynamical systems modeling of dyadic data. This modeling approach provided new insights into specific interpersonal regulation processes, such as damping of relationship partners' responses, that would not have been addressable using more conventional linear models. Ultimately, this dissertation work provides an illustration of how cutting-edge statistical techniques can be used to better answer important theoretical questions. Future relationships research could use the present work as a foundation for exploring other ways of developing statistical translations of complex dyadic phenomena to provide more targeted tests of hypotheses about how relationships function and what implications they have for individuals and dyads.

Contributions to Self-Regulation and Motivation Literature

This research also has implications for the study of self-regulation and motivation. Chapter 2 provides direct empirical evidence for the importance of truth and control in helping people feel effective and in predicting downstream self-regulatory success (Higgins, 2012). This work also adds to knowledge of self-regulatory effectiveness by showing that interpersonal interactions may play a noteworthy part in enabling individuals to experience truth effectiveness and control effectiveness.

Across studies, this work also offers further support for the notion that self-regulation is deeply enmeshed in an interpersonal context. This suggests important future directions aimed at understanding, for example, how self-regulation and goal pursuit change as a function of relationship quality, social support, rivalry, status, and a variety of other interpersonal factors. The results from Chapter 4, though preliminary, also offer some of the first insights into how coregulation relates to self-regulation in adulthood. This is an advance beyond earlier understanding of how individuals in a relationship influence each other's self-regulation by underscoring the importance of studying how partner jointly regulate each other *as a dyadic unit.*

Contributions to Aging Literature

Findings from this research speak to the value of integrating insights from relationships science and self-regulation to better understand, and enhance, the aging process. Although theories of lifespan development have acknowledged the importance of relationships for healthy aging (Antonucci et al., 2014; Lang & Carstensen, 1994; Uchino & Rook, 2020; Uchino et al., 2016), they have tended to posit a general role of relationships. This research proposes a variety of specific pathways through which relationships are likely to influence developmental regulation, such as effective support and coregulation. Integrating these insights could be useful, for example, for leveraging relationships in interventions to help older adults live longer and healthier lives.

Concluding Remarks

This work proposes that relationships function as interdependent regulatory systems. Focusing on the context of social support interactions, this research reveals the important role that relationship partners play in scaffolding self-regulation, coregulation, and developmental regulation. Ultimately, these findings open a window of understanding into how various relationship and regulation processes work interactively, across levels of analysis and different timescales, to positively impact individual and interpersonal well-being.

References

Antonucci, T. C., Ajrouch, K. J., & Birditt, K. S. (2014). The convoy model: Explaining social relations from a multidisciplinary perspective. *Gerontologist*, *54*, 82–92.

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of other in the self scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology*, *63*, 596–612.

Baltes, M. M., & Carstensen, L. L. (2003). The process of successful aging: Selection, optimization and compensation. In U. M. Staudinger (Ed.), *Understanding human development: Dialogues with lifespan psychology.* (pp. 81–104). New York: Springer Science; Business Media.

Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: The model of selective optimization with compensation. In P. B. Baltes & M. M. Baltes (Eds.), *Successful aging: Perspectives from the behavioral sciences* (pp. 1–34. PMCID: N/A). New York, NY: Cambridge University Press.

Bar-Kalifa, E., & Rafaeli, E. (2013). Disappointment's sting is greater than help's balm: Quasi-signal detection of daily support matching. *Journal of Family Psychology*, *27*, 956–967.

Baumeister, R. F. (2003). Ego depletion and self-regulation failure: A resource model of self-control. *Alcoholism: Clinical and Experimental Research*, *27*, 281–284.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*, 497–529.

Berntson, G. G., Quigley, K. S., & Lozano, D. (2007). Cardiovascular Psychophysiology. In J. Cacioppo, L. Tassinary, & G. Berntson (Eds.), *Handbook of psychophysiology* (pp. 182–210). New York: Cambridge University Press.

Bisconti, T. L., Bergeman, C. S., & Boker, S. M. (2006). Social support as a predictor of variability: An examination of the adjustment trajectories of recent widows. *Psychology and Aging*, *21*, 590–599.

Blascovich, J., Mendes, W. B., Vanman, E., & Dickerson, S. S. (2011). *Social Psychophysiology for Social and Personality Psychology* (pp. 1–124).

Bodenmann, G., Meuwly, N., Germann, J., Nussbeck, F. W., Heinrichs, M., & Bradbury, T. N. (2015). Effects of Stress on the Social Support Provided by Men and Women in Intimate Relationships. *Psychological Science*, *26*, 1584–1594.

Boker, S. M. (2012). Dynamical systems and differential equation models of change. *APA Handbook of Research Methods in Psychology, Vol 3: Data Analysis and Research Publication.*, *3*, 323–333.

Boker, S. M., & Laurenceau, J.-P. (2006). Dynamical systems modeling: An application to the regulation of intimacy and disclosure in marriage. In T. A. Walls & J. L. Schafer (Eds.), *Models for intensive longitudinal data* (pp. 195–218). New York, NY: Oxford University Press, Inc.

Boker, S. M., & Nesselroade, J. R. (2002). A Method for Modeling the Intrinsic Dynamics of Intraindividual Variability: Recovering the Parameters of Simulated Oscillators in Multi-Wave Panel Data. *Multivariate Behavioral Research*, *37*, 127–160.

Boker, S. M., Deboeck, P. R., Edler, C., & Keel, P. K. (2010). Generalized Local Linear Approximation of Derivatives from Time Series. In S.-M. Chow, E. Ferrer, & F. Hsieh (Eds.), *Statistical methods for modeling human dynamics: An interdisciplinary dialogue* (pp. 161–178. PMCID: N/A). New York, NY: Taylor & Francis Group.

Bolger, N., & Amarel, D. (2007). Effects of social support visibility on adjustment to stress: Experimental evidence. *Journal of Personality and Social Psychology*, *92*, 458–475.

Bolger, N., & Laurenceau, J.-P. (2013). *Intensive Longitudinal Methods*. New York: The Guildford Press.

Bolger, N., & Zee, K. S. (2019a). Heterogeneity in Temporal Processes: Implications for Theories in Health Psychology. *Applied Psychology: Health and Well-Being*, *11*, 198–201.

Bolger, N., & Zee, K. S. (2019b). Heterogeneity in Temporal Processes: Implications for Theories in Health Psychology. *Applied Psychology: Health and Well-Being*. doi:10.1111/aphw.12159

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: capturing life as it is lived. *Annu Rev Psychol*, *54*, 579–616.

Bolger, N., Foster, M., Vinokur, A. D., & Ng, R. (1996). Close relationships and adjustment to a life crisis: the case of breast cancer. *Journal of Personality and Social Psychology*, *70*, 283–294.

Bolger, N., Zee, K. S., Rossignac-Milon, M., & Hassin, R. R. (2019). Causal processes in psychology are heterogeneous. *Journal of Experimental Psychology: General*, *148*, 601–618.

Bolger, N., Zuckerman, A., & Kessler, R. C. (2000). Invisible support and adjustment to stress. *Journal of Personality and Social Psychology*, *79*, 953–961.

Burkner, P.-C. (2017). brms: An R package for Bayesian Multilevel Modeling using Stan. *Journal of Statistical Software*, *80*, 1–28.

Butler, E. A. (2011). Temporal interpersonal emotion systems: The "TIES" that form relationships. *Personality and Social Psychology Review*, *15*, 367–393.

Butler, E. A., & Barnard, K. J. (2019). Quantifying Interpersonal Dynamics for Studying Socio-Emotional Processes and Adverse Health Behaviors. *Psychosomatic Medicine*, *81*, 749–758.

Butler, E. A., & Randall, A. K. (2013). Emotional coregulation in close relationships. *Emotion Review*, *5*, 202–210.

Carpenter, R. (2009). Bayesian Counterpart to Fisher Exact Test on Contingency Tables. Retrieved from https://lingpipe-blog.com/2009/10/13/bayesian-counterpart-to-fisher-exact-test-on-contingency-tables/

Carstensen, L. L., Fung, H. H., & Charles, S. T. (2003). Socioemotional selectivity theory and emotion regulation in the second half of life. *Motivation and Emotion*, *27*, 103–123.

Carstensen, L. L., Gottman, J. M., & Levenson, R. W. (1995). Emotional behavior in long-term marriage. *Psychology and Aging*, *10*, 1–10.

Carver, C. S., Scheier, M. F., & Weintraub, J. K. (1989). Assessing coping strategies: A theoretically based approach. *Journal of Personality and Social Psychology*, *56*, 267–283.

Cavallo, J. V., Zee, K. S., & Higgins, E. T. (2016). Giving the help that is needed: How Regulatory Mode impacts tailoring social support provision. *Personality and Social Psychology Bulletin*, *42*, 1111–1128.

Charles, S. T. (2010). Strength and Vulnerability Integration: A Model of Emotional Well-Being Across Adulthood. *Psychological Bulletin*, *136*, 1068–1091.

Chernikova, M., Lo Destro, C., Mauro, R., Pierro, A., Kruglanski, A. W., & Tory Higgins, E. (2016). Different strokes for different folks: Effects of regulatory mode complementarity and task complexity on performance. *Personality and Individual Differences*, *89*, 134–142.

Coan, J. A., & Maresh, E. L. (2014). Social baseline theory and the social regulation of emotion. In *Handbook* *of emotion regulation* (Vol. 2, pp. 221–236).

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*, 155–159.

Cohen, S., & Wills, T. A. (1985). Stress, social support, and the buffering hypothesis. *Psychological Bulletin*, *98*, 310–57.

Cohen, S., Sherrod, D. R., & Clark, M. S. (1986). Social skills and the stress-protective role of social support. *Journal of Personality and Social Psychology*, *50*, 963–973.

Cornwell, J. F., Franks, B., & Higgins, E. T. (2014). Truth, control, and value motivations: the "what," "how," and "why" of approach and avoidance. *Frontiers in Systems Neuroscience*, *8*, 1–15.

Cornwell, J. F., Franks, B., & Higgins, E. T. (2015). Distress from motivational dis-integration: When fundamental motives are too weak or too strong. In *Current topics in behavioral neuroscience* (pp. 289–320). Springer International Publishing.

Cranford, J. A., Shrout, P. E., Iida, M., Rafaeli, E., Yip, T., & Bolger, N. (2006). A procedure for evaluating sensitivity to within-person change: can mood measures in diary studies detect change reliably? *Personality & Social Psychology Bulletin*, *32*, 917–29.

Crockett, E. E., Morrow, Q. J., & Muyshondt, A. C. (2016). Circumnavigating the cost of support: Variations in cortisol as a function of self-efficacy and support visibility. *Journal of Social and Personal Relationships*, *34*, 578–593.

Cutrona, C. E. (1990). Stress and social support: In search of optimal matching. *Journal of Social and Clinical Psychology*, *9*, 3–14.

Cutrona, C. E., & Cole, V. (2000). Optimizing support in the natural network. In S. Cohen, L. Underwood, & B. Gottlieb (Eds.), *Social support measurement and intervention: A guide for health and social scientists* (pp. 278–308). New York: Oxford University Press.

Cutrona, C. E., & Russell, D. W. (2017). Autonomy promotion, responsiveness, and emotion regulation promote effective social support in times of stress. *Current Opinion in Psychology*, *13*, 126–130.

Cutrona, C. E., Cohen, B. B., & Igram, S. (1990). Contextual determinants of the perceived supportiveness of helping behaviors. *Journal of Social and Personal Relationships*, *7*, 553–562.

Cutrona, C. E., Shaffer, P. A., Wesner, K. A., & Gardner, K. A. (2007). Optimally matching support and perceived spousal sensitivity. *Journal of Family Psychology*, *21*, 754–758.

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin*, *130*, 355–391.

Doherty, R. W., Orimoto, L., Singelis, T. M., Hatfield, E., & Hebb, J. (1995). Emotional contagion: Gender and Occupational Differences. *Psychology of Women Quarterly*, *19*, 355–371.

Feeney, B. C., & Collins, N. L. (2015). A new look at social support: A theoretical perspective on thriving through relationships. *Personality and Social Psychology Review*, *19*, 113–147.

Fingerman, K. L., & Charles, S. T. (2010). It Takes Two to Tango. *Current Directions in Psychological Science*, *19*, 172–176.

Finkel, E. J., Cheung, E. O., Emery, L. F., Carswell, K. L., & Larson, G. M. (2015). The Suffocation Model: Why Marriage in America Is Becoming an All-or-Nothing Institution. *Current Directions in Psychological Science*, *24*, 238–244.

Fisher, J. D., Nadler, A., & Whitcher-Alagna, S. (1982). Recipient reactions to aid. *Psychological Bulletin*, *91*, 27–54.

Fitzsimons, G. M., & Finkel, E. J. (2010). Interpersonal influences on self-regulation. *Current Directions in Psychological Science*, *19*, 101–105.

Fitzsimons, G. M., Finkel, E. J., & VanDellen, M. R. (2015). Transactive goal dynamics. *Psychological Review*, *122*, 648–673.

Folkman, S., Lazarus, R. S., Dunkel Schetter, C., DeLongis, A., & Gruen, R. J. (1986). Dynamics of a stressful encounter: Cognitive appraisal, coping, and encounter outcomes. *Journal of Personality and Social Psychology*, *50*, 992–1003.

Fox, J. (2016). *Applied Regression Analysis and Generalized Linear Model*. Thousand Oaks, CA: SAGE Publications, Inc.

Gable, S. L., & Reis, H. T. (2010). Good news! Capitalizing on positive events in an interpersonal context. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Volume 42, pp. 195–257). London: Elsevier Inc.

Gable, S. L., Gonzaga, G. C., & Strachman, A. (2006). Will you be there for me when things go right? Supportive responses to positive event disclosures. *Journal of Personality and Social Psychology*, *91*, 904–17.

Gable, S. L., Gosnell, C. L., Maisel, N. C., & Strachman, A. (2012). Safely testing the alarm: Close others' responses to personal positive events. *Journal of Personality and Social Psychology*, *103*, 963–981.

Gelman, A. (2009). *What is the Bayesian counterpart to the so-called Fisher exact test?* (PhD thesis). Retrieved from https://statmodeling.stat.columbia.edu/2009/10/13/what{_}is{_}the{_}bay/

Gelman, A., & Stern, H. (2006). The difference between "significant" and "not significant" is not itself statistically significant. *The American Statistician*, *60*, 328–331.

Gleason, M. E. J., Iida, M., Bolger, N., & Shrout, P. E. (2003). Daily supportive equity in close relationships. *Personality and Social Psychology Bulletin*, *29*, 1036–1045.

Gleason, M. E. J., Iida, M., Shrout, P. E., & Bolger, N. (2008). Receiving support as a mixed blessing: Evidence for dual effects of support on psychological outcomes. *Journal of Personality and Social Psychology*, *94*, 824–838.

Grey, R. G. K. D., Uchino, B. N., Trettevik, R., Cronan, S., & Hogan, J. N. (2018). Social Support and Sleep : A Meta-Analysis. *Health Psychology*, *37*, 787–798.

Gross, J. J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology*, *39*, 281–291.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, *85*, 348–362.

Haase, C. M., Heckhausen, J., & Wrosch, C. (2013). Developmental regulation across the life span: Toward a new synthesis. *Developmental Psychology*, *49*, 964–972.

Hagger, M. S. (2010). Sleep, self-regulation, self-control and health. *Stress and Health*, *26*, 181–185.

Heckhausen, J. (1997). Developmental regulation across adulthood: primary and secondary control of age-related challenges. *Developmental Psychology*, *33*, 176–187.

Helm, J. L., Miller, J. G., Kahle, S., Troxel, N. R., & Hastings, P. D. (2018). On Measuring and Modeling Physiological Synchrony in Dyads. *Multivariate Behavioral Research*, *53*, 521–543.

Helm, J. L., Sbarra, D. A., & Ferrer, E. (2012). Assessing cross-partner associations in physiological responses via coupled oscillator models. *Emotion*, *12*, 748–762.

Helm, J. L., Sbarra, D. A., & Ferrer, E. (2014). Coregulation of respiratory sinus arrhythmia in adult romantic partners. *Emotion*, *14*, 522–531.

Higgins, E. T. (2012). *Beyond pleasure and pain: How motivation works.* Oxford University Press.

Higgins, E. T. (2018). Going in the right direction: Locomotion control and assessment truth, working together. In C. Kopetz & A. Fishbach (Eds.), *The motivation-cognition interface: From the lab to the real world* (pp. 88–105). New York: Taylor & Francis.

Higgins, E. T., Cornwell, J. F., & Franks, B. (2014). "Happiness" and "The Good life" as motivations working together. In A. Elliot (Ed.), *Advances in motivation science* (Vol. 1, pp. 135–179). Elsevier Inc.

Hofmann, W., Finkel, E. J., & Fitzsimons, G. M. (2015). Close relationships and self-regulation: How relationship satisfaction facilitates momentary goal pursuit. *Journal of Personality and Social Psychology*, *109*, 434–452.

Holt-Lunstad, J. (2018). Why Social Relationships Are Important for Physical Health: A Systems Approach to Understanding and Modifying Risk and Protection. *Annual Review of Psychology*, *69*, 437–458.

Holt-Lunstad, J., Smith, T. B., & Layton, J. B. (2010). Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine*, *7*, e1000316.

House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science*, *241*, 540–545.

Howland, M., & Simpson, J. A. (2010). Getting in under the radar: A dyadic view of invisible support. *Psychological Science*, *21*, 1878–85.

Inagaki, T. K., & Orehek, E. (2017). On the benefits of giving social support. *Current Directions in Psychological Science*, *26*, 109–113.

Jakubiak, B. K., & Feeney, B. C. (2016). Affectionate Touch to Promote Relational, Psychological, and Physical Well-Being in Adulthood: A Theoretical Model and Review of the Research. *Personality and Social Psychology Review*, 1–25.

Jakubiak, B. K., Feeney, B. C., & Ferrer, R. A. (2019). Benefits of daily support visibility versus invisibility across the adult life span. *Journal of Personality and Social Psychology.* doi:10.1037/pspi0000203

Jiang, L., Drolet, A., & Kim, H. S. (2018). Age and social support seeking: Understanding the role of perceived social costs to others. *Personality and Social Psychology Bulletin*, 014616721876079.

Judd, C. M., Westfall, J., & Kenny, D. a. (2012). Treating stimuli as a random factor in social psychology: a new and comprehensive solution to a pervasive but largely ignored problem. *Journal of Personality and Social Psychology*, *103*, 54–69.

Kelley, H. H., & Thibaut, J. W. (1978). *Interpersonal Relations: A Theory of Interdependence.* John Wiley & Sons Inc.

Kenny, D. A., Kashy, D. A., & Cook, W. L. (2006). *Dyadic data analysis.* New York: The Guilford Press.

Kiecolt-Glaser, J. K., & Newton, T. L. (2001). Marriage and health: his and hers. *Psychological Bulletin*, *127*, 472–503.

Kiss, P., De Meester, M., & Braeckman, L. (2008). Differences between younger and older workers in the need for recovery after work. *International Archives of Occupational and Environmental Health*, *81*, 311–320.

Krause, N. (1986). Social support, stress, and well-being among older adults. *Journal of Gerontology*, *41*, 512–9.

Lakey, B., & Orehek, E. (2011). Relational regulation theory: A new approach to explain the link between perceived social support and mental health. *Psychological Review*, *118*, 482–495.

Lang, F. R., & Carstensen, L. L. (1994). Close emotional relationships in late life: Further support for proactive aging in the social domain. *Psychology and Aging*, *9*, 315–324.

Levenson, R. W., Carstensen, L. L., & Gottman, J. M. (1993). Long-Term Marriage : Age, Gender, and Satisfaction. *Psychology and Aging*, *8*, 301–313.

Maisel, N. C., & Gable, S. L. (2009). The paradox of received social support: The importance of responsiveness. *Psychological Science*, *20*, 928–932.

Maisel, N. C., Gable, S. L., & Strachman, A. (2008). Responsive behaviors in good times and in bad. *Personal Relationships*, *15*, 317–338.

Marroquín, B. (2011). Interpersonal emotion regulation as a mechanism of social support in depression. *Clinical Psychology Review*, *31*, 1276–1290.

Martire, L. M., & Schulz, R. (2007). Involving Family in Psychosocial Interventions for Chronic Illness. *Current Directions in Psychological Science.*, *16*, 90–94.

Maxwell, S. E., & Boker, S. M. (2007). Multilevel models of dynamical systems. In S. M. Boker & M. J. Wenger (Eds.), *Data analytic techniques for dynamical systems* (pp. 161–187). New York: Routledge.

McClure, M. J., Xu, J. H., Craw, J. P., Lane, S. P., Bolger, N., & Shrout, P. E. (2014). Understanding the costs of support transactions in daily life. *Journal of Personality*, *82*, 563–574.

