UNIVERSITY OF CALIFORNIA

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Investigating the Neural Correlates of Empathy in Couples' Communication

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Psychology

by

Lucy Shen

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ABSTRACT OF THE DISSERTATION

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Professor Benjamin R. Karney, Chair

Despite the importance of communication for relationship functioning and maintenance, even partners who love each other often struggle to communicate *effectively*. Although conflict is inevitable in close relationships, couples vary significantly in their capacity to resolve disagreements. Partners also often struggle to communicate support and comfort to one another in sensitive ways during stressful times. The purpose of this dissertation was to examine the role of neural synchrony in empathy-associated brain regions on couples' communication throughout social support and conflict interactions. Towards this end, the primary aim of Study 1 was to examine associations between neural synchrony in regions corresponding with perspective taking and post-conflict outcomes in couples. Expanding on Study 1, the primary purpose of *Study 2* was to examine and compare effects of neural synchrony corresponding to two different forms of

empathy (perspective-taking and empathic distress) on post-support outcomes in couples. Expanding on Studies 1 and 2, the primary aim of Study 3 was to capture and assess time-dependent dynamics between neural synchrony and observed behavior throughout couples' conflict and social support interactions as they unfold. In line with this aim, I assessed concurrent associations between second-to-second neural synchrony and second-to-second observed behavior, as well as bidirectional lagged associations between neural synchrony and observed behavior across various time-intervals. Findings from the dissertation overall shed light on the complicated nature of empathy and how it may impact communication and close relationships, in which separate facets of empathy relate to communication in different ways and behave differently across various social contexts. Only thinking of empathy as a stable, trait-based construct is likely an oversimplification, as this research shows that it's the dynamic shifts throughout communication in real time that correspond to changes in behavior. To further our knowledge regarding associations between neural synchrony in empathy-related regions and relationship functioning, future research may consider examining these associations across diverse couples using a mixed methods approach with both cross-sectional and longitudinal methods.

The dissertation of Lucy Shen is approved.

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Dedication

This dissertation is dedicated to all the loved ones in my life, who have supported me through my most vulnerable moments and cheered alongside me during my biggest triumphs. This dissertation is also dedicated to the incredible couples who participated in my research studies. I was amazed by how bravely they tackled tough conversations and openly shared stories about some of their most difficult life experiences. They have been nothing short of inspiring, and I will forever be grateful that they entrusted their stories with me.

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Introduction

Background

Have you ever had trouble seeing eye-to-eye with someone, where the frustrations behind that disconnect led you to say things you later regretted? Have you ever seen someone you care about go through a difficult time, where despite desperately wanting to help end their suffering, you just couldn't find the right words to say at the right moment? Have you yourself ever felt inconsolable while going through your own difficult time, where peoples' attempts to make you feel better… only made you feel worse? If you can relate to any of these scenarios, perhaps you would agree firsthand that it can be tough to endure these difficult conversations, even with the ones you love most. Yet, it's often the way we communicate throughout these conversations that can make or break our relationships.

The quality of our close relationships has a profound impact on our ability to maintain successful careers, healthy family dynamics, and optimal physical and mental health (e.g., Kiecolt-Glaser & Newton, 2001). While strong social bonds can be a valuable asset, families are at risk for a variety of adverse outcomes when these same relationships falter (Amato & Sobolewski, 2001). Given that the quality of our intimate relationships has such a powerful impact on wellbeing, it is crucial to understand close relationship processes and their downstream consequences (Baucom, Shoham, Mueser, Daiuto, & Stickle, 1998).

Because intimate relationships are defined by behavioral interdependence (Kelley & Thibaut, 1978), intervention researchers (Doss et al., 2016), practicing psychotherapists (Halford et al., 2015), and relationships scientists (Stanley, Markman, & Whitton, 2002) all highlight *communication* as central to healthy relationship functioning and maintenance. Indeed, meta-analytic research (e.g.,Woodin, 2011) and longitudinal studies (Karney & Bradbury, 1995) have found that the observed quality of couples' interactions reliably predicts their long-term relationship stability and satisfaction.

Yet despite the importance of communication for relationship functioning and maintenance, even partners who love each other often struggle to communicate *effectively*. For example, although conflict is inevitable in close relationships, couples vary significantly in their capacity to resolve disagreements (e.g., Ridley, Wilhelm, & Surra, 2001). Even newlyweds, despite loving one another, often fail to resolve conflict, leading to long-term declines in relationship satisfaction and dissolution (e.g.,Carrere & Gottman, 1999). Partners may also struggle to communicate support and comfort to one another during stressful times. Even in satisfying relationships, well-intended but miscarried attempts to provide emotional support are common, and may lead to emotional distress, undermined coping, and damage to health (Kessler, et. al., 1985; Wortman & Lehman, 1985). The bereavement literature offers especially poignant examples of miscarried support: individuals who experienced a death in their family rated 80% of supportive attempts by loved ones as unhelpful (Davidowitz and Myrick, 1984), such that well-meaning comments intended to provide support and reassurance (e.g., "It's just a part of life; you can't change the direction of the wind, but you can adjust your sails") were often perceived as insensitive.