Meuwly, N., Bodenmann, G., Germann, J., Bradbury, T. N., & Heinrichs, M. (2012). Dyadic Coping , Insecure Attachment , and Cortisol Stress Recovery Following Experimentally Induced Stress. *Journal of Family Psychology*, *26*, 937–947.

Neff, L. A., & Karney, B. R. (2005). Gender differences in social support: a question of skill or responsiveness? *Journal of Personality and Social Psychology*, *88*, 79–90.

Nelson, B. W., Laurent, S. M., Bernstein, R., & Laurent, H. K. (2016). Perspective-taking influences autonomic attunement between partners during discussion of conflict. *Journal of Social and Personal Relationships*, 1–27.

Newsom, J. T. (1999). Another Side to Caregiving. *Current Directions in Psychological Science*, *8*, 183–187.

Orehek, E., & Forest, A. L. (2016). When people serve as means to goals: Implications of a motivational account of close relationships. *Current Directions in Psychological Science*, *25*, 79–84.

Palumbo, R. V., Marraccini, M. E., Weyandt, L. L., Wilder-Smith, O., McGee, H. A., Liu, S., & Goodwin, M. S. (2017). Interpersonal Autonomic Physiology: A Systematic Review of the Literature. *Personality and Social Psychology Review*, *21*, 99–141.

Parkinson, C., Kleinbaum, A. M., & Wheatley, T. (2018). Similar neural responses predict friendship. *Nature Communications*, *9*. doi:10.1038/s41467-017-02722-7

Pauw, L. S., Sauter, D. A., Kleef, G. A. van, & Fischer, A. H. (2017). Sense or sensibility? Social sharers' evaluations of socio-affective vs. cognitive support in response to negative emotions. *Cognition and Emotion*, *0*, 1–18.

Peters, B. J., & Jamieson, J. P. (2016). The Consequences of Suppressing Affective Displays in Romantic Relationships : A Challenge and Threat Perspective. *Emotion*, *16*, 1050–1066.

Pierro, A., Chernikova, M., Lo Destro, C., Higgins, E. T., & Kruglanski, A. W. (2018). *Assessment and*

Locomotion Conjunction: How Looking Complements Leaping ... But Not Always (1st ed., Vol. 58, pp. 243–299). Elsevier Inc.

Pietromonaco, P. R., Uchino, B. N., & Dunkel Schetter, C. (2013). Close relationship processes and health: Implications of attachment theory for health and disease. *Health Psychology*, *32*, 499–513.

Rafaeli, E., & Gleason, M. E. J. (2009). Skilled support within intimate relationships. *Journal of Family Theory and Review*, *1*, 20–37.

Reeck, C., Ames, D. R., & Ochsner, K. N. (2016). The social regulation of emotion: An integrative, cross-disciplinary model. *Trends in Cognitive Sciences*, *20*, 47–63.

Reed, R. G., Barnard, K., & Butler, E. A. (2015). Distinguishing emotional coregulation from codysregulation: An investigation of emotional dynamics and body weight in romantic couples. *Emotion*, *15*, 45–60.

Reed, R. G., Randall, A. K., Post, J. H., & Butler, E. A. (2013). Partner influence and in-phase versus anti-phase physiological linkage in romantic couples. *International Journal of Psychophysiology*, *88*, 309–316.

Reis, H. T., & Gable, S. L. (2015). Responsiveness. *Current Opinion in Psychology*, *1*, 67–71.

Reis, H. T., Clark, M. S., & Holmes, J. G. (2004). Perceived partner responsiveness as an organizing construct in the study of intimacy and closeness. In D. J. Mashek & A. Aron (Eds.), *Handbook of closeness and intimacy* (pp. 201–225). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Reis, H. T., Crasta, D., Rogge, R. D., Maniaci, M. R., & Carmichael, C. L. (2018). Profile 51: Perceived Partner Responsiveness Scale (PPRS). In D. L. Worthington & G. D. Bodie (Eds.), *The sourcebook of listening research: Methodology and measures* (pp. 516–521). Hoboken, NJ: John Wiley & Sons, Inc.

Reis, H. T., Smith, S. M., Carmichael, C. L., Caprariello, P. A., Tsai, F. F., Rodrigues, A., & Maniaci, M. R. (2010). Are you happy for me? How sharing positive events with others provides personal and interpersonal benefits. *Journal of Personality and Social Psychology*, *99*, 311–329.

Righetti, F., & Finkenauer, C. (2011). If you are able to control yourself, I will trust you: the role of perceived self-control in interpersonal trust. *Journal of Personality and Social Psychology*, *100*, 874–886.

Rimé, B. (2009). Emotion elicits the social sharing of emotion: Theory and empirical review. *Emotion Review*, *1*, 60–85.

Rini, C., & Dunkel Schetter, C. (2010). The effectiveness of social support attempts in intimate relationships. In *Support processes in intimate relationships* (pp. 26–67). Oxford University Press.

Rini, C., Dunkel Schetter, C., Hobel, C. J., Glynn, L. M., & Sandman, C. A. (2006). Effective social support: Antecedents and consequences of partner support during pregnancy. *Personal Relationships*, *13*, 207–229.

Robles, T. F., Slatcher, R. B., Trombello, J. M., & McGinn, M. M. (2014). Marital quality and health: A meta-analytic review. *Psychological Bulletin*, *140*, 140–187.

Rosenthal, R., & Rosnow, R. L. (1985). *Contrast Analysis: Focused Comparisons in the Analysis of Variance*. New York, NY: Cambridge University Press.

Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*, 1–36.

Rusbult, C. E., & Van Lange, P. A. M. (2003). Interdependence, Interaction, and Relationships. *Annual Review of Psychology*, *54*, 351–375.

Rusbult, C. E., Kumashiro, M., Kubacka, K. E., & Finkel, E. J. (2009). "The part of me that you bring out":

Ideal similarity and the Michelangelo phenomenon. *Journal of Personality and Social Psychology*, *96*, 61–82.

Ryan, R. M., & Solky, J. A. (1996). What Is Supportive about Social Support? In G. R. Pierce, B. R. Sarason, & I. G. Sarason (Eds.), *Handbook of social support and the family* (Vol. XII, pp. 249–267). New York: Springer Science; Business Media.

Sbarra, D. A., & Hazan, C. (2008). Coregulation, Dysregulation, Self-Regulation: An Integrative Analysis and Empirical Agenda for Understanding Adult Attachment, Separation, Loss, and Recovery. *Personality and Social Psychology Review*, *12*, 141–167.

Scarpa, A., Ashley, R. A., Waldron, J. C., Zhou, Y., Swain, D. M., Dunsmore, J. C., & Bell, M. A. (2018). Side by side: Modeling dyadic physiological linkage in strangers. *Emotion*, *18*, 615–624.

Seidman, G., Shrout, P. E., & Bolger, N. (2006). Why is enacted social support associated with increased distress? Using simulation to test two possible sources of spuriousness. *Personality and Social Psychology Bulletin*, *32*, 52–65.

Sels, L., Cabrieto, J., Butler, E. A., Reis, H. T., Ceulemans, E., & Kuppens, P. (2019). The occurrence and correlates of emotional interdependence in romantic relationships. *Journal of Personality and Social Psychology*. doi:10.1037/pspi0000212

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods*, *7*, 422–445.

Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin*, *86*, 420–428.

Shrout, P. E., & Yip-Bannicq, M. (2016). Inferences about competing measures based on patterns of binary significance tests are questionable. *Psychological Methods*, *21*, 84–93.

Shrout, P. E., Bolger, N., Iida, M., Burke, C. T., Gleason, M. E. J., & Lane, S. P. (2010). The effects of daily support transactions during acute stress: Results from a diary study of bar exam preparation. In K. T. Sullivan & J. Davila (Eds.), *Support processes in intimate relationships* (pp. 175–199). New York: Oxford University Press, Inc.

Simpson, J. A., & Rholes, W. S. (2017). Adult attachment, stress, and romantic relationships. *Current Opinion in Psychology*, *13*, 19–24.

Slatcher, R. B., & Selcuk, E. (2017). A Social Psychological Perspective on the Links Between Close Relationships and Health. *Current Directions in Psychological Science*, *26*, 16–21.

Terry, P. C., Lane, A. M., & Fogarty, G. J. (2003). Construct validity of the Profile of Mood States - Adolescents for use with adults. *Psychology of Sport and Exercise*, *4*, 125–139.

Thoits, P. A. (1986). Social support as coping assistance. *Journal of Consulting and Clinical Psychology*, *54*, 416–423.

Thorson, K. R., West, T. V., & Mendes, W. B. (2017). Measuring Physiological Influence in Dyads: A Guide to Designing, Implementing, and Analyzing Dyadic Physiological Studies. *Psychological Methods*. doi:10.1037/met0000166

Timmons, A. C., Margolin, G., & Saxbe, D. E. (2015). Physiological Linkage in Couples and Its Implications for Individual and Interpersonal Functioning : A Literature Review. *Journal of Family Psychology*, *29*, 720–731.

Tomlinson, J. M., Feeney, B. C., & Peters, B. J. (2020). Psychology and Aging Growing Into Retirement : Longitudinal Evidence for the Importance of Partner Support for Self-Expansion Growing Into

Retirement : Longitudinal Evidence for the Importance of Partner Support for Self-Expansion.

Tuskeviciute, R., Snyder, K. A., Stadler, G., & Shrout, P. E. (2018). Coping concordance in couples. *Personal Relationships*, *25*, 351–373.

Uchino, B. N. (2009). Understanding the links between social support and physical health. *Perspectives on Psychological Science*, *4*, 236–255.

Uchino, B. N., & Rook, K. S. (2020). Emotions, Relationships, Health and Illness into Old Age. *Maturitas*, 135577.

Uchino, B. N., Birmingham, W., & Berg, C. A. (2010). Are older adults less or more physiologically reactive? A meta-analysis of age-related differences in cardiovascular reactivity to laboratory tasks. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, *65 B*, 154–162.

Uchino, B. N., Cacioppo, J. T., & Kiecolt-Glaser, J. K. (1996). The relationship between social support and physiological processes: A review with emphasis on underlying mechanisms and implications for health. *Psychological Bulletin*, *119*, 488–531.

Uchino, B. N., Holt-Lunstad, J., Bloor, L. E., & Campo, R. A. (2005). Aging and cardiovascular reactivity to stress: Longitudinal evidence for changes in stress reactivity. *Psychology and Aging*, *20*, 134–143.

Uchino, B. N., Ong, A. D., Queen, T. L., & Kent De Grey, R. G. (2016). Theories of Social Support in Health and Aging. In V. L. Bengtson & R. A. Settersten (Eds.), *Handbook of theories of aging* (3rd ed., pp. 235–258). New York, NY: Springer Publishing Company.

Van Lange, P. A. M., & Rusbult, C. E. (2012). Interdependence Theory. In P. A. Van Lange, A. W. Kruglanski, & E. T. Higgins (Eds.), *Handbook of theories of social psychology* (pp. 251–272). London: Sage Publications Ltd.

Vehtari, A., Simpson, D. P., Yao, Y., & Gelman, A. (2019). Limitations of "Limitations of Bayesian Leave-one-out Cross-Validation for Model Selection". *Computational Brain & Behavior*, *2*, 22–27.

Vohs, K. D., Finkenauer, C., & Baumeister, R. F. (2010). The sum of friends' and lovers' self-control scores predicts relationship quality. *Social Psychological and Personality Science*, *2*, 138–145.

Waite, L., Laumann, E., Das, A., & Schumm, L. P. (2009). Sexuality: Measures of partnerships, practices, attitudes, and problems in the National Social Life, Health, and Aging Study. *Journal of Gerontology: Social Sciences*, *64*, 56–66.

Waters, S. F., West, T. V., & Mendes, W. B. (2014). Stress Contagion: Physiological Covariation Between Mothers and Infants. *Psychological Science*, *25*, 934–942.

Weinstein, N., Legate, N., Kumashiro, M., & Ryan, R. M. (2015). Autonomy support and diastolic blood pressure: Long term effects and conflict navigation in romantic relationships. *Motivation and Emotion*, *40*, 212–225.

Williams, D. R., Rast, P., & Bürkner, P.-C. (2018). Bayesian meta-analysis with weakly informative prior distributions. *PsyArXiv*, 1–19.

Williams, W. C., Morelli, S. A., Ong, D. C., & Zaki, J. (2018). Interpersonal emotion regulation: Implications for affiliation, perceived support, relationships, and well-being. *Journal of Personality and Social Psychology*, *115*, 224–254.

Wills, T. A., & Shinar, O. (2000). Measuring Perceived and Received Social Support. In S. Cohen, L. Underwood, & B. Gottlieb (Eds.), *Social support measurement and intervention: A guide for health and social scientists* (pp. 86–135). New York: Oxford University Press.

Wrzus, C., Hanel, M., Wagner, J., & Neyer, F. J. (2013). Social Network Changes and Life Events Across the

Life Span: A Meta-Analysis. *Psychological Bulletin*, *139*, 53–80.

Zaki, J., & Williams, W. C. (2013). Interpersonal emotion regulation. *Emotion*, *13*, 803–10.

Zee, K. S., & Bolger, N. (2019). Visible and Invisible Social Support: How, Why, and When. *Current Directions in Psychological Science*, *28*, 314–320.

Zee, K. S., & Bolger, N. (2020a). *Physiological Coregulation during Social Support Discussions.* doi:10.31234/osf.io/83hpa

Zee, K. S., & Bolger, N. (2020b). Using Coupled Oscillators to Examine Physiological Coregulation during Social Support Interactions. *Multivariate Behavioral Research*, *55*, 157–158.

Zee, K. S., Bolger, N., & Higgins, E. T. (2020). Regulatory Effectiveness of Social Support. *Journal of Personality and Social Psychology.* doi:http://dx.doi.org/10.1037/pspi0000235

Zee, K. S., Cavallo, J. V., Flores, A. J., Bolger, N., & Higgins, E. T. (2018). Motivation moderates the effects of social support visibility. *Journal of Personality and Social Psychology*, *114*, 735–765.

Appendix A: Supplemental Materials for Chapter 2

Overview

This appendix presents additional details and analyses relating to Chapter 2, including details about tests involving posterior distributions to assess heterogeneity, correlations among variables, random effect estimates, and additional analyses referenced in the main text.

Posterior Probabilities

Using Posterior Probabilities to Assess Between-Person Heterogeneity in Diary Studies (Studies 3-5)

To further assess between-person heterogeneity in effects of RES and PR, we capitalized on our Bayesian approach by dividing the posterior distribution for the random effect by the corresponding posterior distribution for its fixed effect. This allowed us to assess the percentage of posterior samples falling above the proposed .25 cutoff (Bolger et al., 2019). For all effects of RES and PR from across the three diary studies, these posterior probabilities collectively pointed in favor of a relative size of .25 or larger, thereby underscoring the relatively high degree of between-subject heterogeneity in the effects of RES and PR.

Using Posterior Probabilities to Assess Cardiovascular Reactivity (Study 7)

We also sought to assess patterns of stress reactivity at higher levels of RES and PR across all study phases in a more holistic way, an approach made possible by our use of Bayesian modeling. To do this, we computed the percentage of posterior samples in which all three of the interaction effects involving RES were negative, which would reflect attenuated physiological reactivity during the speech for participants higher than average on RES. We found a 0.67 probability that participants higher (vs. lower) on RES showed tempered IBI reactivity across all three phases. We also repeated this procedure for PR, however there was only a 0.1 probability that participants higher (vs. lower) on PR showed tempered IBI reactivity across all phases. Overall, these results provide preliminary evidence that RES and PR differentially affected patterns of cardiovascular reactivity in response to the stressor.

Using Posterior Probabilities to Assess Heterogeneity due to Studies and Outcomes (Meta-Analysis)

To further assess heterogeneity due to studies and outcomes, we capitalized on our Bayesian approach and used a version of the procedure for assessing between-subject heterogeneity in the diary studies (Chapter 2, Studies 3-5). We divided the posterior distribution for the random effect by the corresponding posterior distribution for its fixed effect, thereby creating a posterior distribution for the relative size of the random effect to the fixed effect. This allowed us to assess the percentage of posterior samples falling above the .25 cutoff, a type of posterior probability. Generally, posterior probabilities for the meta-analysis results suggested strong evidence in favor of noteworthy heterogeneity. For meta-analytic effects of RES and PR, nearly all of these posterior draws assessing the degree of heterogeneity due to outcome exceed .25, RES: 0.99; PR: 1. In contrast, the degree of heterogeneity due to study was somewhat less pronounced, indicated by smaller percentages of these posterior draws exceeding .25, RES: 0.33; PR: 0.75.

There was a somewhat different pattern for RES-PR (the difference in their effects). Posterior probabilities assessing the percentage of posterior samples exceeding .25 was 0.7 for heterogeneity due to study, and 0.32 for heterogeneity due to outcomes.

Overall, these findings suggested that there was heterogeneity in the predicted effects for RES, PR, and their difference across studies and across outcomes, and that the heterogeneity in effects of RES and PR were largely due to outcomes, whereas heterogeneity in the difference of RES and PR was largely due to studies.

Correlations Tables, Studies 2-7

Table 20: Correlations among variables, Study 2

Variables	Estimate	Lower	Upper
RES, PR	0.65	0.56	0.73
RES, Neg. Mood	-0.42	-0.53	-0.30
RES, Pos. Mood	0.55	0.45	0.64
RES, IOS	0.41	0.29	0.53
PR, Neg. Mood	-0.34	-0.46	-0.21
PR, Pos. Mood	0.49	0.38	0.59
PR, IOS	0.52	0.42	0.63
Neg. Mood, Pos. Mood	-0.29	-0.41	-0.15
Neg. Mood, IOS	-0.34	-0.46	-0.21
Pos. Mood, IOS	0.43	0.31	0.54

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self.

Table 21: Within-person correlations among variables, Studies 3-5

	Study 3			Study 4			Study 5		
Variables	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
RES, PR	0.39	0.32	0.46	0.53	0.45	0.61	0.37	0.29	0.45
RES, Sup. Eff.	0.41	0.34	0.48	0.45	0.37	0.53	0.38	0.30	0.46
RES, Neg. Mood	-0.20	-0.28	-0.12	-0.15	-0.24	-0.07	-0.10	-0.18	-0.03
RES, Pos. Mood	0.22	0.14	0.30	0.10	0.02	0.19	0.05	-0.03	0.13
RES, Coping	0.17	0.09	0.25	0.12	0.04	0.21	0.16	0.09	0.24
RES, IOS	0.29	0.21	0.37	0.29	0.21	0.37	0.27	0.19	0.34
RES, Sleep Quality	-	-	-	0.07	-0.03	0.17	-0.05	-0.15	0.05
RES, Task Motivation	-	-	-	-	-	-	0.07	-0.03	0.17
RES, Task Performance	-	-	-	-	-	-	0.04	-0.04	0.13
PR, Sup. Eff.	0.36	0.28	0.43	0.41	0.32	0.49	0.34	0.25	0.43
PR, Neg. Mood	-0.15	-0.23	-0.07	-0.10	-0.19	-0.02	-0.06	-0.14	0.03
PR, Pos. Mood	0.19	0.11	0.27	0.12	0.04	0.20	0.10	0.02	0.18
PR, Coping	0.10	0.02	0.18	0.10	0.01	0.19	0.25	0.16	0.33
PR, IOS	0.42	0.35	0.48	0.40	0.32	0.48	0.33	0.25	0.41
PR, Sleep Quality	-	-	-	0.02	-0.09	0.12	0.03	-0.07	0.13
PR, Task Motivation	-	-	-	-	-	-	0.09	-0.02	0.19
PR, Task Performance	-	-	-	-	-	-	0.03	-0.06	0.13
Sup. Eff., Neg. Mood	-0.13	-0.21	-0.05	-0.10	-0.18	-0.02	-0.10	-0.17	-0.02

Table 21: Within-person correlations among variables, Studies 3-5

(continued)

	Study 3			Study 4			Study 5		
Variables	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Sup. Eff., Pos. Mood	0.19	0.11	0.27	0.06	-0.03	0.14	0.02	-0.05	0.10
Sup. Eff., Coping	0.17	0.09	0.25	0.15	0.06	0.23	0.12	0.04	0.20
Sup. Eff., IOS	0.23	0.15	0.30	0.35	0.27	0.43	0.24	0.16	0.32
Sup. Eff., Sleep Quality	-	-	-	-0.02	-0.12	0.07	-0.03	-0.12	0.07
Sup. Eff., Task Motivation	-	-	-	-	-	-	-0.02	-0.12	0.07
Sup. Eff., Task Performance	-	-	-	-	-	-	-0.03	-0.12	0.06
Neg. Mood, Pos. Mood	-0.47	-0.54	-0.41	-0.50	-0.56	-0.44	-0.48	-0.54	-0.43
Neg. Mood, Coping	-0.01	-0.09	0.08	0.10	0.03	0.17	0.04	-0.02	0.10
Neg. Mood, IOS	-0.21	-0.29	-0.13	-0.11	-0.18	-0.04	-0.12	-0.19	-0.06
Neg. Mood, Sleep Quality	-	-	-	-0.01	-0.10	0.07	-0.09	-0.17	-0.01
Neg. Mood, Task Motivation	-	-	-	-	-	-	-0.13	-0.21	-0.06
Neg. Mood, Task Performance	-	-	-	-	-	-	-0.10	-0.17	-0.02
Pos. Mood, Coping	0.10	0.02	0.19	0.02	-0.05	0.09	0.07	0.01	0.14
Pos. Mood, IOS	0.18	0.09	0.26	0.21	0.13	0.27	0.16	0.10	0.22
Pos. Mood, Sleep Quality	-	-	-	0.07	-0.01	0.15	0.05	-0.03	0.13
Pos. Mood, Task Motivation	-	-	-	-	-	-	0.14	0.06	0.22
Pos. Mood, Task Performance	-	-	-	-	-	-	0.13	0.05	0.20

Table 21: Within-person correlations among variables, Studies 3-5

(continued)

	Study 3			Study 4			Study 5		
Variables	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Coping, IOS	0.10	0.01	0.18	0.27	0.20	0.34	0.23	0.17	0.30
Coping, Sleep Quality	-	-	-	0.04	-0.04	0.12	-0.07	-0.15	0.01
Coping, Task Motivation	-	-	-	-	-	-	-0.01	-0.09	0.07
Coping, Task Performance	-	-	-	-	-	-	0.03	-0.04	0.11
IOS, Sleep Quality	-	-	-	0.04	-0.05	0.12	0.00	-0.08	0.08
IOS, Task Motivation	-	-	-	-	-	-	0.00	-0.08	0.08
IOS, Task Performance	-	-	-	-	-	-	0.03	-0.05	0.11
Sleep Quality, Task Motivation	-	-	-	-	-	-	0.07	-0.02	0.16
Sleep Quality, Task Performance	-	-	-	-	-	-	0.16	0.08	0.25
Task Motivation, Task Performance	-	-	-	-	-	-	0.33	0.25	0.41

Note:

RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Sup. Eff. = Support Effectiveness.

Table 22: Between-person correlations among variables, Studies 3-5

	Study 3			Study 4			Study 5		
Variables	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
RES, PR	0.64	0.55	0.72	0.66	0.56	0.74	0.54	0.43	0.63
RES, Sup. Eff.	0.48	0.35	0.58	0.63	0.52	0.72	0.48	0.36	0.59
RES, Neg. Mood	-0.15	-0.29	-0.01	-0.31	-0.45	-0.16	-0.15	-0.28	0.00
RES, Pos. Mood	0.26	0.12	0.40	0.39	0.24	0.51	0.36	0.23	0.48
RES, Coping	0.17	0.03	0.30	0.22	0.06	0.36	0.05	-0.09	0.20
RES, IOS	0.31	0.17	0.44	0.51	0.38	0.62	0.28	0.14	0.41
RES, Sleep Quality	-	-	-	0.19	0.03	0.34	0.10	-0.04	0.24
RES, Task Motivation	-	-	-	-	-	-	0.20	0.06	0.33
RES, Task Performance	-	-	-	-	-	-	0.20	0.06	0.34
PR, Sup. Eff.	0.52	0.40	0.61	0.61	0.49	0.71	0.50	0.38	0.61
PR, Neg. Mood	-0.13	-0.27	0.01	-0.22	-0.37	-0.06	-0.18	-0.31	-0.04
PR, Pos. Mood	0.11	-0.04	0.25	0.17	0.02	0.32	0.21	0.07	0.34
PR, Coping	0.20	0.06	0.34	0.21	0.05	0.36	0.03	-0.12	0.17
PR, IOS	0.50	0.39	0.60	0.59	0.47	0.69	0.48	0.36	0.58
PR, Sleep Quality	-	-	-	0.10	-0.06	0.26	0.23	0.09	0.36
PR, Task Motivation	-	-	-	-	-	-	0.09	-0.06	0.23
PR, Task Performance	-	-	-	-	-	-	0.14	-0.01	0.27
Sup. Eff., Neg. Mood	-0.13	-0.27	0.02	-0.19	-0.34	-0.03	-0.21	-0.35	-0.07

Table 22: Between-person correlations among variables, Studies 3-5

(continued)

	Study 3			Study 4			Study 5		
Variables	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Sup. Eff., Pos. Mood	0.11	-0.04	0.25	0.24	0.09	0.39	0.21	0.07	0.34
Sup. Eff., Coping	0.15	0.00	0.29	0.18	0.02	0.33	0.02	-0.12	0.17
Sup. Eff., IOS	0.29	0.16	0.42	0.52	0.39	0.63	0.24	0.10	0.38
Sup. Eff., Sleep Quality	-	-	-	0.16	0.01	0.31	0.14	-0.01	0.28
Sup. Eff., Task Motivation	-	-	-	-	-	-	0.16	0.03	0.30
Sup. Eff., Task Performance	-	-	-	-	-	-	0.20	0.06	0.34
Neg. Mood, Pos. Mood	-0.30	-0.43	-0.16	-0.41	-0.54	-0.26	-0.16	-0.31	-0.02
Neg. Mood, Coping	-0.06	-0.21	0.08	0.04	-0.12	0.21	0.10	-0.05	0.24
Neg. Mood, IOS	-0.16	-0.29	-0.02	-0.22	-0.37	-0.05	-0.14	-0.28	0.00
Neg. Mood, Sleep Quality	-	-	-	-0.15	-0.31	0.01	-0.33	-0.45	-0.20
Neg. Mood, Task Motivation	-	-	-	-	-	-	-0.02	-0.16	0.13
Neg. Mood, Task Performance	-	-	-	-	-	-	-0.09	-0.23	0.05
Pos. Mood, Coping	0.13	-0.01	0.27	-0.10	-0.26	0.06	0.11	-0.04	0.25
Pos. Mood, IOS	0.20	0.06	0.34	0.28	0.13	0.42	0.15	0.00	0.29
Pos. Mood, Sleep Quality	-	-	-	0.28	0.13	0.42	0.30	0.16	0.43
Pos. Mood, Task Motivation	-	-	-	-	-	-	0.08	-0.07	0.22
Pos. Mood, Task Performance	-	-	-	-	-	-	0.11	-0.04	0.25

Table 22: Between-person correlations among variables, Studies 3-5

(continued)

	Study 3			Study 4			Study 5		
Variables	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
Coping, IOS	0.11	-0.03	0.25	0.15	-0.01	0.31	-0.05	-0.20	0.10
Coping, Sleep Quality	-	-	-	-0.03	-0.18	0.14	0.04	-0.11	0.18
Coping, Task Motivation	-	-	-	-	-	-	0.04	-0.10	0.19
Coping, Task Performance	-	-	-	-	-	-	-0.11	-0.25	0.03
IOS, Sleep Quality	-	-	-	0.23	0.07	0.37	0.07	-0.08	0.21
IOS, Task Motivation	-	-	-	-	-	-	0.02	-0.13	0.16
IOS, Task Performance	-	-	-	-	-	-	0.06	-0.09	0.21
Sleep Quality, Task Motivation	-	-	-	-	-	-	0.13	-0.01	0.27
Sleep Quality, Task Performance	-	-	-	-	-	-	0.11	-0.03	0.25
Task Motivation, Task Performance	-	-	-	-	-	-	0.49	0.37	0.60

Note:

RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. Sup. Eff. = Support Effectiveness.

Table 23: Correlations among variables, Study 6

Variables	Estimate	Lower	Upper
RES, PR	0.50	0.39	0.60
RES, Sup. Eff.	0.73	0.66	0.79
RES, Neg. Mood	-0.26	-0.39	-0.14
RES, Pos. Mood	0.43	0.32	0.54
RES, IOS	0.40	0.28	0.52
RES, Closeness	0.40	0.27	0.51
RES, Coder-Rated RES	0.25	0.12	0.37
RES, Coder-Rated PR	0.11	-0.02	0.24
PR, Sup. Eff.	0.52	0.42	0.62
PR, Neg. Mood	-0.15	-0.28	-0.01
PR, Pos. Mood	0.31	0.19	0.43
PR, IOS	0.45	0.34	0.56
PR, Closeness	0.56	0.45	0.65
PR, Coder-Rated RES	0.18	0.05	0.31
PR, Coder-Rated PR	0.30	0.17	0.42
Sup. Eff., Neg. Mood	-0.23	-0.36	-0.10
Sup. Eff., Pos. Mood	0.34	0.21	0.45
Sup. Eff., IOS	0.50	0.39	0.60
Sup. Eff., Closeness	0.38	0.26	0.49
Sup. Eff., Coder-Rated RES	0.27	0.14	0.39
Sup. Eff., Coder-Rated PR	0.10	-0.03	0.23
Neg. Mood, Pos. Mood	-0.49	-0.59	-0.38
Neg. Mood, IOS	-0.25	-0.38	-0.12
Neg. Mood, Closeness	-0.20	-0.32	-0.06
Neg. Mood, Coder-Rated RES	-0.25	-0.38	-0.12
Neg. Mood, Coder-Rated PR	-0.11	-0.24	0.03
Pos. Mood, IOS	0.31	0.18	0.43
Pos. Mood, Closeness	0.22	0.09	0.35
Pos. Mood, Coder-Rated RES	0.11	-0.03	0.24
Pos. Mood, Coder-Rated PR	0.09	-0.05	0.22
IOS, Closeness	0.40	0.27	0.51
IOS, Coder-Rated RES	0.13	-0.01	0.26
IOS, Coder-Rated PR	0.16	0.02	0.30
Closeness, Coder-Rated RES	0.10	-0.04	0.23
Closeness, Coder-Rated PR	0.18	0.05	0.31
Coder-Rated RES, Coder-Rated PR	0.28	0.15	0.40

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self.

Table 24: Correlations among variables, Study 7

Variables	Estimate	Lower	Upper
RES, PR	0.51	0.36	0.64
RES, Sup. Eff.	0.69	0.58	0.78
RES, Neg. Mood	-0.10	-0.28	0.08
RES, Pos. Mood	0.03	-0.15	0.21
RES, IOS	0.34	0.18	0.50
RES, Closeness	0.33	0.16	0.49
RES, Change Motive	0.11	-0.08	0.28
RES, Help with Speech	0.51	0.36	0.64
RES, Performance	-0.08	-0.26	0.11
PR, Sup. Eff.	0.47	0.32	0.61
PR, Neg. Mood	-0.25	-0.42	-0.07
PR, Pos. Mood	0.04	-0.14	0.22
PR, IOS	0.40	0.23	0.55
PR, Closeness	0.40	0.23	0.55
PR, Change Motive	0.00	-0.18	0.18
PR, Help with Speech	0.26	0.09	0.43
PR, Performance	-0.20	-0.37	-0.02
Sup. Eff., Neg. Mood	-0.13	-0.31	0.06
Sup. Eff., Pos. Mood	0.11	-0.07	0.29
Sup. Eff., IOS	0.31	0.13	0.47
Sup. Eff., Closeness	0.34	0.16	0.49
Sup. Eff., Change Motive	0.10	-0.09	0.28
Sup. Eff., Help with Speech	0.54	0.40	0.66
Sup. Eff., Performance	-0.04	-0.22	0.15
Neg. Mood, Pos. Mood	-0.10	-0.27	0.09
Neg. Mood, IOS	-0.11	-0.29	0.08
Neg. Mood, Closeness	-0.07	-0.26	0.13
Neg. Mood, Change Motive	-0.03	-0.22	0.17
Neg. Mood, Help with Speech	-0.12	-0.30	0.07
Neg. Mood, Performance	0.01	-0.19	0.20
Pos. Mood, IOS	-0.08	-0.27	0.12
Pos. Mood, Closeness	0.09	-0.10	0.28
Pos. Mood, Change Motive	-0.08	-0.28	0.11
Pos. Mood, Help with Speech	0.16	-0.03	0.33
Pos. Mood, Performance	0.06	-0.14	0.25
IOS, Closeness	0.29	0.11	0.46
IOS, Change Motive	0.00	-0.19	0.18
IOS, Help with Speech	0.13	-0.05	0.31
IOS, Performance	-0.05	-0.24	0.14
Closeness, Change Motive	-0.07	-0.27	0.13
Closeness, Help with Speech	0.35	0.18	0.51
Change Motive, Help with Speech	0.12	-0.07	0.30
Closeness, Performance	-0.14	-0.31	0.06
Change Motive, Performance	0.14	-0.05	0.32
Help with Speech, Performance	0.10	-0.08	0.28

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self.

Random Effects Tables, Studies 3-5

Table 25: Summary of random effects, Study 3

DV	Term	Estimate	SE	Lower	Upper
Support Effectiveness	Intercept SD	0.37	0.16	0.04	0.64
Support Effectiveness	RES SD	0.15	0.10	0.007	0.35
Support Effectiveness	PR SD	0.18	0.10	0.01	0.37
Support Effectiveness	Intercept-RES Cor	-0.07	0.44	-0.85	0.80
Support Effectiveness	Intercept-PR Cor	-0.21	0.44	-0.90	0.74
Support Effectiveness	RES-PR Cor	-0.11	0.48	-0.88	0.82
Support Effectiveness	Residual	1.17	0.05	1.08	1.26
Support Effectiveness	AR(1)	0.21	0.08	0.04	0.36
Negative Mood	Intercept SD	0.90	0.08	0.75	1.05
Negative Mood	RES SD	0.17	0.07	0.03	0.32
Negative Mood	PR SD	0.19	0.10	0.01	0.40
Negative Mood	Intercept-RES Cor	-0.52	0.27	-0.94	0.08
Negative Mood	Intercept-PR Cor	0.28	0.34	-0.50	0.86
Negative Mood	RES-PR Cor	-0.27	0.42	-0.91	0.69
Negative Mood	Residual	1.03	0.04	0.94	1.12
Negative Mood	AR(1)	0.13	0.08	-0.01	0.29
Positive Mood	Intercept SD	0.63	0.16	0.18	0.86
Positive Mood	RES SD	0.10	0.07	0.005	0.26
Positive Mood	PR SD	0.16	0.10	0.009	0.36
Positive Mood	Intercept-RES Cor	-0.24	0.44	-0.91	0.71
Positive Mood	Intercept-PR Cor	-0.13	0.40	-0.83	0.72
Positive Mood	RES-PR Cor	-0.05	0.49	-0.89	0.85
Positive Mood	Residual	1.18	0.06	1.08	1.30
Positive Mood	AR(1)	0.20	0.10	0.009	0.41
Coping	Intercept SD	0.49	0.15	0.10	0.71
Coping	RES SD	0.12	0.06	0.008	0.24
Coping	PR SD	0.06	0.05	0.003	0.17

Table 25: Summary of random effects, Study 3 *(continued)*

DV	Term	Estimate	SE	Lower	Upper
Coping	Intercept-RES Cor	-0.08	0.37	-0.79	0.71
Coping	Intercept-PR Cor	0.04	0.45	-0.83	0.85
Coping	RES-PR Cor	-0.02	0.49	-0.88	0.86
Coping	Residual	0.84	0.05	0.75	0.93
Coping	AR(1)	0.38	0.13	0.11	0.61
IOS	Intercept SD	1.15	0.07	1.02	1.30
IOS	RES SD	0.18	0.07	0.02	0.31
IOS	PR SD	0.14	0.08	0.01	0.29
IOS	Intercept-RES Cor	-0.10	0.26	-0.62	0.44
IOS	Intercept-PR Cor	-0.06	0.34	-0.71	0.65
IOS	RES-PR Cor	0.28	0.45	-0.69	0.93
IOS	Residual	0.89	0.04	0.81	0.97
IOS	AR(1)	0.07	0.08	-0.08	0.23

Note:

RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of the other in the self. SD = standard deviation. Cor = correlation.

Table 26: Summary of random effects, Study 4

DV	Term	Estimate	SE	Lower	Upper
Support Effectiveness	Intercept SD	0.55	0.12	0.26	0.75
Support Effectiveness	RES SD	0.27	0.12	0.04	0.51
Support Effectiveness	PR SD	0.17	0.12	0.007	0.43
Support Effectiveness	Intercept-RES Cor	-0.52	0.30	-0.94	0.20
Support Effectiveness	Intercept-PR Cor	0.07	0.44	-0.80	0.84
Support Effectiveness	RES-PR Cor	-0.25	0.47	-0.93	0.77
Support Effectiveness	Residual	1.10	0.06	0.99	1.21
Support Effectiveness	AR(1)	0.03	0.10	-0.16	0.23
Negative Mood	Intercept SD	0.99	0.08	0.83	1.15
Negative Mood	RES SD	0.19	0.07	0.04	0.34
Negative Mood	PR SD	0.13	0.09	0.006	0.34
Negative Mood	Intercept-RES Cor	-0.65	0.25	-0.97	-0.03
Negative Mood	Intercept-PR Cor	0.04	0.42	-0.77	0.84
Negative Mood	RES-PR Cor	-0.18	0.48	-0.90	0.79
Negative Mood	Residual	1.01	0.05	0.92	1.11
Negative Mood	AR(1)	-0.04	0.09	-0.21	0.15
Positive Mood	Intercept SD	0.78	0.07	0.65	0.92
Positive Mood	RES SD	0.10	0.08	0.005	0.28
Positive Mood	PR SD	0.14	0.09	0.005	0.35
Positive Mood	Intercept-RES Cor	-0.07	0.45	-0.85	0.81
Positive Mood	Intercept-PR Cor	0.22	0.40	-0.68	0.87
Positive Mood	RES-PR Cor	-0.15	0.50	-0.93	0.82
Positive Mood	Residual	1.09	0.05	1.00	1.19
Positive Mood	AR(1)	-0.25	0.08	-0.40	-0.10
Coping	Intercept SD	0.76	0.06	0.63	0.88
Coping	RES SD	0.13	0.08	0.007	0.30
Coping	PR SD	0.15	0.08	0.009	0.32
Coping	Intercept-RES Cor	-0.19	0.37	-0.86	0.60

Table 26: Summary of random effects, Study 4 *(continued)*

DV	Term	Estimate	SE	Lower	Upper
Coping	Intercept-PR Cor	-0.28	0.34	-0.84	0.55
Coping	RES-PR Cor	0.09	0.47	-0.81	0.90
Coping	Residual	0.74	0.04	0.67	0.82
Coping	AR(1)	0.06	0.10	-0.12	0.26
IOS	Intercept SD	1.08	0.08	0.93	1.24
IOS	RES SD	0.24	0.09	0.03	0.40
IOS	PR SD	0.11	0.08	0.005	0.29
IOS	Intercept-RES Cor	0.07	0.26	-0.45	0.58
IOS	Intercept-PR Cor	0.13	0.41	-0.74	0.86
IOS	RES-PR Cor	0.04	0.47	-0.82	0.87
IOS	Residual	0.84	0.04	0.76	0.93
IOS	AR(1)	0.06	0.10	-0.12	0.27
Sleep Quality	Intercept SD	0.97	0.11	0.75	1.17
Sleep Quality	RES SD	0.15	0.10	0.006	0.38
Sleep Quality	PR SD	0.18	0.12	0.008	0.43
Sleep Quality	Intercept-RES Cor	0.09	0.44	-0.78	0.86
Sleep Quality	Intercept-PR Cor	0.38	0.40	-0.61	0.93
Sleep Quality	RES-PR Cor	-0.12	0.50	-0.90	0.84
Sleep Quality	Residual	1.02	0.08	0.87	1.19
Sleep Quality	AR(1)	-0.22	0.15	-0.48	0.11

Note:

RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of the other in the self. SD = standard deviation. Cor = correlation.