Classical Models of Couples' Communication

In light of these challenges, several theories have attempted to dissect how couples' communication processes unfold to influence partner perceptions and relationship quality. In the Intimacy Process Model, for example, Reis and Shaver (1988) described how an intimate connection begins when one person expresses personal feelings or information to another. In order for that interaction to promote intimacy, the response of the listener must make the discloser feel understood, validated, and cared for. Attribution Theory offers a similar perspective, suggesting that all behaviors exchanged between intimate partners not only send a literal message, but also implicitly communicate how an actor defines his or her relationship with the partner (Watzlawick & Beavin, 1967). For instance, though it may not be directly said outright, the way partner A communicates to partner B may include implicit sentiments regarding "how A sees B", "what A wants B to do", "how A wants B to understand him or her", and so on. Orvis, Kelley, and Butler (1976) argue that, for much of the time in intimate communication, partners may be interpreting and explaining each other's behavior by attending to its implicit messaging, which in turn creates, maintains, and reflects mutual partner understanding and attributions.

The Centrality of *Empathy* in Couples' Communication Models

Taken together, the Intimacy Process Model and Attribution Theory both highlight the necessity for partners to mutually recognize and share the feelings and needs of one another. The Intimacy Process Model (Reis & Shaver, 1988) emphasizes care, validation, and understanding between partners. Attribution Theory emphasizes partners' understanding and interpretation of each others' goals and desires (Kelley & Michela, 1980). Central but implicit in both perspectives is the idea of empathy, defined as "*the action of understanding, being aware of, being sensitive to, and vicariously experiencing the feelings, thoughts, and experience of another, without having the feelings, thoughts, and experience fully communicated in an objectively explicit manner*" (Merriam-Webster Staff, 2004). Indeed, the role of empathy in social relationships has long fascinated social scientists, and its presence has been associated with mitigated aggression between peers (Kaukiainen et al., 1999), development of greater emotional intelligence (Thompson, 1987), and more satisfying relationships (Cramer & Jowett, 2010).

The Challenge of Defining Empathy

Despite the relevance of empathy for understanding close relationships, the nature of empathy continues to be a topic of disagreement in the field (e.g., Duan & Hill, 1996). The term "empathy" is routinely used to refer to two separate phenomena: cognitive role taking and affective reactivity to others' distress (Decety & Jackson, 2004). Returning to the dictionary definition, "the action of *understanding and being aware of* another person's experience" may be distinct from "vicariously *experiencing* the feelings, thoughts, and experience of another being" (Merriam-Webster Staff, 2004). For example, Partner A may understand that Partner B is feeling distressed due to a stressful day at work, without also experiencing shared feelings of distress. Researchers have nearly unanimously acknowledged the presence of these distinct empathic constructs and their potential to have varying impacts on relationships and social communication (e.g., Decety & Jackson, 2004; Decety & Lamm, 2009; Duan & Hill, 1996).

Different Empathic Constructs and Potential Consequences for Couples' Communication

Distinct empathic constructs may each have unique consequences for the quality of couples' communication. *Perspective taking*, for example, refers to the cognitive form of empathy, i.e., the attempt to adopt the viewpoints of others (Davis, 1980), and has been assumed to be of vital importance to social interactions and relationships (Cooley, 1930; Foote & Cottrell, 1955). Indeed, social interactions tend to be more successful when people try to understand the perspectives of their interaction partners, and thus anticipate their partners' behaviors and modify their own accordingly (Turner, 1978). While perspective-taking does not reliably predict empathic accuracy (i.e., accurately predicting another person's thoughts, feelings, or mental states) (Eyal, Steffel, & Epley, 2018), perspective-taking has been associated with greater empathic concern (i.e., emotional response of compassion and concern caused by witnessing someone else in need) (Stocks, Lishner, Waits, & Downum, 2011). Specifically, those who focus on attempting to understand another's feelings experience greater empathic concern, which in turn predicts greater attempts to engage in altruistic, helpful, and prosocial behaviors (Oswald, 1996). Perspective taking has also been associated with more positive behaviors and outcomes in intimate relationships. For example, Davis and Oathout (1987) found that greater levels of self-reported perspective taking were associated with readily listening to a partner, along with acts of appreciation and thoughtfulness, which in turn predicted greater relationship satisfaction. Thus, it is likely that the partners who attempt to engage in perspective taking may experience more adaptive and productive conversations with one another. If partners' goals are at odds with one another during conflict, mutual attempts at perspective-taking may elicit feelings of empathic concern between partners, motivating Partner A and Partner B in attempts to better understand one another. Thus, partners may tailor their original goals towards a mutual compromise. In the context of emotional support provision, attempted perspective taking between partners may prompt support providers to better understand a recipient's needs and desires through increased empathic care, aiding their ability to skillfully offer support in such a way that recipients feel understood, validated, and cared for. It may also benefit support recipients to empathize with positive intentions of providers while sharing their own disclosures, as this may reduce the likelihood of a provider's well-meaning supportive attempts to be misinterpreted.