Table 27: Summary of random effects, Study 5

DV	Term	Estimate	SE	Lower	Upper
Support Effectiveness	Intercept SD	0.34	0.18	0.02	0.65
Support Effectiveness	RES SD	0.31	0.11	0.08	0.51
Support Effectiveness	PR SD	0.29	0.12	0.05	0.52
Support Effectiveness	Intercept-RES Cor	-0.17	0.40	-0.85	0.71
Support Effectiveness	Intercept-PR Cor	-0.03	0.43	-0.81	0.81
Support Effectiveness	RES-PR Cor	-0.52	0.35	-0.95	0.40
Support Effectiveness	Residual	1.16	0.06	1.05	1.27
Support Effectiveness	AR(1)	0.16	0.09	-0.03	0.33
Negative Mood	Intercept SD	0.82	0.11	0.59	1.00
Negative Mood	RES SD	0.20	0.10	0.02	0.39
Negative Mood	PR SD	0.27	0.11	0.04	0.46
Negative Mood	Intercept-RES Cor	-0.28	0.33	-0.86	0.47
Negative Mood	Intercept-PR Cor	-0.01	0.32	-0.64	0.65
Negative Mood	RES-PR Cor	-0.09	0.43	-0.83	0.78
Negative Mood	Residual	1.04	0.05	0.94	1.15
Negative Mood	AR(1)	0.24	0.11	0.03	0.45
Positive Mood	Intercept SD	0.55	0.18	0.09	0.81
Positive Mood	RES SD	0.14	0.09	0.007	0.35
Positive Mood	PR SD	0.16	0.11	0.008	0.39
Positive Mood	Intercept-RES Cor	-0.19	0.44	-0.91	0.75
Positive Mood	Intercept-PR Cor	0.17	0.44	-0.75	0.89
Positive Mood	RES-PR Cor	-0.18	0.50	-0.93	0.81
Positive Mood	Residual	1.24	0.06	1.12	1.36
Positive Mood	AR(1)	0.15	0.11	-0.06	0.36
Coping	Intercept SD	0.82	0.07	0.66	0.95
Coping	RES SD	0.08	0.06	0.003	0.20
Coping	PR SD	0.08	0.06	0.004	0.21
Coping	Intercept-RES Cor	0.19	0.42	-0.71	0.87

Table 27: Summary of random effects, Study 5 *(continued)*

DV	Term	Estimate	SE	Lower	Upper
Coping	Intercept-PR Cor	-0.27	0.42	-0.91	0.70
Coping	RES-PR Cor	-0.16	0.50	-0.92	0.83
Coping	Residual	0.80	0.04	0.73	0.88
Coping	AR(1)	0.14	0.11	-0.06	0.38
IOS	Intercept SD	1.07	0.10	0.87	1.26
IOS	RES SD	0.10	0.07	0.004	0.26
IOS	PR SD	0.38	0.07	0.23	0.53
IOS	Intercept-RES Cor	-0.06	0.43	-0.84	0.79
IOS	Intercept-PR Cor	-0.03	0.19	-0.40	0.36
IOS	RES-PR Cor	-0.06	0.46	-0.86	0.82
IOS	Residual	0.95	0.05	0.84	1.06
IOS	AR(1)	0.37	0.12	0.13	0.61
Sleep Quality	Intercept SD	1.08	0.15	0.75	1.35
Sleep Quality	RES SD	0.16	0.10	0.007	0.38
Sleep Quality	PR SD	0.19	0.13	0.01	0.49
Sleep Quality	Intercept-RES Cor	0.11	0.41	-0.73	0.86
Sleep Quality	Intercept-PR Cor	-0.16	0.41	-0.86	0.71
Sleep Quality	RES-PR Cor	-0.29	0.49	-0.95	0.78
Sleep Quality	Residual	1.00	0.10	0.82	1.22
Sleep Quality	AR(1)	0.17	0.19	-0.20	0.54
Task Motivation	Intercept SD	1.25	0.10	1.05	1.43
Task Motivation	RES SD	0.25	0.08	0.10	0.39
Task Motivation	PR SD	0.13	0.08	0.008	0.30
Task Motivation	Intercept-RES Cor	-0.49	0.24	-0.90	-0.004
Task Motivation	Intercept-PR Cor	-0.27	0.40	-0.90	0.65
Task Motivation	RES-PR Cor	0.31	0.43	-0.64	0.93
Task Motivation	Residual	0.99	0.06	0.89	1.10
Task Motivation	AR(1)	0.29	0.12	0.07	0.53

Table 27: Summary of random effects, Study 5 *(continued)*

DV	Term	Estimate	SE	Lower	Upper
Task Performance	Intercept SD	0.89	0.12	0.64	1.10
Task Performance	RES SD	0.12	0.08	0.005	0.29
Task Performance	PR SD	0.07	0.05	0.003	0.20
Task Performance	Intercept-RES Cor	-0.12	0.40	-0.86	0.72
Task Performance	Intercept-PR Cor	-0.02	0.45	-0.85	0.83
Task Performance	RES-PR Cor	-0.19	0.50	-0.93	0.82
Task Performance	Residual	0.91	0.06	0.79	1.03
Task Performance	AR(1)	0.33	0.15	0.04	0.61

Note:

RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of the other in the self. SD = standard deviation. Cor = correlation.

Additional Speech Performance Variables, Study 7

As discussed in Study 7, our speech performance coding scheme also included measures to assess verbal indicators of speech quality (ICC(A, 3) = 0.87), such as the fluidity and persuasiveness of the speech, and emotional expressions during the speech (higher numbers indicate more positivity and less negativity; (ICC(A, 3) = 0.71). Results for these variables are presented below.

Table 28: Summary of Results for Additional Speech Variables, Study 7

DV	Predictor	Estimate	SE	Lower	Upper	Post_Prob	N_Subj
Verbal Speech Quality	Intercept	4.41	0.10	4.20	4.62	-	106
Verbal Speech Quality	RES	-0.04	0.13	-0.29	0.21	0.37	106
Verbal Speech Quality	PR	-0.06	0.13	-0.32	0.21	0.34	106
Emotional Expression	Intercept	4.11	0.04	4.03	4.20	-	106
Emotional Expression	RES	0.02	0.05	-0.09	0.12	0.63	106
Emotional Expression	PR	0.05	0.06	-0.06	0.16	0.82	106

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. N_Subj = Number of subjects in analysis. Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 29: Differences in Effects of RES and PR for Additional Speech Variables, Study 7

DV	RES-PR	SE	Lower	Upper	Post_Prob
Verbal Speech Quality	0.01	0.23	-0.45	0.48	0.52
Emotional Expression	-0.03	0.10	-0.23	0.16	0.37

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. IOS = Inclusion of Other in the Self. N_Subj = Number of subjects in analysis. Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Cardiovascular Results Tables, Study 7

Table 30: Summary of results for cardiovascular data, Study 7

Coefficient	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Intercept	670.07	11.18	647.89	691.74	-	106	3226
RES	11.18	12.45	-13.57	35.26	0.82	106	3226
PR	-18.64	13.45	-44.53	8.49	0.08	106	3226
Baseline vs. Speech	135.50	10.54	115.32	156.54	1.00	106	3226
Support vs. Speech	58.22	6.37	45.77	70.63	1.00	106	3226
Recovery vs. Speech	137.24	8.54	120.46	154.12	1.00	106	3226
RES x Baseline vs. Speech	-6.90	11.75	-30.55	15.65	0.72	106	3226
RES x Support vs. Speech	**-11.44**	**7.23**	**-25.47**	**2.62**	**0.94**	**106**	**3226**
RES x Recovery vs. Speech	-9.08	9.72	-28.49	10.14	0.83	106	3226
PR x Baseline vs. Speech	0.68	12.49	-23.86	25.62	0.48	106	3226
PR x Support vs. Speech	8.03	7.60	-7.14	22.88	0.14	106	3226
PR x Recovery vs. Speech	4.00	10.25	-15.95	24.06	0.34	106	3226

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. For contrasts, Speech is coded as 0, otherwise 1. Lower and Upper refer to 95% credibility intervals. Post_Prob is the posterior probability that the effect is in the hypothesized direction.

Table 31: Summary of random effects for cardiovascular data, Study 7

Term	Estimate	SE	Lower	Upper
Intercept SD	111.71	8.53	96.19	129.85
Baseline vs. Speech SD	100.55	7.68	86.61	116.54
Support vs. Speech SD	56.97	5.00	47.83	67.55
Recovery vs. Speech SD	79.63	6.76	67.43	93.63
Intercept-Baseline vs. Speech Cor	-0.27	0.10	-0.46	-0.08
Intercept-Support vs, Speech Cor	-0.20	0.11	-0.41	0.01
Intercept-Recovery vs. Speech Cor	-0.19	0.11	-0.39	0.03
Support vs. Speech-Baseline vs. Speech Cor	0.68	0.07	0.53	0.79
Support vs. Speech-Recovery vs. Speech Cor	0.62	0.08	0.44	0.76
Recovery vs. Speech-Baseline vs. Speech Cor	0.81	0.04	0.71	0.88
Residual	39.66	0.56	38.58	40.78
AR(1)	0.39	0.03	0.34	0.45

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. For contrasts, Speech is coded as 0, otherwise 1.

Meta-Analysis without Support Effectiveness

We performed additional versions of our analyses without support effectiveness included in order to reduce potential issues of content overlap with RES and PR.

Table 32: Summary of supplemental meta-analysis results, fixed effects

Variable	Coefficient	Estimate	SE	Lower	Upper	N_Obs
RES	Intercept	0.23	0.05	0.14	0.35	46
RES	Relational Variable	-0.05	0.09	-0.26	0.10	46
RES	Level of Analysis	-0.08	0.03	-0.14	-0.02	46
PR	Intercept	0.05	0.04	-0.04	0.14	46
PR	Relational Variable	0.40	0.06	0.28	0.52	46
PR	Level of Analysis	-0.02	0.03	-0.08	0.04	46
RES-PR	Intercept	0.15	0.05	0.06	0.25	46
RES-PR	Relational Variable	-0.42	0.07	-0.56	-0.29	46
RES-PR	Level of Analysis	-0.06	0.04	-0.15	0.02	46

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. RES-PR = difference of RES and PR (RES minus PR). Relational Variable is coded as 1 = relational variable, 0 = non-relational variable (self-regulation relevant variable). Level of Analysis is coded as 1 = within-person effect, 0 = between-person.

Table 33: Summary of supplemental meta-analysis results without support effectiveness, random effects

Model	Term	Estimate	SE	Lower	Upper
RES	DV SD	0.07	0.06	0.00	0.23
RES	Study SD	0.05	0.05	0.00	0.17
RES	DV x Study SD	0.03	0.02	0.00	0.09
RES	Residual	0.04	0.02	0.00	0.09
PR	DV SD	0.04	0.04	0.00	0.13
PR	Study SD	0.05	0.05	0.00	0.19
PR	DV x Study SD	0.02	0.01	0.00	0.06
PR	Residual	0.05	0.02	0.01	0.09
RES-PR	DV SD	0.04	0.04	0.00	0.14
RES-PR	Study SD	0.04	0.04	0.00	0.14
RES-PR	DV x Study SD	0.03	0.02	0.00	0.08
RES-PR	Residual	0.05	0.03	0.00	0.12

Note:
RES = Regulatory Effectiveness of Support. PR = Perceived Responsiveness. RES-PR = difference of RES and PR (RES minus PR). Relational Variable is coded as 1 = relational variable, 0 = non-relational variable (self-regulation relevant variable). Level of Analysis is coded as 1 = within-person effect, 0 = between-person. SD = standard deviation.

Appendix B: Supplemental Materials for Chapter 3

Overview

This appendix presents additional details and analyses relating to Chapter 3, including analysis of IBI time trends, full model output with individual parameter estimates, details about tests of heterogeneity, and additional tests performed on the posterior distributions.

IBI Time Trends

Table 34: IBI Time Trends (fixed effects)

Term	Estimate	Lower	Upper
F Intercept	791.02	767.99	812.09
M Intercept	806.12	778.77	833.12
F Time	10.57	3.00	18.04
F Effect 1 (Control vs. F Receives)	-3.96	-14.94	7.25
F Effect 2 (M Receives vs. F Receives	11.62	3.37	19.87
F Time X Effect 1	-19.19	-33.01	-5.19
F Time X Effect 2	-12.65	-23.38	-1.76
M Time	10.27	3.32	17.11
M Effect 1 (Control vs. F Receives)	-17.01	-24.81	-9.04
M Effect 2 (M Receives vs. F Receives)	0.001	-7.59	7.59
M Time X Effect 1	5.26	-4.86	15.33
M Time X Effect 2	15.43	3.09	27.80

Note:

Discussion phases are effect coded such that intercepts and main effects correspond to average levels of IBI and changes in IBI over time, respectively, averaging across discussion phases. Effect 1 is the comparison of Control to F Receives and Effect 2 is the comparison of M Receives to F Receives. Time is coded 0 to 1, with 0 corresponding to the first time point and 1 corresponding to the last time point. Thus, intercept estimates correspond to the average IBI values for the typical male and female partners during the first time point of a discussion, and the coefficients for Time correspond to the total average change in IBI across the the discussion for each partner. To faciliate interpretation, IBI values can be converted to heart rate (HR; beats per minute) using the formula HR = 60000/IBI. For the typical female and male partners during a typical discussion, heart rate only changed by -1 (60000/(791.02+10.57) - 60000/791.02) and -0.94 (60000/(806.12+10.27) - 60000/806.12) beats per minute, respectively.

Table 35: IBI Time Trends (random effects)

	Term	Estimate	Lower	Upper
1	F Intercept	105.71	91.00	122.80
2	F Time	32.37	26.60	39.17
3	F Effect 1	48.72	40.74	57.83
4	F Effect 2	31.14	24.26	38.82
5	F Time X Effect 1	52.12	40.56	65.19
6	F Time X Effect 2	30.75	16.80	44.14
7	M Intercept	127.82	110.39	148.27
8	M Time	29.58	24.15	35.98
9	M Effect 1	31.85	25.61	38.90
10	M Effect 2	28.22	21.67	35.69
11	M Time X Effect 1	30.41	17.68	42.65
12	M Time X Effect 2	43.52	31.51	56.23

Note:

Discussion phases are effect coded such that intercepts and main effects correspond to average levels of IBI and changes in IBI over time, respectively, averaging across discussion phases. Effect 1 is the comparison of Control to F Receives and Effect 2 is the comparison of M Receives to F Receives. Time is coded 0 to 1, with 0 corresponding to the first time point and 1 corresponding to the last time point. Thus, intercept estimates correspond to the average IBI values for the typical male and female partners during the first time point of a discussion, and the coefficients for Time correspond to the total average change in IBI across the the discussion for each partner.

Table 36: IBI Time Trends (random effects)

	Term	Estimate	Lower	Upper
13	F Intercept, F Time	-0.09	-0.30	0.13
14	F Intercept, F Effect 1	0.12	-0.08	0.33
15	F Time, F Effect 1	0.02	-0.21	0.26
16	F Intercept, F Effect 2	0.09	-0.15	0.32
17	F Time, F Effect 2	0.08	-0.18	0.34
18	F Effect 1, F Effect 2	0.22	-0.05	0.46
19	F Intercept, F Time X Effect 1	-0.10	-0.33	0.13
20	F Time, F Time X Effect 1	-0.14	-0.38	0.13
21	F Effect 1, F Time X Effect 1	-0.67	-0.80	-0.51
22	F Effect 2, F Time X Effect 1	-0.10	-0.37	0.19
23	F Intercept, F Time X Effect 2	0.24	-0.05	0.52
24	F Time, F Time X Effect 2	-0.11	-0.44	0.21
25	F Effect 1, F Time X Effect 2	-0.17	-0.48	0.19
26	F Effect 2, F Time X Effect 2	-0.41	-0.68	-0.06
27	F Time X Effect 1, F Time X Effect 2	0.10	-0.27	0.44
28	F Intercept, M Intercept	0.13	-0.06	0.32
29	F Time, M Intercept	-0.05	-0.27	0.17
30	F Effect 1, M Intercept	0.05	-0.16	0.25
31	F Effect 2, M Intercept	-0.08	-0.30	0.15
32	F Time X Effect 1, M Intercept	0.06	-0.18	0.29
33	F Time X Effect 2, M Intercept	0.06	-0.24	0.36
34	F Intercept, M Time	0.13	-0.09	0.35
35	F Time, M Time	0.12	-0.12	0.37
36	F Effect 1, M Time	-0.04	-0.27	0.20
37	F Effect 2, M Time	0.007	-0.25	0.27
38	F Time X Effect 1, M Time	0.008	-0.25	0.27
39	F Time X Effect 2, M Time	-0.08	-0.41	0.26
40	M Intercept, M Time	-0.27	-0.47	-0.06

Table 36: IBI Time Trends (random effects) *(continued)*

	Term	Estimate	Lower	Upper
41	F Intercept, M Effect 1	-0.09	-0.31	0.13
42	F Time, M Effect 1	0.03	-0.22	0.29
43	F Effect 1, M Effect 1	0.02	-0.22	0.25
44	F Effect 2, M Effect 1	-0.16	-0.42	0.12
45	F Time X Effect 1, M Effect 1	-0.13	-0.39	0.14
46	F Time X Effect 2, M Effect 1	0.38	0.06	0.68
47	M Intercept, M Effect 1	0.01	-0.21	0.24
48	M Time, M Effect 1	-0.18	-0.43	0.07
49	F Intercept, M Effect 2	-0.02	-0.26	0.21
50	F Time, M Effect 2	0.14	-0.14	0.39
51	F Effect 1, M Effect 2	-0.05	-0.31	0.21
52	F Effect 2, M Effect 2	-0.06	-0.33	0.22
53	F Time X Effect 1, M Effect 2	-0.04	-0.32	0.25
54	F Time X Effect 2, M Effect 2	0.24	-0.12	0.57
55	M Intercept, M Effect 2	-0.11	-0.34	0.13
56	M Time, M Effect 2	-0.15	-0.42	0.11
57	M Effect 1, M Effect 2	0.32	0.04	0.56
58	F Intercept, M Time X Effect 1	0.12	-0.17	0.40
59	F Time, M Time X Effect 1	0.009	-0.31	0.33
60	F Effect 1, M Time X Effect 1	0.28	-0.02	0.57
61	F Effect 2, M Time X Effect 1	0.21	-0.15	0.55
62	F Time X Effect 1, M Time X Effect 1	-0.07	-0.41	0.26
63	F Time X Effect 2, M Time X Effect 1	-0.22	-0.59	0.23
64	M Intercept, M Time X Effect 1	0.12	-0.17	0.40
65	M Time, M Time X Effect 1	-0.07	-0.40	0.26
66	M Effect 1, M Time X Effect 1	-0.25	-0.53	0.11
67	M Effect 2, M Time X Effect 1	-0.14	-0.50	0.26
68	F Intercept, M Time X Effect 2	0.19	-0.04	0.42

Table 36: IBI Time Trends (random effects) *(continued)*

	Term	Estimate	Lower	Upper
69	F Time, M Time X Effect 2	-0.14	-0.40	0.13
70	F Effect 1, M Time X Effect 2	0.16	-0.11	0.41
71	F Effect 2, M Time X Effect 2	0.18	-0.11	0.46
72	F Time X Effect 1, M Time X Effect 2	0.11	-0.18	0.38
73	F Time X Effect 2, M Time X Effect 2	-0.26	-0.60	0.11
74	M Intercept, M Time X Effect 2	0.22	-0.02	0.44
75	M Time, M Time X Effect 2	0.15	-0.11	0.40
76	M Effect 1, M Time X Effect 2	-0.15	-0.42	0.15
77	M Effect 2, M Time X Effect 2	-0.48	-0.69	-0.20
78	M Time X Effect 1, M Time X Effect 2	0.60	0.28	0.84
79	F Residual	47.65	46.90	48.43
80	M Residual	44.13	43.42	44.86
81	Residual Correlation	0.10	0.07	0.12

Note:

Discussion phases are effect coded such that intercepts and main effects correspond to average levels of IBI and changes in IBI over time, respectively, averaging across discussion phases. Effect 1 is the comparison of Control to F Receives and Effect 2 is the comparison of M Receives to F Receives. Time is coded 0 to 1, with 0 corresponding to the first time point and 1 corresponding to the last time point. Thus, intercept estimates correspond to the average IBI values for the typical male and female partners during the first time point of a discussion, and the coefficients for Time correspond to the total average change in IBI across the the discussion for each partner.

Coupled Damped Oscillator Model Output

Fixed Effects

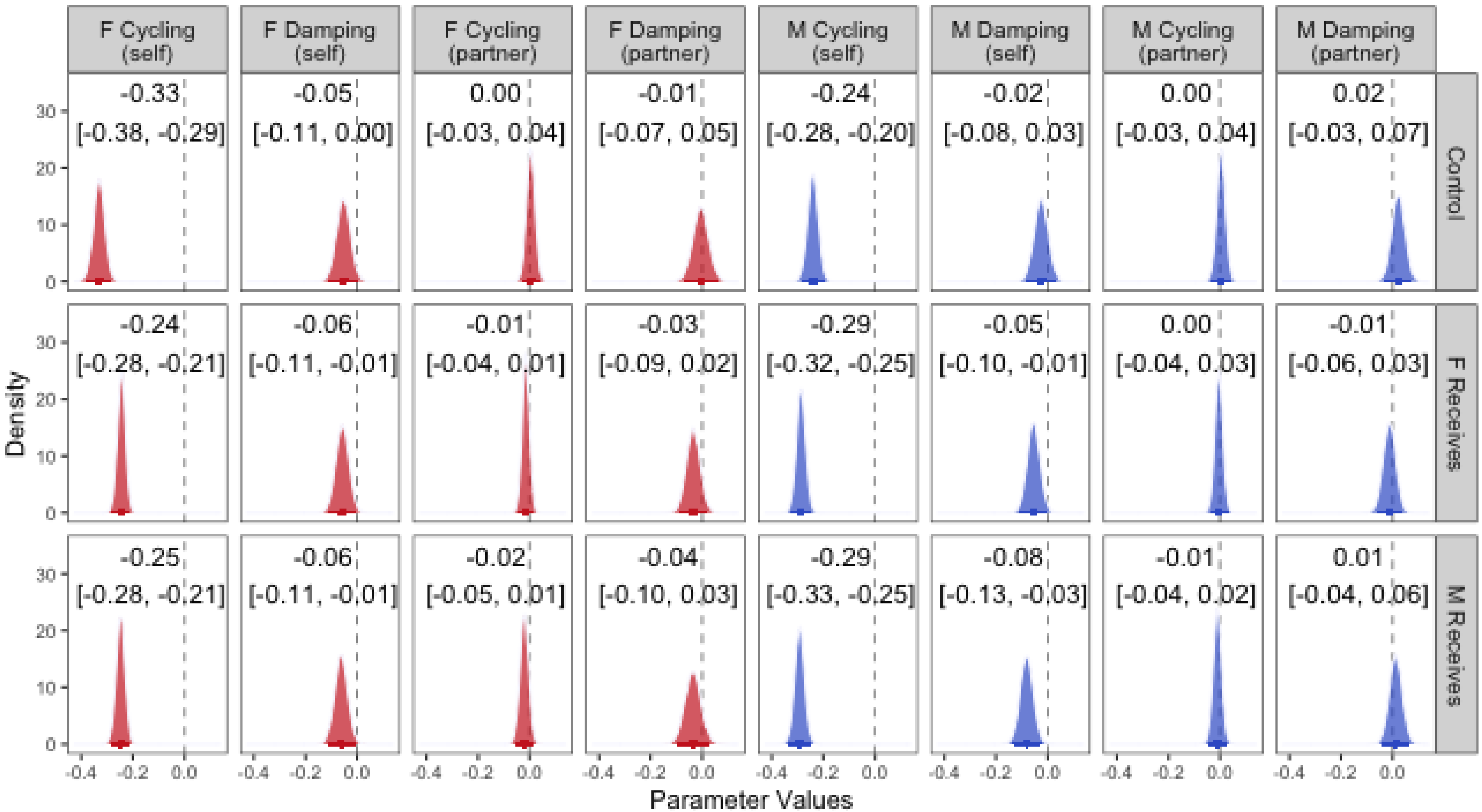

Figure 28: Summary of Fixed Effects by Discussion Condition. Estimates are posterior means (unstandardized), with 95-percent credibility intervals in brackets. Along the rows, F Receives = support discussion in which female partner received support. M Receives = support discussion in which male partner received support. Along the columns, F = Effect on female partner's responses, M = Effect on male partner's responses.

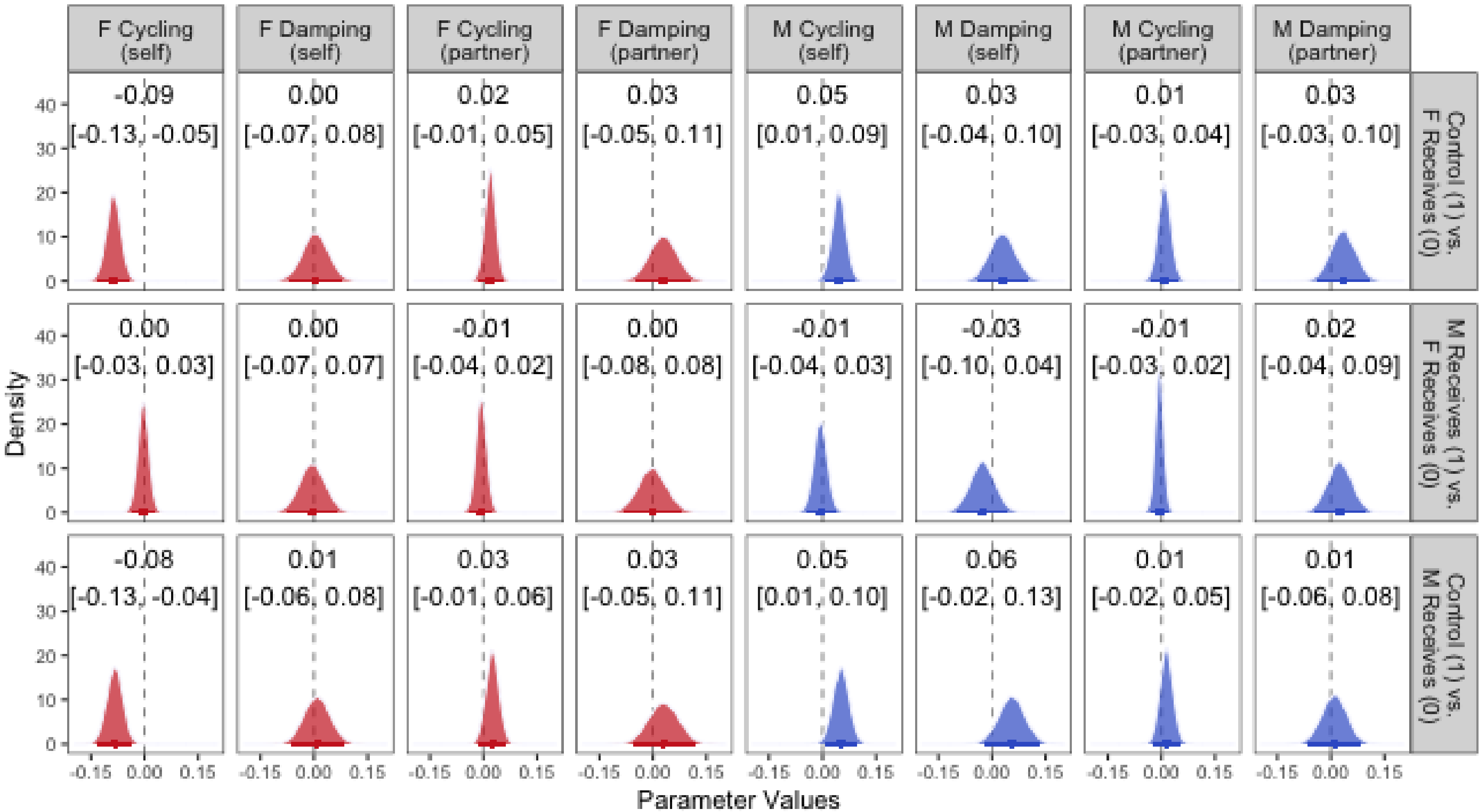

Figure 29: Summary of Differences Between Conditions (Fixed Effects). Estimates are posterior means (unstandardized), with 95-percent credibility intervals in brackets. Along the rows, F Receives = support discussion in which female partner received support. M Receives = support discussion in which male partner received support. Along the columns, F = Effect on female partner's responses, M = Effect on male partner's responses.

Random Effects

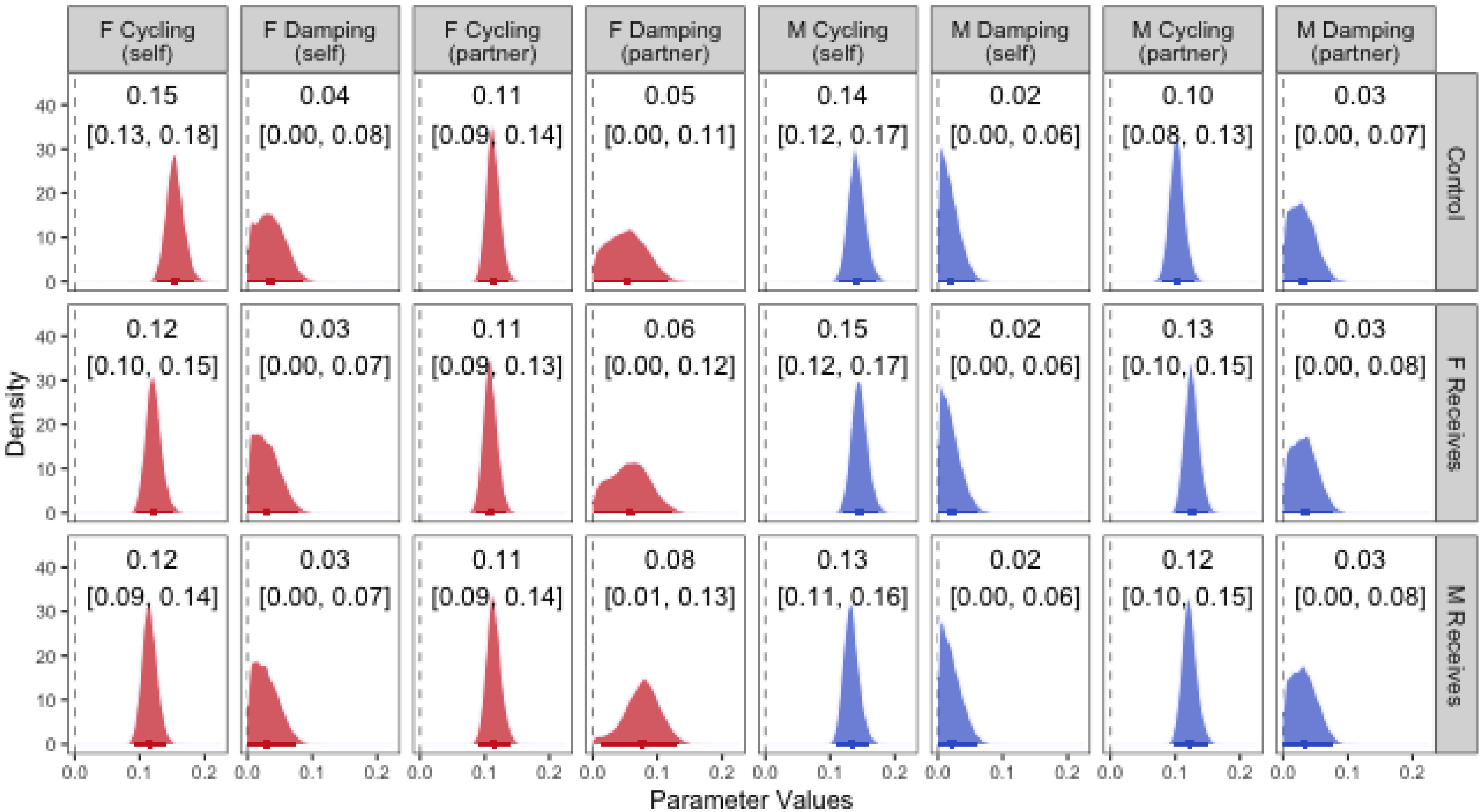

Figure 30: Summary of Random Effects by Discussion Condition. Estimates are posterior means (unstandardized), with 95-percent credibility intervals in brackets. Along the rows, F Receives = support discussion in which female partner received support. M Receives = support discussion in which male partner received support. Along the columns, F = Effect on female partner's responses, M = Effect on male partner's responses.

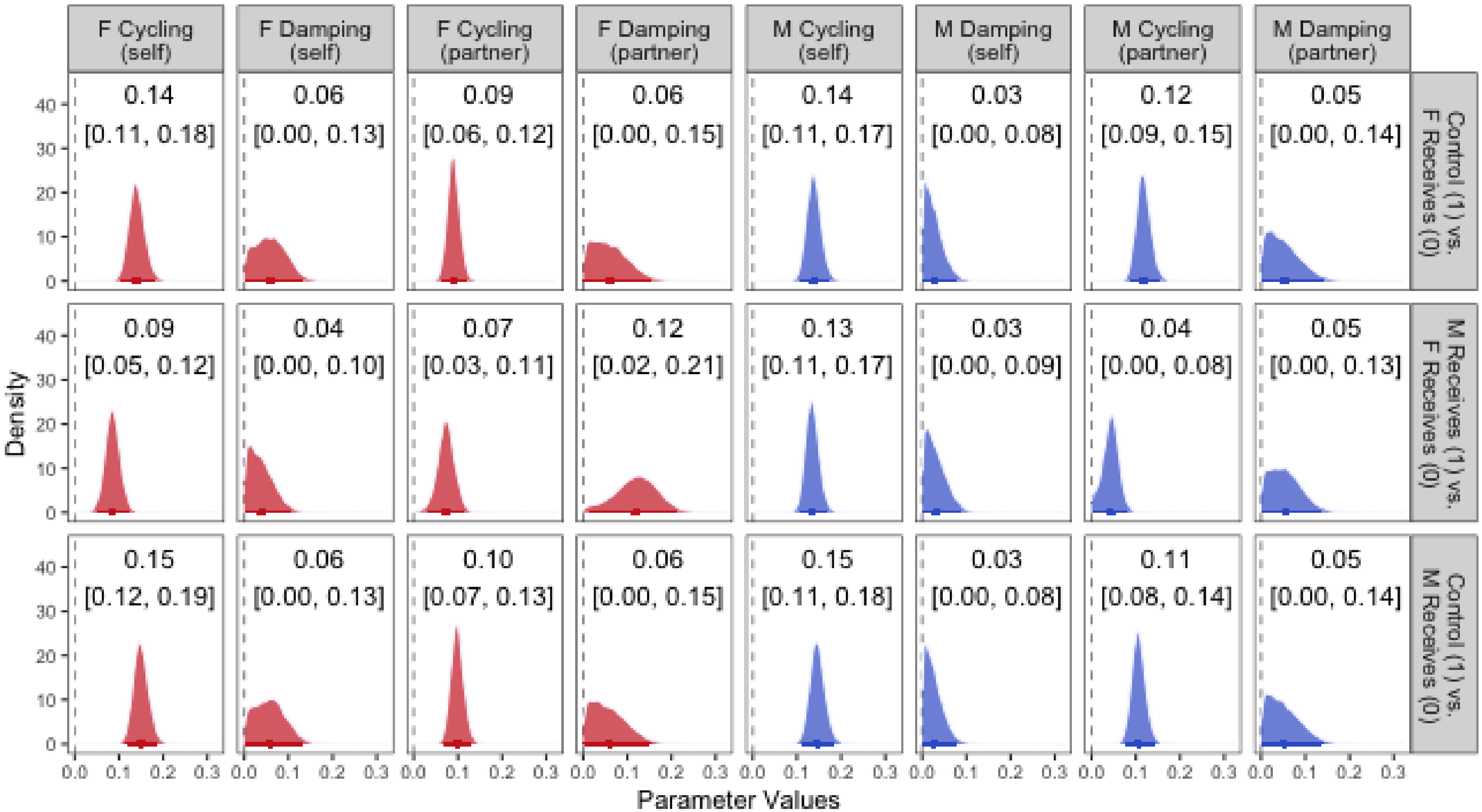

Figure 31: Summary of Differences Between Conditions (Random Effects). Estimates are posterior means (unstandardized), with 95-percent credibility intervals in brackets. Along the rows, F Receives = support discussion in which female partner received support. M Receives = support discussion in which male partner received support. Along the columns, F = Effect on female partner's responses, M = Effect on male partner's responses.

Table 37: Correlations among Random Effects

	Correlation	Estimate	Lower	Upper
1	F Cycling (self), F Damping (self)	-0.03	-0.34	0.29
2	F Cycling (self), F Cycling (partner)	0.04	-0.15	0.23
3	F Damping (self), F Cycling (partner)	0.14	-0.21	0.45
4	F Cycling (self), F Damping (partner)	-0.09	-0.37	0.22
5	F Damping (self), F Damping (partner)	0.00	-0.32	0.32
6	F Cycling (partner), F Damping (partner)	0.12	-0.20	0.42
7	F Cycling (self), F Cycling (self) X Control	-0.03	-0.25	0.20
8	F Damping (self), F Cycling (self) X Control	0.05	-0.28	0.36
9	F Cycling (partner), F Cycling (self) X Control	0.29	0.09	0.48
10	F Damping (partner), F Cycling (self) X Control	0.14	-0.18	0.43
11	F Cycling (self), F Damping (self) X Control	-0.07	-0.38	0.25
12	F Damping (self), F Damping (self) X Control	0.00	-0.32	0.33
13	F Cycling (partner), F Damping (self) X Control	0.10	-0.22	0.41
14	F Damping (partner), F Damping (self) X Control	0.02	-0.31	0.34
15	F Cycling (self) X Control, F Damping (self) X Control	0.10	-0.22	0.40
16	F Cycling (self), F Cycling (self) X M Receives	-0.20	-0.43	0.05
17	F Damping (self), F Cycling (self) X M Receives	0.03	-0.30	0.34
18	F Cycling (partner), F Cycling (self) X M Receives	-0.05	-0.27	0.17
19	F Damping (partner), F Cycling (self) X M Receives	-0.13	-0.43	0.20
20	F Cycling (self) X Control, F Cycling (self) X M Receives	0.05	-0.22	0.30
21	F Damping (self) X Control, F Cycling (self) X M Receives	0.04	-0.28	0.36
22	F Cycling (self), F Damping (self) X M Receives	-0.01	-0.34	0.31
23	F Damping (self), F Damping (self) X M Receives	-0.01	-0.35	0.32
24	F Cycling (partner), F Damping (self) X M Receives	0.07	-0.26	0.38
25	F Damping (partner), F Damping (self) X M Receives	-0.03	-0.35	0.30
26	F Cycling (self) X Control, F Damping (self) X M Receives	-0.02	-0.34	0.30
27	F Damping (self) X Control, F Damping (self) X M Receives	0.01	-0.32	0.34
28	F Cycling (self) X M Receives, F Damping (self) X M Receives	0.04	-0.29	0.36

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
29	F Cycling (self), F Cycling (partner) X Control	-0.11	-0.33	0.13
30	F Damping (self), F Cycling (partner) X Control	0.00	-0.31	0.31
31	F Cycling (partner), F Cycling (partner) X Control	-0.14	-0.35	0.09
32	F Damping (partner), F Cycling (partner) X Control	0.00	-0.31	0.30
33	F Cycling (self) X Control, F Cycling (partner) X Control	-0.19	-0.42	0.05
34	F Damping (self) X Control, F Cycling (partner) X Control	-0.02	-0.33	0.30
35	F Cycling (self) X M Receives, F Cycling (partner) X Control	-0.13	-0.38	0.14
36	F Damping (self) X M Receives, F Cycling (partner) X Control	0.02	-0.31	0.35
37	F Cycling (self), F Damping (partner) X Control	-0.10	-0.41	0.23
38	F Damping (self), F Damping (partner) X Control	0.00	-0.33	0.32
39	F Cycling (partner), F Damping (partner) X Control	0.09	-0.24	0.41
40	F Damping (partner), F Damping (partner) X Control	-0.03	-0.36	0.30
41	F Cycling (self) X Control, F Damping (partner) X Control	0.03	-0.30	0.35
42	F Damping (self) X Control, F Damping (partner) X Control	0.02	-0.32	0.35
43	F Cycling (self) X M Receives, F Damping (partner) X Control	0.01	-0.31	0.33
44	F Damping (self) X M Receives, F Damping (partner) X Control	0.00	-0.33	0.33
45	F Cycling (partner) X Control, F Damping (partner) X Control	0.03	-0.29	0.34
46	F Cycling (self), F Cycling (partner) X M Receives	0.05	-0.21	0.30
47	F Damping (self), F Cycling (partner) X M Receives	0.02	-0.31	0.34
48	F Cycling (partner), F Cycling (partner) X M Receives	0.03	-0.23	0.29
49	F Damping (partner), F Cycling (partner) X M Receives	-0.06	-0.37	0.27
50	F Cycling (self) X Control, F Cycling (partner) X M Receives	0.01	-0.26	0.28
51	F Damping (self) X Control, F Cycling (partner) X M Receives	-0.01	-0.34	0.31
52	F Cycling (self) X M Receives, F Cycling (partner) X M Receives	0.10	-0.19	0.38
53	F Damping (self) X M Receives, F Cycling (partner) X M Receives	0.06	-0.28	0.38
54	F Cycling (partner) X Control, F Cycling (partner) X M Receives	-0.02	-0.30	0.25
55	F Damping (partner) X Control, F Cycling (partner) X M Receives	-0.01	-0.33	0.32
56	F Cycling (self), F Damping (partner) X M Receives	-0.05	-0.33	0.24