In contrast, *empathic distress* reflects a separate affective facet of empathy that captures internalized feelings of anxiety and unease one may experience in response to a partner's feelings of distress or discomfort (Davis, 1980). Although empathic distress also reflects a form of empathy, it captures the experience of distress in response to another's pain or misfortune, which may undermine effective communication (Davis & Oathout, 1987). Those who experience greater degrees of empathic distress tend to feel helpless in highly emotional situations involving others' pain, as though they may fall apart when another person is facing strife (Davis, 1980). For example, empathic distress is positively associated with feelings of fear, sadness, and discomfort, which predict difficulties with emotion regulation and declines in relationship satisfaction (Lada & Kazmierczak, 2019). Other studies find strong associations between emotional distress and neuroticism, which is known to predict negative relationship outcomes (Mooradian, et. al., 2011; Davis & Oathout, 1987; Eisenberg, et. al., 1994). Empathic distress may be especially maladaptive for couples trying to provide each other with emotional support. Partners may be less likely to feel empathic distress during conflict, given that their frustrations are directed at one another to begin with due to competing goals. On the other hand, conversations about emotional support often involve a one-sided stressor, in which couples discuss a distressing issue or incident that only one partner has experienced. In this vein, empathically distressed partners may be less able to provide support effectively, due to self-focused pain they may experience in response to their partner's distress. Thus conversations surrounding emotional support may require an especially delicate balance: partners must be able to understand each other's goals and intentions, without empathizing in a such a way that their own shared distress in response to each others' pain hinders helping.

Methodological Limitations of Prior Research

These distinct empathic constructs hold the promise of a more refined understanding of the role of empathy in couples' communication, yet progress elaborating on the implications of this distinction has been hampered by methodological limitations in the existing research. To date, the impact of perspective-taking and empathic distress on the quality of couples' communication has been predominantly measured via self-report through the well-established Interpersonal Reactivity Index (IRI), which includes self-evaluative statements such as "*I sometimes find it difficult to see things from the 'other guy's' point of view"* and *"I am usually pretty effective at dealing with emergencies"*(Davis, 1983). Self-reported assessments of empathy may be prone to inaccuracy and bias, for several reasons. First, social desirability biases may prompt participants to respond in ways that present themselves more favorably, given that items regarding perspective-taking tendencies have clear positive connotations and items regarding tendencies towards empathic distress have clear negative connotations. Second, a substantial proportion of the questions from the IRI include items asking participants to evaluate their own thoughts or course of action in hypothetical scenarios. It has been well-documented that respondents' hypothetical evaluations often do not match their actual cognition and behavior in comparable real-world situations (e.g., Burton, Carson, Chilton, & Hutchinson, 2007). Finally, given that the IRI is a global measure of empathic tendencies, it may not be the most optimal measurement tool to predict outcomes within a specific behavioral context (e.g., a social support or conflict interaction). Though such questions may provide insight into where people lean on certain dispositional tendencies, in practice empathy may reflect a fluid internal state, rather than a stable dispositional trait. As such, people may think and behave differently depending on various circumstances they confront and the type of interaction they engage in. Thus, to predict specific behavioral outcomes, it would be preferable to measure how empathic processes unfold in real time within a specific social context.

Existing observational methods may also be limited in their abilities to distinguish between varieties of empathy in couples' communication, for several reasons. First, observational research by definition relies on judgments made by third-party raters. Empathy, however, reflects ongoing cognitive states and appraisals that may not be captured by external observation. Thus, the way partners interpret and experience their own behavioral exchanges may predict variability in relationship outcomes in ways that third-party assessments cannot capture. Second, most observational research on couple communication analyzes global observer ratings that characterize the entirety of an interaction. By focusing on mean level differences in behavioral frequencies, rather than on fine-grained sequential dynamics of communication as they unfold in real time between partners, researchers may be oversimplifying the complex nature of communication in couples. Assessing behavior on a moment-to-moment basis, in contrast, may capture behavioral and affective nuances throughout an interaction that global evaluations may miss. Third, existing observational methods have not been able to directly assess the relationship between cognition and behavior. While empathic states such as perspective taking have been hypothesized to have positive implications for behavior that follows, this assumption has been difficult to test empirically. Developing separate temporal, lagged assessments of both empathy and behavior would aid in the study of how these processes unfold in real time and influence one another to predict the quality of couples' communication.