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
57	F Damping (self), F Damping (partner) X M Receives	0.03	-0.31	0.34
58	F Cycling (partner), F Damping (partner) X M Receives	0.02	-0.27	0.30
59	F Damping (partner), F Damping (partner) X M Receives	0.00	-0.33	0.32
60	F Cycling (self) X Control, F Damping (partner) X M Receives	-0.09	-0.37	0.21
61	F Damping (self) X Control, F Damping (partner) X M Receives	-0.01	-0.34	0.32
62	F Cycling (self) X M Receives, F Damping (partner) X M Receives	-0.18	-0.47	0.13
63	F Damping (self) X M Receives, F Damping (partner) X M Receives	0.00	-0.33	0.32
64	F Cycling (partner) X Control, F Damping (partner) X M Receives	0.21	-0.10	0.49
65	F Damping (partner) X Control, F Damping (partner) X M Receives	0.02	-0.30	0.34
66	F Cycling (partner) X M Receives, F Damping (partner) X M Receives	-0.10	-0.40	0.21
67	F Cycling (self), M Cycling (self)	-0.16	-0.35	0.03
68	F Damping (self), M Cycling (self)	-0.03	-0.34	0.28
69	F Cycling (partner), M Cycling (self)	-0.05	-0.23	0.14
70	F Damping (partner), M Cycling (self)	0.04	-0.25	0.33
71	F Cycling (self) X Control, M Cycling (self)	-0.14	-0.35	0.08
72	F Damping (self) X Control, M Cycling (self)	0.02	-0.29	0.33
73	F Cycling (self) X M Receives, M Cycling (self)	0.08	-0.16	0.31
74	F Damping (self) X M Receives, M Cycling (self)	0.01	-0.31	0.33
75	F Cycling (partner) X Control, M Cycling (self)	0.14	-0.08	0.35
76	F Damping (partner) X Control, M Cycling (self)	0.11	-0.22	0.41
77	F Cycling (partner) X M Receives, M Cycling (self)	-0.05	-0.28	0.19
78	F Damping (partner) X M Receives, M Cycling (self)	0.00	-0.26	0.28
79	F Cycling (self), M Damping (self)	-0.03	-0.35	0.30
80	F Damping (self), M Damping (self)	-0.02	-0.35	0.32
81	F Cycling (partner), M Damping (self)	-0.03	-0.36	0.30

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
82	F Damping (partner), M Damping (self)	0.01	-0.32	0.34
83	F Cycling (self) X Control, M Damping (self)	0.00	-0.32	0.32
84	F Damping (self) X Control, M Damping (self)	-0.01	-0.34	0.32
85	F Cycling (self) X M Receives, M Damping (self)	-0.05	-0.38	0.28
86	F Damping (self) X M Receives, M Damping (self)	-0.01	-0.34	0.31
87	F Cycling (partner) X Control, M Damping (self)	0.03	-0.29	0.35
88	F Damping (partner) X Control, M Damping (self)	0.00	-0.32	0.33
89	F Cycling (partner) X M Receives, M Damping (self)	-0.02	-0.35	0.31
90	F Damping (partner) X M Receives, M Damping (self)	0.00	-0.33	0.33
91	M Cycling (self), M Damping (self)	0.00	-0.32	0.32
92	F Cycling (self), M Cycling (partner)	0.13	-0.06	0.31
93	F Damping (self), M Cycling (partner)	0.12	-0.22	0.43
94	F Cycling (partner), M Cycling (partner)	0.58	0.43	0.71
95	F Damping (partner), M Cycling (partner)	0.05	-0.23	0.33
96	F Cycling (self) X Control, M Cycling (partner)	0.23	0.03	0.43
97	F Damping (self) X Control, M Cycling (partner)	0.08	-0.23	0.39
98	F Cycling (self) X M Receives, M Cycling (partner)	-0.01	-0.24	0.23
99	F Damping (self) X M Receives, M Cycling (partner)	0.07	-0.26	0.39
100	F Cycling (partner) X Control, M Cycling (partner)	-0.12	-0.32	0.09
101	F Damping (partner) X Control, M Cycling (partner)	0.07	-0.23	0.37
102	F Cycling (partner) X M Receives, M Cycling (partner)	0.07	-0.16	0.30
103	F Damping (partner) X M Receives, M Cycling (partner)	-0.03	-0.29	0.24
104	M Cycling (self), M Cycling (partner)	-0.01	-0.19	0.16
105	M Damping (self), M Cycling (partner)	-0.05	-0.37	0.28
106	F Cycling (self), M Damping (partner)	0.05	-0.26	0.36
107	F Damping (self), M Damping (partner)	0.01	-0.32	0.34
108	F Cycling (partner), M Damping (partner)	-0.05	-0.35	0.26
109	F Damping (partner), M Damping (partner)	-0.10	-0.43	0.25

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
110	F Cycling (self) X Control, M Damping (partner)	-0.06	-0.36	0.26
111	F Damping (self) X Control, M Damping (partner)	-0.02	-0.34	0.31
112	F Cycling (self) X M Receives, M Damping (partner)	0.05	-0.26	0.37
113	F Damping (self) X M Receives, M Damping (partner)	0.02	-0.32	0.35
114	F Cycling (partner) X Control, M Damping (partner)	-0.08	-0.38	0.24
115	F Damping (partner) X Control, M Damping (partner)	-0.04	-0.37	0.29
116	F Cycling (partner) X M Receives, M Damping (partner)	-0.01	-0.33	0.31
117	F Damping (partner) X M Receives, M Damping (partner)	-0.08	-0.40	0.26
118	M Cycling (self), M Damping (partner)	-0.06	-0.36	0.25
119	M Damping (self), M Damping (partner)	-0.01	-0.34	0.32
120	M Cycling (partner), M Damping (partner)	0.00	-0.31	0.30
121	F Cycling (self), M Cycling (self) X Control	-0.05	-0.25	0.16
122	F Damping (self), M Cycling (self) X Control	0.00	-0.31	0.32
123	F Cycling (partner), M Cycling (self) X Control	-0.15	-0.35	0.05
124	F Damping (partner), M Cycling (self) X Control	-0.05	-0.34	0.25
125	F Cycling (self) X Control, M Cycling (self) X Control	-0.29	-0.50	-0.07
126	F Damping (self) X Control, M Cycling (self) X Control	-0.04	-0.34	0.27
127	F Cycling (self) X M Receives, M Cycling (self) X Control	0.04	-0.21	0.28
128	F Damping (self) X M Receives, M Cycling (self) X Control	0.01	-0.32	0.33
129	F Cycling (partner) X Control, M Cycling (self) X Control	0.08	-0.15	0.31
130	F Damping (partner) X Control, M Cycling (self) X Control	-0.02	-0.33	0.30
131	F Cycling (partner) X M Receives, M Cycling (self) X Control	-0.09	-0.35	0.17
132	F Damping (partner) X M Receives, M Cycling (self) X Control	0.11	-0.18	0.38
133	M Cycling (self), M Cycling (self) X Control	-0.27	-0.44	-0.08
134	M Damping (self), M Cycling (self) X Control	-0.02	-0.34	0.30
135	M Cycling (partner), M Cycling (self) X Control	-0.21	-0.39	-0.02
136	M Damping (partner), M Cycling (self) X Control	0.03	-0.28	0.34
137	F Cycling (self), M Damping (self) X Control	0.01	-0.33	0.34

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
138	F Damping (self), M Damping (self) X Control	-0.01	-0.33	0.32
139	F Cycling (partner), M Damping (self) X Control	0.00	-0.33	0.33
140	F Damping (partner), M Damping (self) X Control	0.01	-0.32	0.34
141	F Cycling (self) X Control, M Damping (self) X Control	0.02	-0.31	0.35
142	F Damping (self) X Control, M Damping (self) X Control	0.00	-0.32	0.33
143	F Cycling (self) X M Receives, M Damping (self) X Control	-0.02	-0.34	0.31
144	F Damping (self) X M Receives, M Damping (self) X Control	-0.01	-0.34	0.33
145	F Cycling (partner) X Control, M Damping (self) X Control	-0.01	-0.35	0.31
146	F Damping (partner) X Control, M Damping (self) X Control	0.00	-0.33	0.33
147	F Cycling (partner) X M Receives, M Damping (self) X Control	0.00	-0.34	0.33
148	F Damping (partner) X M Receives, M Damping (self) X Control	-0.01	-0.34	0.32
149	M Cycling (self), M Damping (self) X Control	0.02	-0.30	0.34
150	M Damping (self), M Damping (self) X Control	-0.01	-0.34	0.32
151	M Cycling (partner), M Damping (self) X Control	0.00	-0.33	0.33
152	M Damping (partner), M Damping (self) X Control	0.00	-0.34	0.33
153	M Cycling (self) X Control, M Damping (self) X Control	-0.05	-0.37	0.28
154	F Cycling (self), M Cycling (self) X M Receives	-0.09	-0.29	0.13
155	F Damping (self), M Cycling (self) X M Receives	0.01	-0.30	0.32
156	F Cycling (partner), M Cycling (self) X M Receives	0.14	-0.06	0.34
157	F Damping (partner), M Cycling (self) X M Receives	0.08	-0.22	0.37
158	F Cycling (self) X Control, M Cycling (self) X M Receives	0.17	-0.06	0.39
159	F Damping (self) X Control, M Cycling (self) X M Receives	-0.01	-0.32	0.31
160	F Cycling (self) X M Receives, M Cycling (self) X M Receives	-0.13	-0.38	0.12
161	F Damping (self) X M Receives, M Cycling (self) X M Receives	0.00	-0.32	0.32
162	F Cycling (partner) X Control, M Cycling (self) X M Receives	0.13	-0.11	0.36
163	F Damping (partner) X Control, M Cycling (self) X M Receives	-0.03	-0.34	0.28
164	F Cycling (partner) X M Receives, M Cycling (self) X M Receives	0.00	-0.25	0.25
165	F Damping (partner) X M Receives, M Cycling (self) X M Receives	0.13	-0.15	0.40

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
166	M Cycling (self), M Cycling (self) X M Receives	-0.38	-0.54	-0.20
167	M Damping (self), M Cycling (self) X M Receives	0.00	-0.32	0.32
168	M Cycling (partner), M Cycling (self) X M Receives	0.03	-0.16	0.21
169	M Damping (partner), M Cycling (self) X M Receives	-0.07	-0.37	0.25
170	M Cycling (self) X Control, M Cycling (self) X M Receives	0.19	-0.02	0.40
171	M Damping (self) X Control, M Cycling (self) X M Receives	0.00	-0.33	0.32
172	F Cycling (self), M Damping (self) X M Receives	-0.03	-0.35	0.30
173	F Damping (self), M Damping (self) X M Receives	-0.01	-0.34	0.32
174	F Cycling (partner), M Damping (self) X M Receives	-0.02	-0.34	0.31
175	F Damping (partner), M Damping (self) X M Receives	0.00	-0.32	0.33
176	F Cycling (self) X Control, M Damping (self) X M Receives	-0.03	-0.36	0.30
177	F Damping (self) X Control, M Damping (self) X M Receives	-0.01	-0.34	0.32
178	F Cycling (self) X M Receives, M Damping (self) X M Receives	-0.05	-0.38	0.28
179	F Damping (self) X M Receives, M Damping (self) X M Receives	-0.01	-0.34	0.32
180	F Cycling (partner) X Control, M Damping (self) X M Receives	0.05	-0.28	0.38
181	F Damping (partner) X Control, M Damping (self) X M Receives	0.00	-0.34	0.32
182	F Cycling (partner) X M Receives, M Damping (self) X M Receives	0.00	-0.32	0.33
183	F Damping (partner) X M Receives, M Damping (self) X M Receives	0.02	-0.31	0.34
184	M Cycling (self), M Damping (self) X M Receives	0.01	-0.31	0.33
185	M Damping (self), M Damping (self) X M Receives	-0.01	-0.34	0.32
186	M Cycling (partner), M Damping (self) X M Receives	-0.04	-0.35	0.28
187	M Damping (partner), M Damping (self) X M Receives	-0.01	-0.34	0.32
188	M Cycling (self) X Control, M Damping (self) X M Receives	0.01	-0.31	0.34
189	M Damping (self) X Control, M Damping (self) X M Receives	0.01	-0.32	0.33
190	M Cycling (self) X M Receives, M Damping (self) X M Receives	0.00	-0.33	0.32
191	F Cycling (self), M Cycling (partner) X Control	-0.11	-0.32	0.10
192	F Damping (self), M Cycling (partner) X Control	-0.07	-0.38	0.25

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
193	F Cycling (partner), M Cycling (partner) X Control	-0.14	-0.34	0.07
194	F Damping (partner), M Cycling (partner) X Control	0.00	-0.30	0.29
195	F Cycling (self) X Control, M Cycling (partner) X Control	-0.17	-0.39	0.06
196	F Damping (self) X Control, M Cycling (partner) X Control	-0.07	-0.38	0.25
197	F Cycling (self) X M Receives, M Cycling (partner) X Control	-0.16	-0.40	0.08
198	F Damping (self) X M Receives, M Cycling (partner) X Control	0.00	-0.33	0.32
199	F Cycling (partner) X Control, M Cycling (partner) X Control	0.51	0.30	0.69
200	F Damping (partner) X Control, M Cycling (partner) X Control	0.01	-0.30	0.32
201	F Cycling (partner) X M Receives, M Cycling (partner) X Control	-0.01	-0.27	0.25
202	F Damping (partner) X M Receives, M Cycling (partner) X Control	0.14	-0.14	0.41
203	M Cycling (self), M Cycling (partner) X Control	0.17	-0.05	0.38
204	M Damping (self), M Cycling (partner) X Control	0.05	-0.28	0.37
205	M Cycling (partner), M Cycling (partner) X Control	-0.41	-0.59	-0.22
206	M Damping (partner), M Cycling (partner) X Control	-0.12	-0.42	0.22
207	M Cycling (self) X Control, M Cycling (partner) X Control	0.00	-0.22	0.22
208	M Damping (self) X Control, M Cycling (partner) X Control	0.01	-0.32	0.33
209	M Cycling (self) X M Receives, M Cycling (partner) X Control	0.13	-0.09	0.35
210	M Damping (self) X M Receives, M Cycling (partner) X Control	0.06	-0.27	0.38
211	F Cycling (self), M Damping (partner) X Control	0.10	-0.24	0.42
212	F Damping (self), M Damping (partner) X Control	-0.01	-0.33	0.32
213	F Cycling (partner), M Damping (partner) X Control	-0.01	-0.32	0.30
214	F Damping (partner), M Damping (partner) X Control	-0.01	-0.34	0.31
215	F Cycling (self) X Control, M Damping (partner) X Control	-0.04	-0.36	0.27
216	F Damping (self) X Control, M Damping (partner) X Control	-0.02	-0.36	0.31
217	F Cycling (self) X M Receives, M Damping (partner) X Control	-0.04	-0.36	0.28
218	F Damping (self) X M Receives, M Damping (partner) X Control	0.01	-0.33	0.34
219	F Cycling (partner) X Control, M Damping (partner) X Control	-0.02	-0.34	0.30

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
220	F Damping (partner) X Control, M Damping (partner) X Control	-0.06	-0.39	0.28
221	F Cycling (partner) X M Receives, M Damping (partner) X Control	0.03	-0.29	0.35
222	F Damping (partner) X M Receives, M Damping (partner) X Control	0.03	-0.31	0.35
223	M Cycling (self), M Damping (partner) X Control	-0.04	-0.35	0.29
224	M Damping (self), M Damping (partner) X Control	-0.01	-0.35	0.32
225	M Cycling (partner), M Damping (partner) X Control	0.02	-0.29	0.33
226	M Damping (partner), M Damping (partner) X Control	-0.02	-0.35	0.30
227	M Cycling (self) X Control, M Damping (partner) X Control	-0.03	-0.34	0.29
228	M Damping (self) X Control, M Damping (partner) X Control	0.00	-0.34	0.33
229	M Cycling (self) X M Receives, M Damping (partner) X Control	-0.02	-0.33	0.30
230	M Damping (self) X M Receives, M Damping (partner) X Control	0.00	-0.33	0.33
231	M Cycling (partner) X Control, M Damping (partner) X Control	-0.04	-0.36	0.28
232	F Cycling (self), M Cycling (partner) X M Receives	0.12	-0.17	0.39
233	F Damping (self), M Cycling (partner) X M Receives	0.00	-0.33	0.33
234	F Cycling (partner), M Cycling (partner) X M Receives	-0.05	-0.33	0.22
235	F Damping (partner), M Cycling (partner) X M Receives	0.01	-0.31	0.32
236	F Cycling (self) X Control, M Cycling (partner) X M Receives	0.08	-0.23	0.37
237	F Damping (self) X Control, M Cycling (partner) X M Receives	0.01	-0.32	0.33
238	F Cycling (self) X M Receives, M Cycling (partner) X M Receives	-0.02	-0.31	0.29
239	F Damping (self) X M Receives, M Cycling (partner) X M Receives	0.00	-0.33	0.33
240	F Cycling (partner) X Control, M Cycling (partner) X M Receives	-0.02	-0.32	0.28
241	F Damping (partner) X Control, M Cycling (partner) X M Receives	-0.02	-0.34	0.31
242	F Cycling (partner) X M Receives, M Cycling (partner) X M Receives	0.17	-0.15	0.46

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
243	F Damping (partner) X M Receives, M Cycling (partner) X M Receives	0.05	-0.27	0.35
244	M Cycling (self), M Cycling (partner) X M Receives	-0.02	-0.30	0.27
245	M Damping (self), M Cycling (partner) X M Receives	0.00	-0.33	0.33
246	M Cycling (partner), M Cycling (partner) X M Receives	-0.02	-0.31	0.27
247	M Damping (partner), M Cycling (partner) X M Receives	-0.05	-0.37	0.28
248	M Cycling (self) X Control, M Cycling (partner) X M Receives	-0.09	-0.37	0.21
249	M Damping (self) X Control, M Cycling (partner) X M Receives	0.01	-0.32	0.34
250	M Cycling (self) X M Receives, M Cycling (partner) X M Receives	0.01	-0.28	0.30
251	M Damping (self) X M Receives, M Cycling (partner) X M Receives	-0.01	-0.33	0.32
252	M Cycling (partner) X Control, M Cycling (partner) X M Receives	0.12	-0.19	0.41
253	M Damping (partner) X Control, M Cycling (partner) X M Receives	0.01	-0.32	0.34
254	F Cycling (self), M Damping (partner) X M Receives	-0.02	-0.34	0.29
255	F Damping (self), M Damping (partner) X M Receives	0.01	-0.32	0.34
256	F Cycling (partner), M Damping (partner) X M Receives	0.03	-0.28	0.33
257	F Damping (partner), M Damping (partner) X M Receives	-0.03	-0.36	0.30
258	F Cycling (self) X Control, M Damping (partner) X M Receives	0.09	-0.24	0.41
259	F Damping (self) X Control, M Damping (partner) X M Receives	0.00	-0.32	0.33
260	F Cycling (self) X M Receives, M Damping (partner) X M Receives	0.10	-0.24	0.41
261	F Damping (self) X M Receives, M Damping (partner) X M Receives	0.02	-0.31	0.34
262	F Cycling (partner) X Control, M Damping (partner) X M Receives	-0.06	-0.37	0.26
263	F Damping (partner) X Control, M Damping (partner) X M Receives	0.00	-0.33	0.33

Table 37: Correlations among Random Effects *(continued)*

	Correlation	Estimate	Lower	Upper
264	F Cycling (partner) X M Receives, M Damping (partner) X M Receives	0.02	-0.30	0.33
265	F Damping (partner) X M Receives, M Damping (partner) X M Receives	-0.14	-0.47	0.21
266	M Cycling (self), M Damping (partner) X M Receives	-0.03	-0.34	0.28
267	M Damping (self), M Damping (partner) X M Receives	0.00	-0.32	0.33
268	M Cycling (partner), M Damping (partner) X M Receives	0.03	-0.28	0.33
269	M Damping (partner), M Damping (partner) X M Receives	-0.02	-0.35	0.31
270	M Cycling (self) X Control, M Damping (partner) X M Receives	-0.04	-0.35	0.28
271	M Damping (self) X Control, M Damping (partner) X M Receives	0.00	-0.33	0.33
272	M Cycling (self) X M Receives, M Damping (partner) X M Receives	0.03	-0.28	0.34
273	M Damping (self) X M Receives, M Damping (partner) X M Receives	-0.01	-0.34	0.32
274	M Cycling (partner) X Control, M Damping (partner) X M Receives	-0.06	-0.37	0.26
275	M Damping (partner) X Control, M Damping (partner) X M Receives	-0.01	-0.34	0.31
276	M Cycling (partner) X M Receives, M Damping (partner) X M Receives	-0.03	-0.36	0.29
277	Residual Correlation	0.09	0.06	0.11

Note:

The support discussion in which the female partner received support (F Receives) is the reference group. Control refers to a dummy variable indicating differences between the control discussion and female recipient support discussion (Control = 1, F Receives = 0). M Receives refers to a second dummy variable indicating differences between the male recipient and female recipient support discussions (M Receives = 1, F Receives = 0).

Analysis of Between-Dyad Heterogeneity using Posterior Probabilities

We further assessed heterogeneity through the use of directional posterior probabilities. Directional posterior probabilities refer to the percentage of posterior sample values falling above or below a particular threshold. We reasoned that if a substantial percentage of posterior samples for the fixed/random ratio exceeds .25, this can be taken as further evidence for the extent of heterogeneity (for other work using this approach, see Zee, Bolger, & Higgins, 2020). Indeed, we found that the probability that the fixed/random ratio exceeded .25 ranged from 0.48 to 1, with a median probability of 0.99. Taken together, the random effect estimates revealed, with a high degree of certainty, that coregulation processes are heterogeneous. Within the population, some dyads can be expected to show patterns of coregulation that resemble the patterns found for the average dyad, but many dyads can be expected to show markedly different patterns.

Tests on Posterior Samples

In addition to the test presented in the main text, we also conducted an additional examination of the model's posterior distributions to understand patterns of effects across multiple parameters. Through simulation, we identified a possible pattern of cross-partner coregulatory influence involving the signs of the cross-partner cycling effects. As shown in Figure 32, these simulations suggested that the simultaneous presence of opposite-sign partner cycling (η_p) coefficients (one negative coefficient and one positive coefficient) can generate a pattern of *dys*regulation. Other parameter values being equal, these opposite-sign parameters push partners away from equilibrium, manifested as increasing amplitudes over time. Thus, a possible way of characterizing beneficial patterns of coregulation could be to assess whether there is a lower probability of opposite-sign partner cycling coefficients, or, put differently, by a *higher* probability of *same*-sign partner cycling coefficients.

We note that in conducting further simulations, we noticed that this pattern was more apparent in the context of larger partner cycling effects (in absolute terms), that fell beyond the range of our observed effects. This pattern was less clear for smaller partner cycling effects. Nevertheless, our analysis is reported here for transparency.

For each posterior sample, we coded whether the two partner cycling parameters (η_{px}, the male partner's effect on the female partner; η_{py}, the female partner's effect on the male partner) were both negative in sign, both positive in sign, or of opposite signs. We then computed a probability of these patterns of partner cycling effects across all posterior samples for each discussion. As noted above, a limitation of this approach is that it does not take capture the magnitude of the partner cycling effects or the relative size of these effects to each other.

There was a reliable difference between the male recipient support discussion and the other discussions. The probability of same-sign partner cycling coefficients was 0.72 during the male recipient support discussion, 0.65 during the female recipient support discussion, and 0.64 during the control discussion.

Breaking this down further, a similar pattern of results was found for the probability of both partner cycling coefficients being negative. The probability of same-sign partner cycling coefficients was 0.66 during the male recipient support discussion, 0.55 during the female recipient support discussion, and 0.21 during the control discussion.

Although somewhat difficult to interpret because the patterns may depend on the overall magnitude of the effects and other parameter values, the results from this analysis were generally in line with those discussed in the main text: The probability of more beneficial patterns of coregulation occurring appeared to be higher during the support discussion when the male partner received support, and lower during the control discussion and female partner's support discussion.

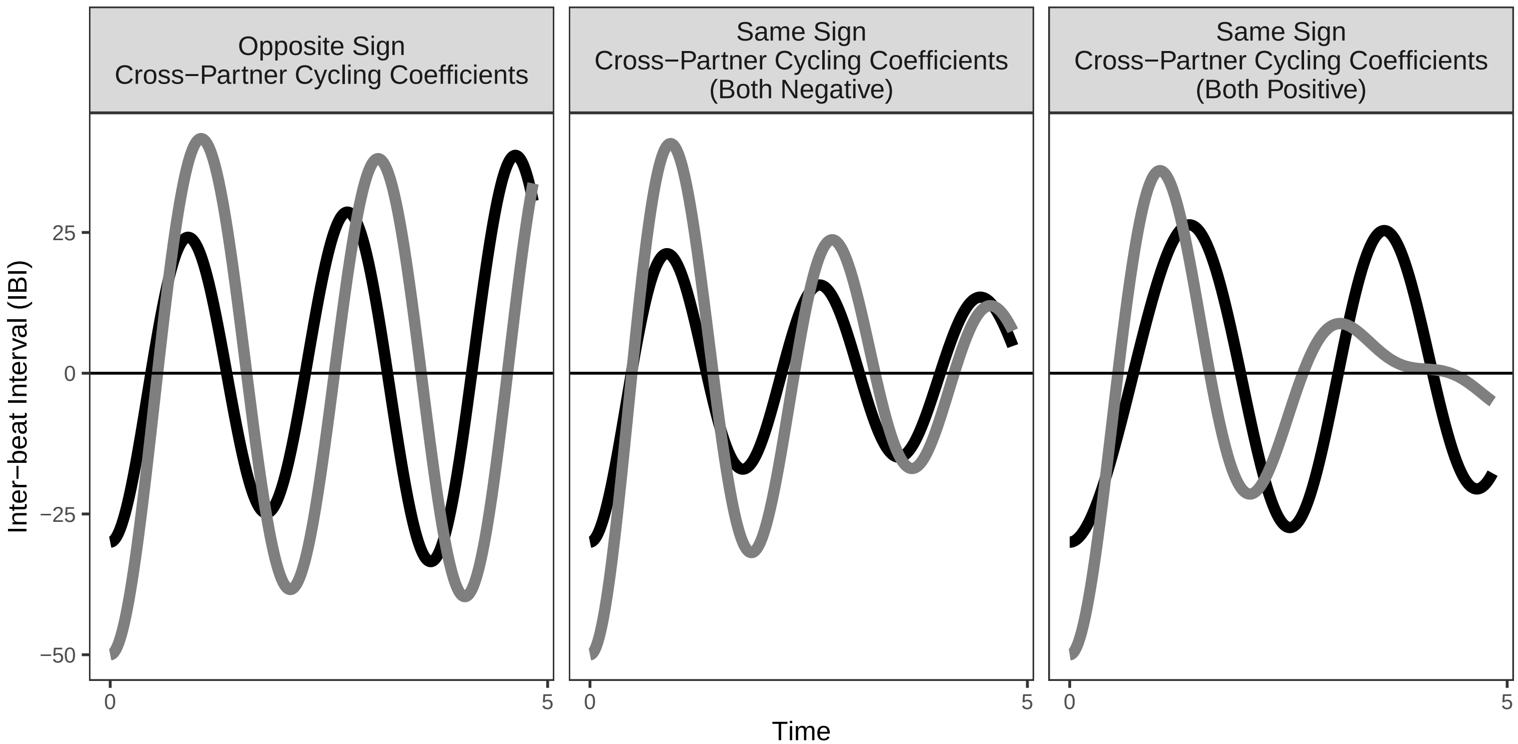

Figure 32: Simulated system trajectories when partner cycling coefficents are of opposite sign (left panel), both negative (middle panel), and both positive (right panel), and starting values are below equilibrium, all other coefficients equal across plots. For purposes of illustration, partner cycling effects = |0.06|. The remaining parameter values are set to the values of the fixed effects from the control discussion for all plots.

Appendix C: Supplemental Materials for Chapter 4

Overview

This appendix presents additional details and analyses relating to Chapter 4, including full model output with individual parameter estimates, random effect estimates, details about tests of heterogeneity, and results from additional models performed on the stressor data.

Analysis of Heterogeneity using Posterior Probabilities

We assessed heterogeneity in couples' physiological trajectories during the discussion and targets' trajectories during the speech using directional posterior probabilities. Directional posterior probabilities refer to the percentage of posterior sample values falling above or below a particular threshold. We reasoned that if a substantial percentage of posterior samples for the fixed/random ratio exceeds .25, this can be taken as further evidence for the extent of heterogeneity (for other work using this approach, see Zee, Bolger, & Higgins, 2020). For the discussions, We found that the probability that the fixed/random ratio exceeded .25 ranged from 0.71 to 1, with a median probability of 0.865. For the speech, there was a 0.99 probability of this ratio exceeding .25 for target cycling and 0.96 probability for target damping. Taken together, these random effect posterior proabilities provide further evidence for the extent of heterogeneity in coregulatory and self-regulatory processes.

Model Output Summary - Discussion Phases

Results for Discussion Phases - Fixed Effects

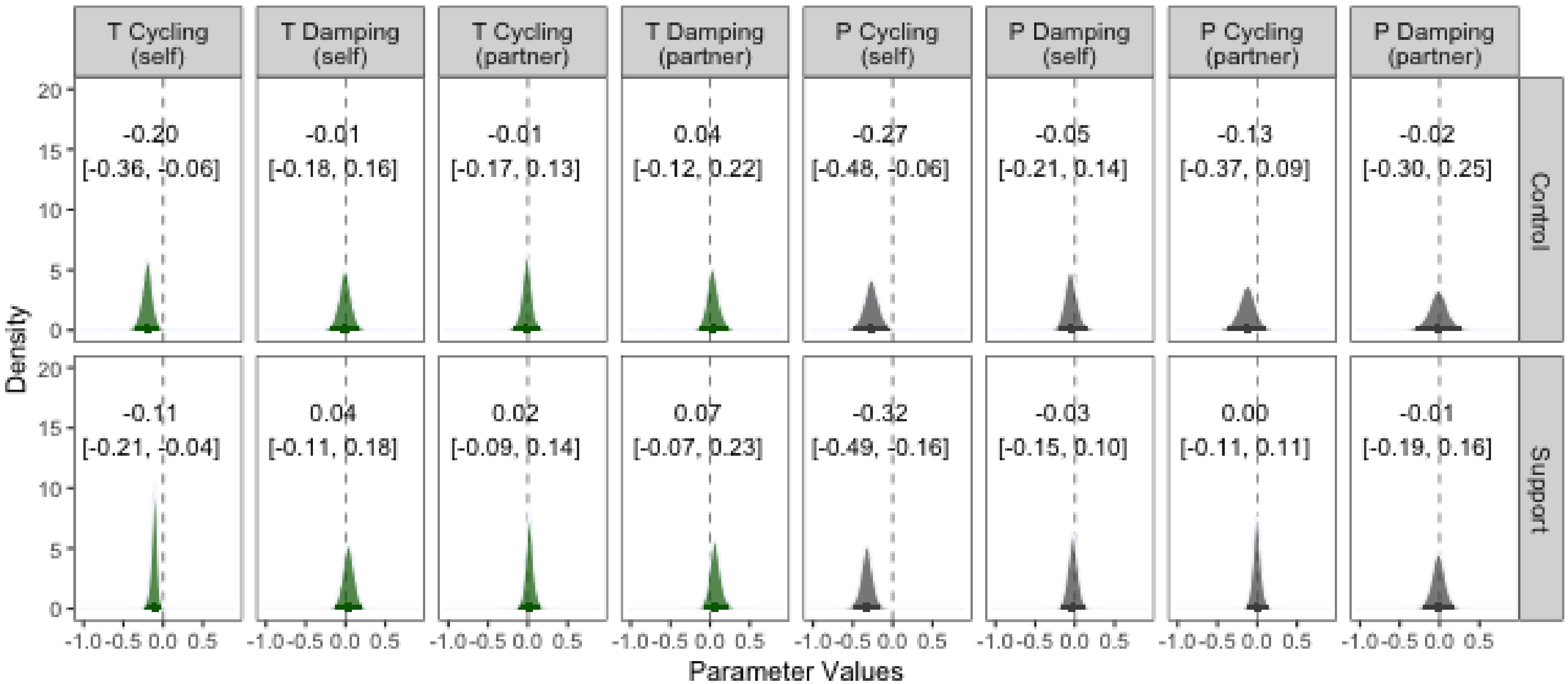

Figure 33: Summary of Fixed Effects by Discussion Condition. Estimates are posterior means, with 95-percent credibility intervals in brackets. Along the columns, T = Effect on Target IBI, P = Effect on Provider IBI.

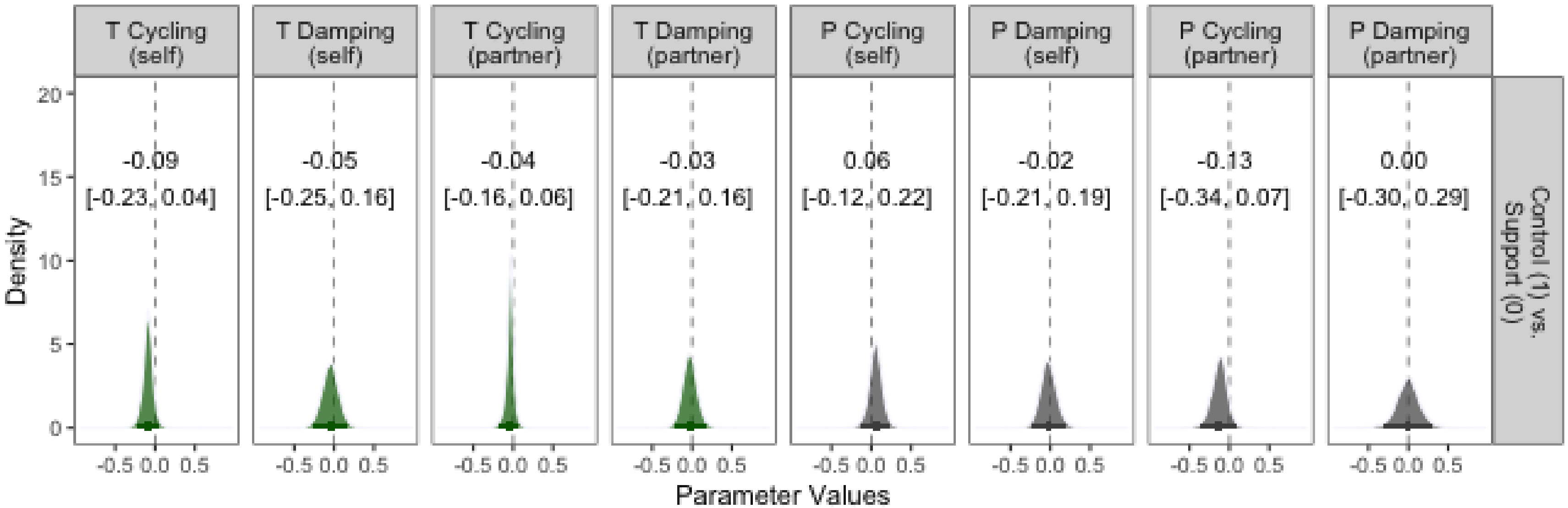

Figure 34: Summary of Differences in Effects between Discussion Conditions (fixed effects). Estimates are posterior means, with 95-percent credibility intervals in brackets. Along the columns, T = Effect on Target IBI, P = Effect on Provider IBI

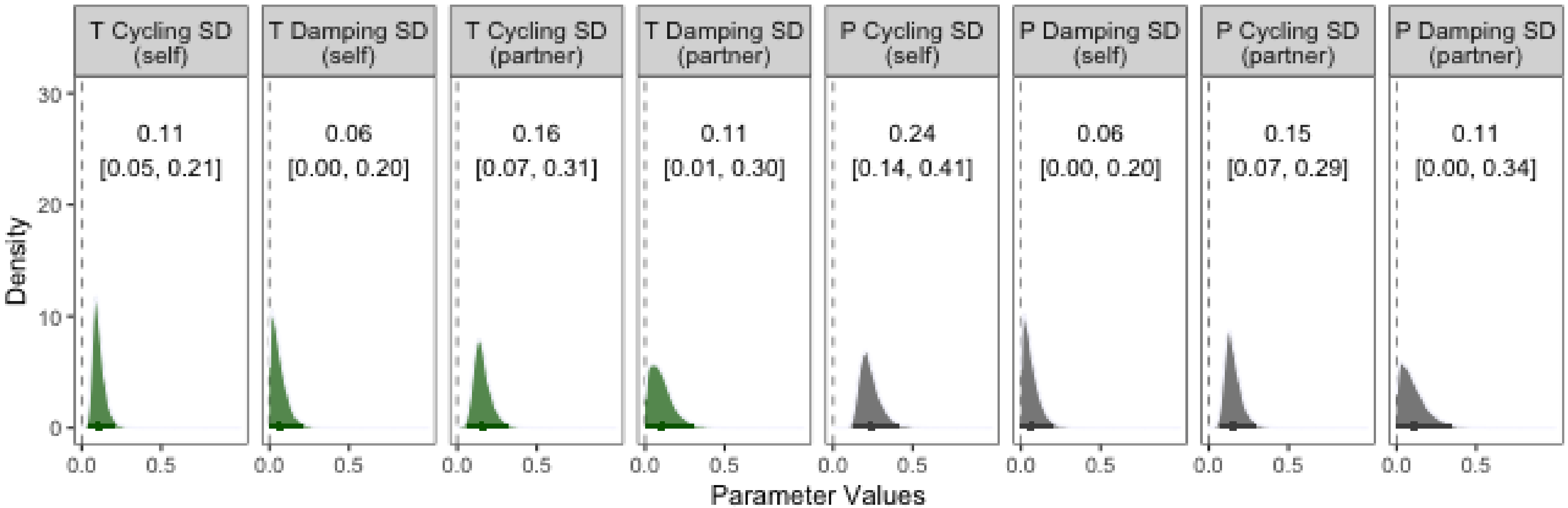

Figure 35: Summary of Random Effects, in standard deviation units. Estimates are posterior means, with 95-percent credibility intervals in brackets. Along the columns, T = Effect on Target IBI, P = Effect on Provider IBI

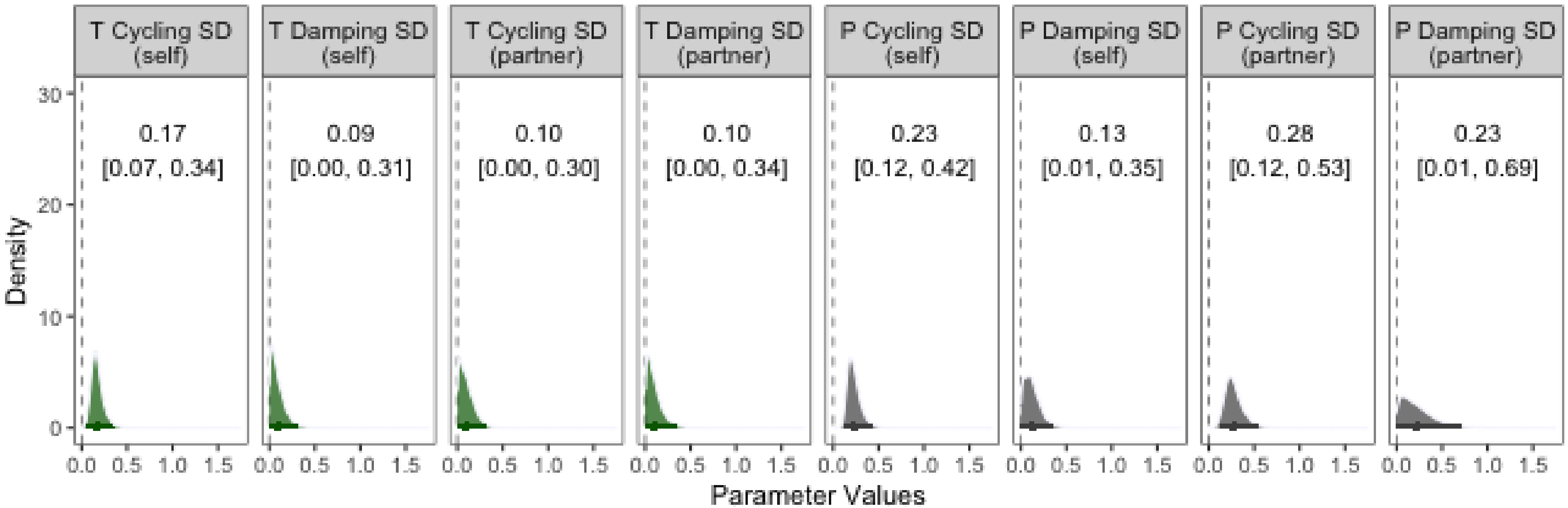

Figure 36: Differences in Effects between Discussion Conditions (random effects), in standard deviation units. Estimates are posterior means, with 95-percent credibility intervals in brackets. Along the columns, T = Effect on Target IBI, P = Effect on Provider IBI