Empathy in the Brain

Given that empathy represents an internal state that is difficult to fully capture via self-report or external observation, some researchers have turned to neuroimaging methods to study these processes in the brain. With the emergence of social cognitive neuroscience (Adolphs, 2003; Ochsner & Lieberman, 2001), functional neuroimaging studies have begun to identify the neural correlates associated with various aspects of human behavior and cognition. Related to the empathic construct of perspective taking, adopting a third-person perspective (as opposed to a first-person perspective) in domains of action, knowledge, or emotion has been associated with activity in the medial prefrontal cortex (mPFC) (Ruby & Decety, 2001, 2003, 2004). Studies that have investigated neural associations with abilities to infer the mental states of others (i.e., ‘‘theory of mind’’ or ‘‘mentalizing’’) also point to the mPFC along with the temporal parietal junction (TPJ) (*see Figure 1*) as important regions involved in understanding and appreciating the intentions, beliefs, or desires of others (C. D. Frith & Frith, 2006; U. Frith & Frith, 2003; Gallagher & Frith, 2003). Thus, existing research may support the prediction that greater activation in mentalizing regions corresponds with other-oriented understanding and cooperation to promote more effective support provision and conflict resolution in couples.

Figure 1: Anatomical depictions of the medial prefrontal cortex (mPFC) and temporal parietal junction (TPJ)

Given that empathy is thought to be comprised of distinct self-oriented and other-oriented components, some studies have attempted to distinguish between self-oriented feelings of empathic pain from other-oriented empathic care at the neural level. For example, Ashar, Andrews-Hanna, Dimidjian, and Wager (2017) developed fMRI markers predicting moment-by-moment intensity levels of care and distress intensity while participants listened to true biographies of human suffering, and found that empathic care was associated with nucleus accumbens and medial orbitofrontal cortex activity, whereas empathic distress was associated with premotor and somatosensory cortical activity. Thus, existing research may support the prediction that greater activation in somatosensory cortices (*see Figure 2*) corresponds to self-oriented distress in response to a partner's disclosure, possibly hindering partners' capacity to provide emotional support effectively due to self-focused empathic pain for what partners may be experiencing.

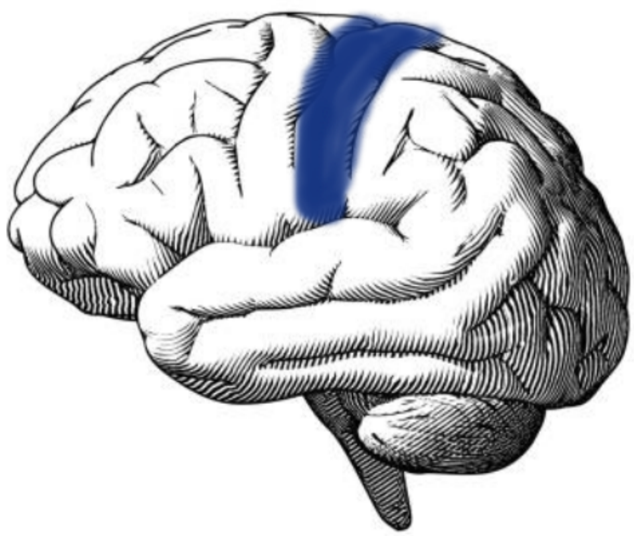

Figure 2: Anatomical depiction of the somatosensory cortex

Understanding Empathy in Couples' Communication through fNIRS

Despite the promise of neuroimaging for distinguishing between forms of empathy, research has yet to examine how various empathic processes unfold during couples' communication, for several reasons. First, traditional neuroimaging methods such as Functional Magnetic Resonance Imaging (fMRI) and Magnetoencephalography (MEG) involve heavy operating equipment that must be fixed in a specific position and location, limiting the mobility needed to study naturalistic interactions. Second, MEG and fMRI imaging methods can typically only scan one participant's brain at a time, and require their heads to remain confined in a small space, further limiting mobility. Third, these methods are highly sensitive to head movement, which is less than ideal for assessing interactions between partners, where occasional head movement is naturally likely to occur. fMRI and MEG are also costly to operate, which may limit statistical power to the extent that fewer participants are able to be scanned.

An emerging technology called functional near infrared spectroscopy (fNIRS) overcomes these limitations to allow for the study of real-time brain dynamics between individuals interacting in real time. fNIRS is a noninvasive neuroimaging device that tracks and records brain activity through the BOLD signal (e.g., the blood oxygen level dependent signal that occurs when localized populations of neurons fire, consume oxygen, and thereby require more oxygen to be pumped to the area in order to continue operating). A protein called hemoglobin delivers the oxygen, which has a different light absorption spectrum compared to the surrounding metabolic compounds and organic tissue. Light in the visible red and near infrared wavelength range from approximately 700-900 nanometers, and is able to pass through skin and bone fairly easily. This light is mostly reflected by hemoglobin, thus fNIRS can detect concentrations of hemoglobin and indirectly measure brain activity by projecting this light into the head and measuring how much is reflected back. [For further detail on the biophysics surrounding fNIRS, see Ferrari, Mottola, and Quaresima (2004) and Scholkmann et al. (2014).]