Results for Discussion Phases - Correlations among Random Effects

Table 38: Correlations among random effects

	Correlation	Estimate	Lower	Upper
1	T Damping (self), T Damping (self)	-0.01	-0.41	0.38
2	T Damping (self), T Cycling (partner)	0.04	-0.29	0.38
3	T Damping (self), T Cycling (partner)	-0.04	-0.42	0.36
4	T Damping (self), T Damping (partner)	-0.06	-0.44	0.33
5	T Damping (self), T Damping (partner)	0.01	-0.39	0.41
6	T Cycling (partner), T Damping (partner)	-0.15	-0.54	0.27
7	T Damping (self), T Damping (self) X Control	-0.19	-0.51	0.16
8	T Damping (self), T Damping (self) X Control	0.02	-0.38	0.42
9	T Cycling (partner), T Damping (self) X Control	-0.24	-0.56	0.11
10	T Damping (partner), T Damping (self) X Control	0.11	-0.29	0.50
11	T Damping (self), T Damping (self) X Control	-0.02	-0.41	0.38
12	T Damping (self), T Damping (self) X Control	-0.02	-0.41	0.38
13	T Cycling (partner), T Damping (self) X Control	-0.04	-0.42	0.35
14	T Damping (partner), T Damping (self) X Control	0.02	-0.37	0.42
15	T Damping (self) X Control, T Damping (self) X Control	0.02	-0.37	0.40
16	T Damping (self), T Cycling (partner) X Control	-0.07	-0.45	0.33
17	T Damping (self), T Cycling (partner) X Control	0.00	-0.40	0.39
18	T Cycling (partner), T Cycling (partner) X Control	-0.10	-0.50	0.32
19	T Damping (partner), T Cycling (partner) X Control	0.02	-0.39	0.42
20	T Damping (self) X Control, T Cycling (partner) X Control	0.07	-0.33	0.46
21	T Damping (self) X Control, T Cycling (partner) X Control	-0.01	-0.40	0.39
22	T Damping (self), T Damping (partner) X Control	0.03	-0.37	0.42
23	T Damping (self), T Damping (partner) X Control	0.01	-0.39	0.41
24	T Cycling (partner), T Damping (partner) X Control	-0.04	-0.44	0.37
25	T Damping (partner), T Damping (partner) X Control	-0.03	-0.43	0.37
26	T Damping (self) X Control, T Damping (partner) X Control	0.00	-0.39	0.39
27	T Damping (self) X Control, T Damping (partner) X Control	0.01	-0.39	0.42
28	T Cycling (partner) X Control, T Damping (partner) X Control	-0.02	-0.42	0.38
29	T Damping (self), P Cycling (self)	0.17	-0.15	0.48
30	T Damping (self), P Cycling (self)	-0.02	-0.42	0.38
31	T Cycling (partner), P Cycling (self)	0.13	-0.21	0.46
32	T Damping (partner), P Cycling (self)	-0.06	-0.44	0.34
33	T Damping (self) X Control, P Cycling (self)	0.00	-0.33	0.33
34	T Damping (self) X Control, P Cycling (self)	-0.02	-0.42	0.38

Table 38: Correlations among random effects *(continued)*

	Correlation	Estimate	Lower	Upper
35	T Cycling (partner) X Control, P Cycling (self)	0.02	-0.37	0.40
36	T Damping (partner) X Control, P Cycling (self)	-0.03	-0.42	0.37
37	T Damping (self), P Damping (self)	-0.01	-0.41	0.39
38	T Damping (self), P Damping (self)	0.00	-0.40	0.40
39	T Cycling (partner), P Damping (self)	0.00	-0.40	0.41
40	T Damping (partner), P Damping (self)	0.00	-0.40	0.40
41	T Damping (self) X Control, P Damping (self)	-0.04	-0.44	0.37
42	T Damping (self) X Control, P Damping (self)	-0.01	-0.41	0.40
43	T Cycling (partner) X Control, P Damping (self)	0.00	-0.40	0.40
44	T Damping (partner) X Control, P Damping (self)	0.00	-0.40	0.40
45	P Cycling (self), P Damping (self)	-0.01	-0.40	0.40
46	T Damping (self), P Cycling (partner)	0.03	-0.35	0.41
47	T Damping (self), P Cycling (partner)	0.00	-0.40	0.40
48	T Cycling (partner), P Cycling (partner)	0.15	-0.25	0.51
49	T Damping (partner), P Cycling (partner)	-0.05	-0.43	0.35
50	T Damping (self) X Control, P Cycling (partner)	-0.05	-0.42	0.34
51	T Damping (self) X Control, P Cycling (partner)	0.00	-0.40	0.39
52	T Cycling (partner) X Control, P Cycling (partner)	-0.02	-0.41	0.38
53	T Damping (partner) X Control, P Cycling (partner)	0.00	-0.40	0.40
54	P Cycling (self), P Cycling (partner)	0.03	-0.36	0.40
55	P Damping (self), P Cycling (partner)	-0.01	-0.41	0.39
56	T Damping (self), P Damping (partner)	0.01	-0.38	0.41
57	T Damping (self), P Damping (partner)	0.00	-0.40	0.40
58	T Cycling (partner), P Damping (partner)	0.04	-0.36	0.43
59	T Damping (partner), P Damping (partner)	-0.03	-0.42	0.37
60	T Damping (self) X Control, P Damping (partner)	-0.04	-0.43	0.35
61	T Damping (self) X Control, P Damping (partner)	-0.01	-0.41	0.39
62	T Cycling (partner) X Control, P Damping (partner)	0.00	-0.41	0.40
63	T Damping (partner) X Control, P Damping (partner)	-0.01	-0.41	0.39
64	P Cycling (self), P Damping (partner)	-0.01	-0.40	0.40
65	P Damping (self), P Damping (partner)	0.00	-0.40	0.40
66	P Cycling (partner), P Damping (partner)	0.01	-0.40	0.41
67	T Damping (self), P Cycling (self) X Control	-0.01	-0.36	0.33
68	T Damping (self), P Cycling (self) X Control	0.00	-0.40	0.40
69	T Cycling (partner), P Cycling (self) X Control	-0.20	-0.53	0.17

Table 38: Correlations among random effects *(continued)*

	Correlation	Estimate	Lower	Upper
70	T Damping (partner), P Cycling (self) X Control	0.05	-0.35	0.43
71	T Damping (self) X Control, P Cycling (self) X Control	0.13	-0.22	0.47
72	T Damping (self) X Control, P Cycling (self) X Control	0.00	-0.40	0.40
73	T Cycling (partner) X Control, P Cycling (self) X Control	0.03	-0.37	0.42
74	T Damping (partner) X Control, P Cycling (self) X Control	-0.02	-0.41	0.38
75	P Cycling (self), P Cycling (self) X Control	-0.31	-0.61	0.04
76	P Damping (self), P Cycling (self) X Control	-0.01	-0.41	0.39
77	P Cycling (partner), P Cycling (self) X Control	-0.09	-0.46	0.30
78	P Damping (partner), P Cycling (self) X Control	-0.01	-0.41	0.38
79	T Damping (self), P Damping (self) X Control	0.01	-0.38	0.41
80	T Damping (self), P Damping (self) X Control	0.00	-0.40	0.40
81	T Cycling (partner), P Damping (self) X Control	0.00	-0.40	0.40
82	T Damping (partner), P Damping (self) X Control	0.00	-0.40	0.41
83	T Damping (self) X Control, P Damping (self) X Control	-0.03	-0.42	0.37
84	T Damping (self) X Control, P Damping (self) X Control	0.00	-0.39	0.40
85	T Cycling (partner) X Control, P Damping (self) X Control	0.00	-0.40	0.41
86	T Damping (partner) X Control, P Damping (self) X Control	0.00	-0.40	0.40
87	P Cycling (self), P Damping (self) X Control	0.03	-0.37	0.41
88	P Damping (self), P Damping (self) X Control	-0.02	-0.42	0.39
89	P Cycling (partner), P Damping (self) X Control	-0.01	-0.41	0.39
90	P Damping (partner), P Damping (self) X Control	0.01	-0.39	0.41
91	P Cycling (self) X Control, P Damping (self) X Control	-0.03	-0.42	0.37
92	T Damping (self), P Cycling (partner) X Control	-0.11	-0.50	0.30
93	T Damping (self), P Cycling (partner) X Control	0.00	-0.41	0.40
94	T Cycling (partner), P Cycling (partner) X Control	0.00	-0.38	0.38
95	T Damping (partner), P Cycling (partner) X Control	0.02	-0.38	0.41
96	T Damping (self) X Control, P Cycling (partner) X Control	0.07	-0.32	0.44
97	T Damping (self) X Control, P Cycling (partner) X Control	0.00	-0.40	0.40
98	T Cycling (partner) X Control, P Cycling (partner) X Control	0.05	-0.36	0.44
99	T Damping (partner) X Control, P Cycling (partner) X Control	-0.01	-0.41	0.39
100	P Cycling (self), P Cycling (partner) X Control	0.01	-0.37	0.39
101	P Damping (self), P Cycling (partner) X Control	0.00	-0.40	0.39
102	P Cycling (partner), P Cycling (partner) X Control	-0.06	-0.45	0.34
103	P Damping (partner), P Cycling (partner) X Control	0.00	-0.41	0.39
104	P Cycling (self) X Control, P Cycling (partner) X Control	-0.03	-0.41	0.36

Table 38: Correlations among random effects *(continued)*

	Correlation	Estimate	Lower	Upper
105	P Damping (self) X Control, P Cycling (partner) X Control	0.01	-0.40	0.40
106	T Damping (self), P Damping (partner) X Control	-0.03	-0.43	0.38
107	T Damping (self), P Damping (partner) X Control	0.00	-0.41	0.40
108	T Cycling (partner), P Damping (partner) X Control	0.00	-0.39	0.38
109	T Damping (partner), P Damping (partner) X Control	0.00	-0.40	0.40
110	T Damping (self) X Control, P Damping (partner) X Control	0.01	-0.37	0.40
111	T Damping (self) X Control, P Damping (partner) X Control	-0.01	-0.41	0.40
112	T Cycling (partner) X Control, P Damping (partner) X Control	0.02	-0.38	0.42
113	T Damping (partner) X Control, P Damping (partner) X Control	-0.03	-0.43	0.38
114	P Cycling (self), P Damping (partner) X Control	0.01	-0.38	0.41
115	P Damping (self), P Damping (partner) X Control	0.01	-0.39	0.41
116	P Cycling (partner), P Damping (partner) X Control	-0.02	-0.42	0.39
117	P Damping (partner), P Damping (partner) X Control	-0.03	-0.43	0.38
118	P Cycling (self) X Control, P Damping (partner) X Control	0.02	-0.38	0.41
119	P Damping (self) X Control, P Damping (partner) X Control	0.01	-0.40	0.41
120	P Cycling (partner) X Control, P Damping (partner) X Control	0.00	-0.39	0.40
121	Residual Correlation	0.08	0.03	0.13
122	Prior	0.00	-0.40	0.40

Note:

T = Target, P = Partner. Discussion phase is coded as support = 0, control = 1.

Model Output Summary - Stressor Phase

Results for Stressor Phase - Fixed Effects

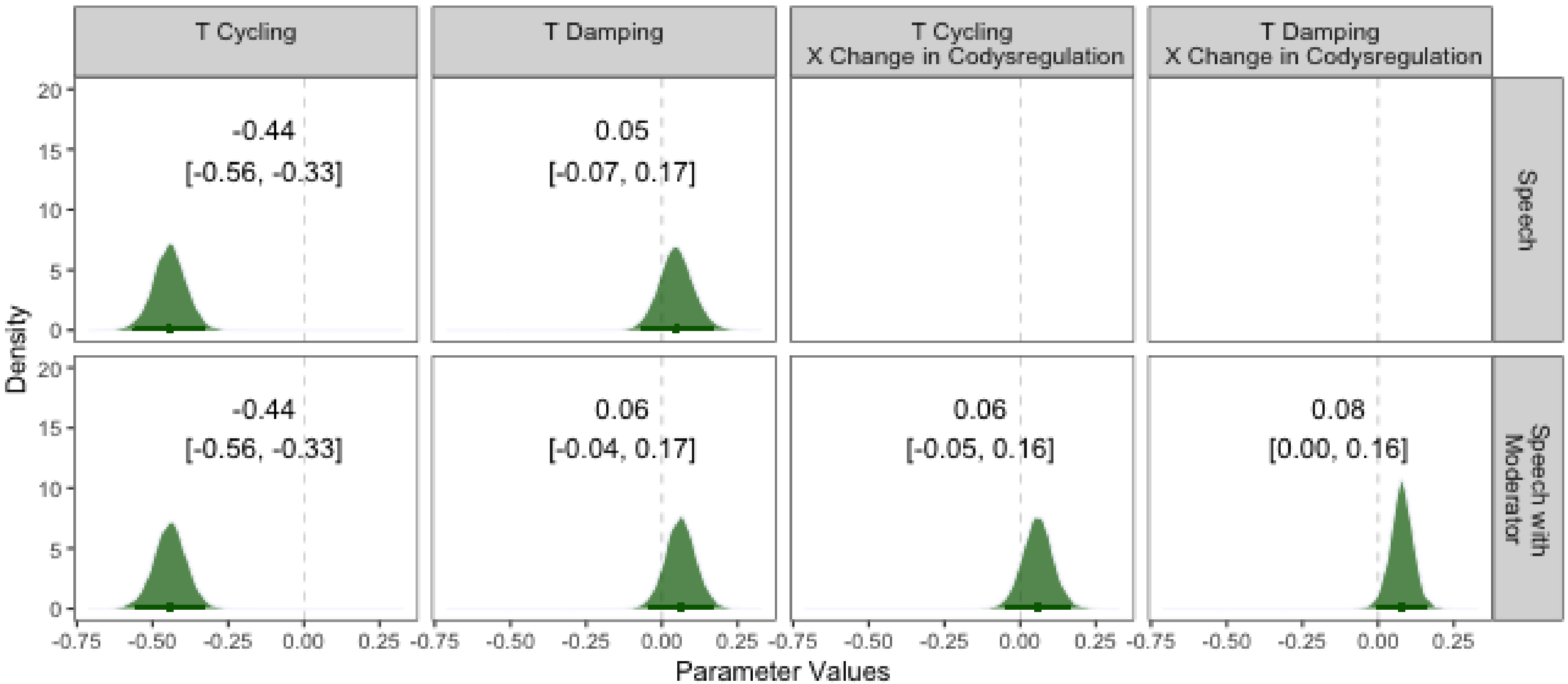

Figure 37: Summary of Fixed Effects (Stressor). T = Target partner. Estimates are posterior means, with 95-percent credibility intervals in brackets.

Results for Stressor Phase - Random Effects

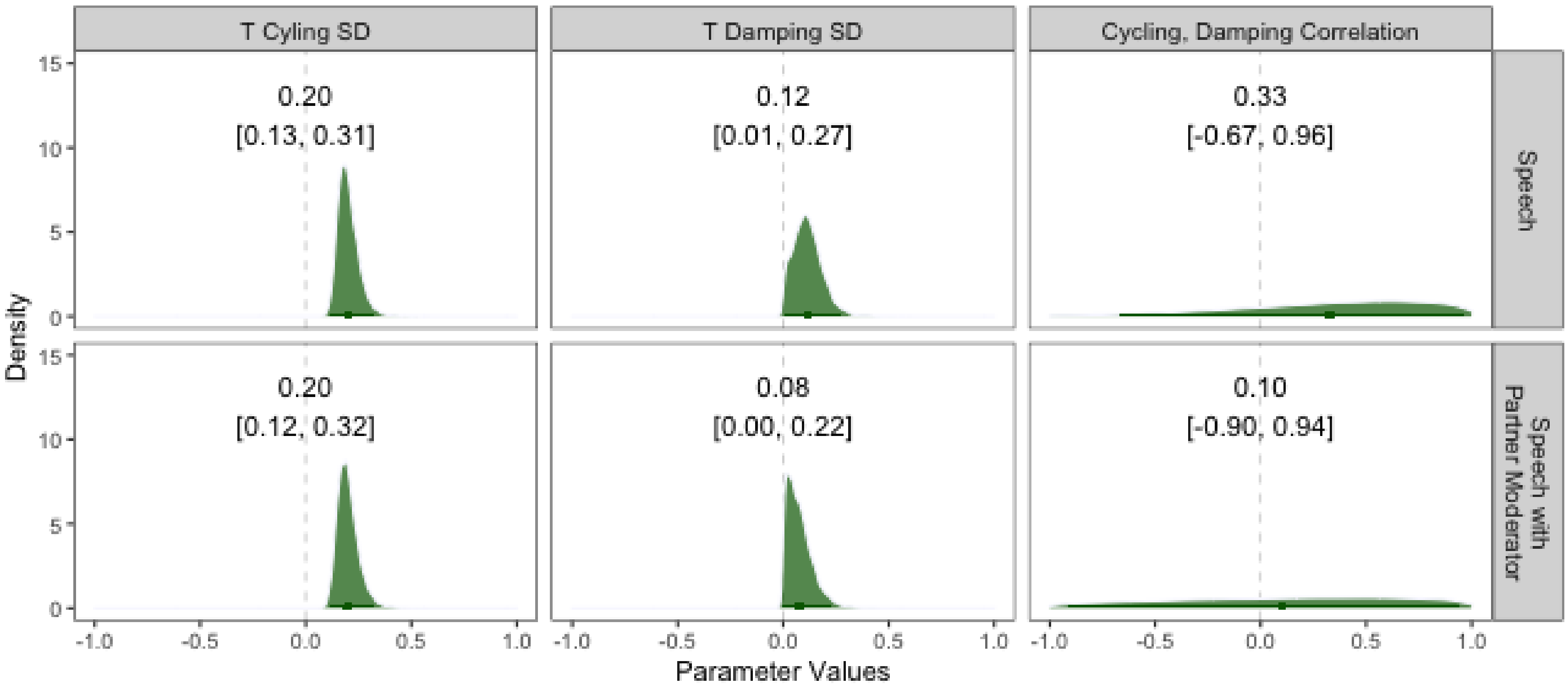

Figure 38: Summary of Random Effects (Stressor). T = Target partner. Estimates are posterior means, with 95-percent credibility intervals in brackets.

Ruling Out an Alternative Explanation

To address the possibility the moderating effect of changes in codysregulation between discussions on targets' damping during the speech was driven by changes in *targets' self-regulation* between discussions, we fit another version of the damped oscillator model in which targets' cycling and damping effects were moderated by (a) targets' own changes in damping between discussions (self-regulation moderator; in standardized units) and (b) changes in codysregulation (original moderator; in standardized units). The results from this model are displayed in Tables 39 and 40. As these results show, the interaction of target damping and change in codysregulation was essentially unchanged with the inclusion of targets' changes in coregulation.

As noted in the main text, we then used a directional posterior probabilities to test whether the damping × change in codysregulation moderation effect was stronger (more negative) than the damping × change in self-regulation moderation effect. This analysis indicated a 0.91 probability in favor of the codysregulation moderator.

Table 39: Summary of results from damped oscillator model with moderators (Random Fixed)

Coefficient	Estimate	SE	Lower	Upper	Post_Prob	N_Subj	N_Obs
Cycling	-0.45	0.06	-0.56	-0.33	1.00	18	466
Damping	0.06	0.06	-0.05	0.17	0.15	18	466
Cycling x Change in Self-Reg.	0.05	0.06	-0.08	0.17	0.21	18	466
Damping x Change in Self-Reg.	0.02	0.05	-0.08	0.12	0.32	18	466
Cycling x Change in Codysreg.	0.08	0.06	-0.04	0.21	0.09	18	466
Damping x Change in Codysreg.	0.09	0.05	-0.01	0.18	0.04	18	466

Note:
Cycling and Damping refer to target's self-regulation effects during the stressor. Change in self-regulation is the change in target's self-regulation damping effect between the support and control discussions. Change in codysregulation is the change in target's effect on the provider's damping between the support and control discussions (higher values indicate that dysregulation increased more during support). Posterior probability is the percentage of posterior samples falling in the hypothesized (negative) direction.

Table 40: Summary of results from damped oscillator model with moderators (Random Effects)

Term	Estimate	SE	Lower	Upper
Cycling SD	0.20	0.05	0.12	0.33
Damping SD	0.08	0.07	0.003	0.25
Cycling, Damping Correlation	0.05	0.53	-0.92	0.93
Residual	9.20	0.30	8.63	9.82

Note:
Cycling and Damping refer to target's self-regulation effects during the stressor. Change in self-regulation is the change in target's self-regulation damping effect between the support and control discussions. Change in codysregulation is the change in target's effect on the provider's damping between the support and control discussions.

Model Comparisons

To assess coregulation in Chapter 4, we performed model comparisons using Leave-Out-Out cross-validation (for details on this approach, see Chapter 3). We compared our orginal coupled oscillator model that included cross-partner cycling and damping effects to a model that omitted cross-partner effects.

The difference in model fit in the LOO metric was 16.9 ($SE = 13.9$). Translated into a standardized metric, this amounted to a difference of 1.2 z-score units (17/14). Thus, contrary to our expectations, we were not able to conclude from this model comparison that the model that included cross-partner effects provided a better fit for the data compared the model that omitted cross-partner effects. This may be due to the small sample size, which may not have provided enough data to detect differences in model fit.