Unlike comparable imaging methods such as fMRI and EEG, fNIRS can examine the neural underpinnings of psychological processes with reasonably high spatial resolution, while maintaining naturalistic features of social interactions. In addition to being highly affordable with no additional costs for scanning, fNIRS is portable and measures brain activation silently, unobtrusively, and without significant motion sensitivity. Thus, it is an ideal way to scan two people simultaneously during a face-to-face conversation. Using fNIRS, partners can actively communicate with each other as if outside the lab, offering a clearer understanding of internal dyadic processes in context. This new capability thus opens the door for researchers to study the neural correlates of empathic processes between communicating partners in real-time.

Empathy as an Interpersonal Process and the Role of Neural Synchrony

Some researchers view empathy as a process that unfolds in stages such as emotional contagion, identification, and role taking (e.g., Gladstein, 1983; Shamasundar, 1999). Given the dynamic nature of empathy, isolated assessments within separate individuals may be missing important dynamics regarding how cognitive and emotional exchanges *between* individuals contribute to empathic processes. fNIRS may be a particularly useful tool to assess empathy in the brain, given its capability to measure *simultaneous* patterns of brain activation in empathy-related regions between partners as they communicate. To this end, the assessment of *neural synchrony (*i.e., correlated fluctuations across two (or more) people in a particular brain region) has been a growing domain of interest in psychological research (Uhlhaas et al., 2009). Of the many different physiological processes that may covary between partners, neural synchrony in particular has been prioritized and studied as a separate area of research to gain insight into overlap between cognitive and behavioral processes taking place throughout social interactions. As such, assessing neural synchrony in empathy-associated brain regions may lend unique insight into how empathy unfolds through its temporal and interpersonal dynamics in couples' communication.

Neural Synchrony in Couples' Research and Gaps in the Existing Literature

While neural synchrony research is still in its infancy, relationship researchers have become increasingly interested in applying it towards efforts to understand the cognitive and behavioral processes that may contribute to variability in relationship functioning. One of the earliest studies of neural synchrony in couples investigated whether affective communication through facial expressions predicted brain activity between romantic partners and found that ongoing affective facial communication between senders and receivers led to encoding in similar brain networks (Anders, Heinzle, Weiskopf, Ethofer, & Haynes, 2011). Furthermore, there was a clear temporal flow in the communication of affective information between sender and receivers, such that activity in the receiver's brain was delayed relative to activity in the sender's brain. Other studies have evaluated neural synchrony in couples during cooperative motor tasks (Pan, Cheng, Zhang, Li, & Hu, 2017; Tang et al., 2020). For example, lovers performed better on cooperative tasks compared to strangers and friends and displayed greater levels of brain synchrony; moreover, higher levels of brain synchrony were positively correlated with better task performance (Pan et al., 2017). Researchers have also examined the association between levels of neural synchrony and certain social behaviors between couples. For example, Kinreich, Djalovski, Kraus, Louzoun, and Feldman (2017) made the first systematic attempt to map couples' neural synchrony during naturalistic social interactions onto synchrony in gaze and affect and found that neural synchrony was anchored in moments of social gaze and positive affect between partners.

Though existing studies on neural synchrony in couples have offered novel insights to our knowledge of close relationship processes, several notable gaps in the literature remain. First, although these studies are most commonly used to assess associations between brain activity and behavior, no study has yet examined neural synchrony in couples during their most well-studied interactions, i.e., conflict and social support. Second, no study has assessed synchrony between couples in brain regions associated with threat or distress. Given that synchrony has only been examined within positive frameworks to date (e.g., throughout kissing, handholding, and cooperation tasks), it remains unclear whether greater synchrony will consistently predict better relationship outcomes during potentially difficult conversations. Couples may demonstrate greater synchrony in regions associated with pain and threat while discussing a stressful topic, circumstances under which greater neural synchrony in couples may be maladaptive. Distinguishing between different forms of empathy in couples' communication may lend insight into both positive and negative implications of neural synchrony on outcomes of interactions and relationship quality. For example, synchrony in brain areas associated with perspective taking (e.g., mPFC and TPJ regions) may be associated with more adaptive patterns of communication while synchrony in brain areas associated with empathic distress (e.g., somatosentory cortex regions) may be associated with maladaptive communication patterns. Third, although there has been speculation about the associations between brain activity and behavior in couples, most propositions have yet to be tested empirically. For example, a key facet of the Biobehavioral Synchrony Model is that physiological coordination operates in a bottom-up way, triggered by and dependent on the coordination of social action (e.g., motor activity, facial mimicking, or the synchrony of nonverbal interactive signals including shared gaze, joint laugh or mutual expression of positive affect). Thus it is thought that shared behaviors during an interaction may regulate neural synchrony throughout that same interaction (Feldman, 2017), with the underlying assumption that behavioral synchrony may *precede* and *drive* neural synchrony. However, it is also plausible that neural synchrony may precede behavior, such that partners' shared internal states and appraisals may implicitly drive their subsequent behavioral sequence. Furthermore, it is equally plausible that neural synchrony is independent of observable behaviors. In order to empirically test these possibilities, lagged sequential analyses should be conducted throughout to simultaneously measure neural synchrony and behavior, in which behavior at a given point in time can be used to predict fluctuations in neural activity at the following time point, and vice versa.

Overview of the Current Investigation

To distinguish between forms of empathy that may have distinct implications for couples' interactions, and to overcome the limitations of existing research, my dissertation examined the real-time brain dynamics of intimate couples engaging in conflict resolution and support-provision interactions. Across three studies, I measured neural synchrony between partners in regions associated with empathic processes hypothesized to be relevant to emotional support provision (*Study 1*) and conflict resolution (*Study 2*). Synchrony was assessed in two ways: (1) average degrees of covarying brain activation between partners in specific regions across the course of their interaction, as well as (2) moment-to-moment fluctuations in degrees of covariation in brain activity between partners in specific regions throughout their interaction. I also examined the associations between real-time brain dynamics and real-time observationally coded behavior throughout the conflict resolution and social support provision tasks (*Study 3*). This was the first study to measure the association between moment-to-moment internal brain dynamics and moment-to-moment external behavioral patterns between partners as they communicated. This study was also the first that attempted to directly assess empathy in real time as a dialectical, interactive activity involving two parties, in which the role of communication and the broader social context at hand play an important role in its assessment.

Study 1: The Neural Correlates of Empathy in Couples' Conflict Resolution

The primary aim of *Study 1* was to investigate the role of empathy in conflict resolution. Disagreements are a fact of life across many interpersonal relationships (e.g., in marriage, friendships, and across the workplace) (e.g., Ayoko, Callan, & Härtel, 2003; De Wied, Branje, & Meeus, 2007; Fincham & Beach, 1999), where it can be difficult to have meaningful connections with a partner without encountering occasional opposing viewpoints or opinions. The presence of conflict and its downstream consequences is especially salient in intimate relationships, where high interdependence between romantic partners raises the likelihood that competing goals and attitudes will emerge (Rusbult & Van Lange, 2003). To resolve disagreements effectively, empathy has long been viewed as a necessary skill (Klimecki, 2019): understanding and experiencing the attitudes, goals, and intentions of another may be a preliminary step towards fostering the motivation to negotiate and compromise. Thus, a conflict resolution paradigm was an ideal way to assess the role of neural synchrony in regions associated with perspective taking (i.e., attempts to understand the thoughts/intentions of others) on post-communication outcomes and relationship outcomes.

Our measurement of neural regions associated with perspective-taking have distinct advantages over alternative assessments of empathy. For example, a heightened emotional context often surrounds conflict resolution discussions, in which participants may have a difficult time providing accurate self-reports on their own empathic tendencies throughout a conversation. Furthermore, self-report assessments are vulnerable to sentiment override, such that participants may have difficulty teasing apart their empathic tendencies within a specific interaction from their global assessments of themselves and their relationships. Given the newly emerging capability of fNIRS for studying naturalistic, interpersonal dynamics, my study was the first to analyze the real-time brain dynamics underlying the role of empathy in effective conflict resolution in couples. Specifically, the primary aim of Study 1 was to examine whether greater neural synchrony in regions corresponding to perspective taking are associated with more favorable post-conflict outcomes in couples. Toward this end, I examined synchrony between partners in temporal parietal junction (TPJ) and medial prefrontal cortex (mPFC) activity throughout a conflict resolution task. Research with fMRI suggests that these regions constitute the "mentalizing" system, enabling extraction and understanding of other peoples' goals and intentions. Synchronous activation in these regions may correspond to greater partner attempts to understand each other's goals and motivations; thus I predicted that greater activity in these regions would be associated with more positive post-conflict appraisals and post-conflict affect, and greater relationship satisfaction. The secondary aim of Study 1 was to test the robustness of any significant associations between synchrony in mentalizing regions and outcomes of interest by assessing whether they remain significant, over and above self-reported relationship satisfaction and self-reported perspective-taking as additional predictors. Relationship satisfaction was chosen as a control given its wide use as a key predictor and outcome across couples' research (cite). Perspective-taking was chosen as a self-reported matched control of empathy for comparison to my neural assessments of mPFC and TPJ synchrony. If neural synchrony in these regions predicts outcomes over and above these self-report measures, it would lend greater confidence in the strength of our findings.

Method

Sampling

Couples were recruited through flyers posted around the University of California, Los Angeles campus and through the online university study participant recruitment system. Eligibility criteria required that all participants: (a) had been in a relationship for at least 6 months, (b) were at least 18 years of age, (c) were right-handed (a common requirement for neuroimaging studies), and (d) were fluent in English. Each partner received either two course credits or $25 as compensation for their participation.

Participants

Our sample consisted of 56 couples, ranging in age from 18 to 37 years old (M = 21 years old), with an average age difference between partners of approximately 3 months. Couples were in relationships for an average of 24.05 months, where 98.2% were dating and only 1.8% were married. 93% of couples identified as different-gender couples and 7% of couples identified as same-gender couples. No couples in our sample reported having children. 40.2% of participants identified as Caucasian, 26.8% identified as Asian, 1.8% identified as Black, 10.7% identified as Hispanic or Latino, and 19.6% identified as Multiracial or Other (note that percentages add up to greater than 100 because some participants identified as multiracial). 60% of couples were same-race couples and 40% were different-race couples. Regarding educational background, 11% of participants had a high school degree, 58% completed some college credits, 25% had a bachelor's degree, and 6% had a graduate school or post-baccalaureate degree. 86.3% of couples had similar educational backgrounds, whereas 13.6% had different educational backgrounds.

fNIRS Acquisition and Preprocessing

Participants were scanned using a NIRSport2 mobile fNIRS system (NIRx Medical Technologies, LLC, New York, USA). The probe layout was comprised of 16 light sources and 16 detectors with a 3-cm average source-detector separation distance, which forms 42 channels for partial-brain coverage across mentalizing (i.e., mPFC and TPJ) and non-mentalizing regions (i.e., Lateral Prefrontal Cortex and Superior Parietal Lobule, see 'Neural Synchrony' in the 'Measures' section for more information on why these regions were assessed) (*see Figure 3*). This layout was created in accordance with the 10-10 UI external positioning system to ensure consistency across head sizes. Participants had their head sizes measured, and then were fitted with caps that affix the optodes to the scalp. Raw light intensity data was collected at a sampling rate of 5.09 Hz at wavelengths of 760 and 850 nm.

Preprocessing. Collected NIRS data was preprocessed in MATLAB with a customized fNIRS preprocessing pipeline and scripts from the Homer2 software (Huppert, Diamond, Franceschini, & Boas, 2009) in accordance with recommended fNIRS best practices (Yücel, 2021). To remove unrelated data, each time-course was truncated based on a trigger that indicated the start of the conversation. For noisy and oversaturated channels, a modified quartile coefficient of dispersion (Bonnet, 2006) was used to remove any channel that exceeded the coefficient cutoff (C_{thresh} = 0.6 – 0.03*sampling rate) for two seconds or more. Spike artifacts in the raw optical data were removed with a discrete wavelet transform from the Homer2 software (Molavi & Dumont, 2012). After initial motion correction, a bandpass filter window (0.008-0.2 Hz) was used to remove non-cortical activity (e.g., respiration, heart rate, etc.) and baseline drift. We chose a conservative approach for our bandpass filter, compared to a GLM based fNIRS preprocessing pipeline, based on previous work that has shown the cognitive processes of interest in the current work are dominated by low frequency fluctuations (Sasai, Homae, Watanabe, & Taga, 2011; Zuo et al., 2010). Filtered data was then transformed from optical density to hemoglobin concentration values using the modified Beer Lambert Law (MBLL) with a standard differential path length filter [6, 6] for adult cortical light dispersion. A final quality assessment was then run on the preprocessed data by comparing change in autocorrelation before and after removal of possible existing motion artifacts. Any channel that was marked with a change in autocorrelation bigger than r = 0.1 was removed from further analysis with the assumption that the change was due to motion. Recorded fNIRS channels were translated into MNI space using probabilistic modelling (Singh, Okamoto, Dan, Jurcak, & Dan, 2005) to localize the ROIs within a common brain space for ease of comparison to fMRI data and visualization purposes. Once converted to MNI coordinates, ROIs were converted for imaging with xjView (http://www.alivelearn.net/xjview/) and superimposed on a 3D cortical surface with the SurfIce software.

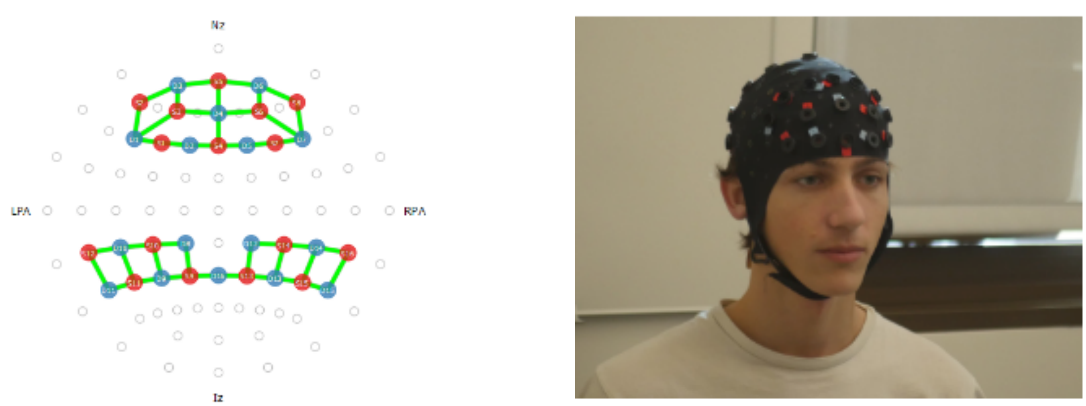

Figure 1. Partial-head layout in the 10-10 system, with 16 sources and 16 detectors comprising 40 data channels.

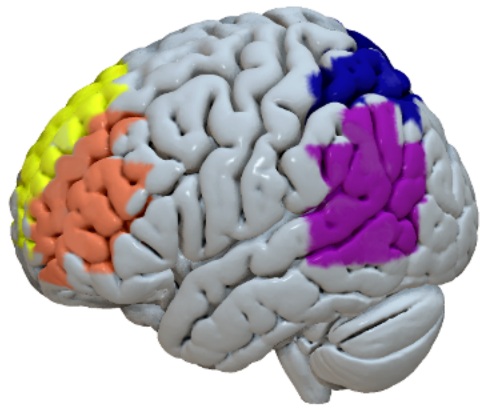

Figure 2. A cortical projection visualizing the mentalizing and comparison ROIs. The mPFC (yellow), lPFC (orange), TPJ (purple), and SPL (blue).

Procedure

Before arriving to the lab for the study session, a background questionnaire assessing individual differences, personal history, and relationship history was administered to participants online to complete at home (*see Appendix*). Upon arrival, participants were provided with an informed consent sheet and participant bill of rights. Next, their heads were measured and then fitted with an appropriately sized stretchy cap, which held the fNIRS optodes against the skull. Couples were then introduced to an overview of their discussion task. During the scanning portion of the study, couples were instructed to *engage in a single discussion together to identify and work through a topic of disagreement that they have not resolved yet*. Couples were first prompted by the experimenter to decide together on a topic to discuss. If partners were unable to do so, they were given a sheet with a list of common disagreements that couples may face in their relationships to help them decide on a topic *(see Appendix)*. Partners discussed their topic for eight minutes, and were instructed not to touch one another physically throughout the conversation. Discussions were unobtrusively videotaped, and both partners' brains were simultaneously scanned throughout each discussion (*see Figure 3*). Preceding each discussion, couples were instructed for fill out a pre-discussion questionnaire assessing their current feelings and expectations for the upcoming conversation (*see Appendix*). Following each discussion, couples were instructed to complete post-discussion questionnaires assessing their immediate feelings and evaluations of the conversation they just had (*see Appendix*).

Figure 3. Example layout of couples being scanned in the lab throughout their discussion.

Measures

Neural Synchrony

Inter-subject Correlations (ISC). As one measure of neural synchrony, inter-subject correlation (ISC) analyses were conducted separately for each dyad in the pre-selected regions of interest (ROI) consisting of channels corresponding to mPFC and TPJ activity as our key mentalizing regions of interest. Based on previous fNIRS work (Pan, Cheng, Zhang, Li, & Hu, 2017) that has found oxyhemoglobin (HbO) concentrations to be more sensitive to change in cerebral blood flow compared to deoxyhemoglobin (HbR), primary analysis of neural data is reported in reference to HbO. Neural synchrony in the two other ROIs corresponding to lateral prefrontal cortex (lPFC) and superior parietal lobule (SPL) were also assessed as comparative control regions. Both mentalizing ROIs are primarily associated with distinct cognitive processes from the mPFC and TPJ, making them ideal to comparatively examine to eliminate the alternative explanation that any region of the brain may be associated with the same outcomes. Specifically, lPFC activity is primarily associated with working memory and reasoning (Rottschy et al., 2012) while SPL activity is primarily associated with sensorimotor integration and visual attention and perception, together these two areas are often referred to as the frontoparietal network or analytic network (Lee et al., 2006).

To assess the synchrony of each brain region within a dyad, ISC values were computed using Pearson correlations between conversation partner's time-courses and ISC values were compared against a correlation of 0 in dependent-sample t-tests. To control the false discovery rate while avoiding an overconservative rejection approach, p-values were FDR-corrected with a q criterion of 0.10 (Benjamini, Krieger, & Yekutieli, 2006). Channels loss due to oversaturation or excessive movement is often inevitable with fNIRS study. As such, to ensure reliability of synchrony findings if channel loss was >25% for a specific ROI within a given couple, their synchrony data for that ROI was omitted from further analysis. All ISC values were transformed into Fisher's z-statistic before averaging or performing any parametric tests. Note that given this study examined the impact of synchrony on time-invariant outcomes (i.e., self-report outcomes), thus I did not utilize a moment-to-moment measurement of synchrony in this study. Lagged measurements assess the single contribution of each lagged measurement occasion on the outcome at a following time-point (see Wang, Hamaker, & Bergeman, 2012). Given that self-reported outcomes do not change over time, there was no variability to capture.

Self-report Predictor

Perspective-taking. Using items from the Brief Interpersonal Reactivity Index (B-IRI) (Ingoglia, Lo Coco, & Albiero, 2016), self-reported perspective taking was measured with seven items assessing the degree to which partners report they are able to adopt an understanding of others' point of view (e.g., "*I try to look at everybody's side of a disagreement before I make a decision.") (See Appendix for complete measure).* Items were rated on a 5-point scale (*1 = does not describe me well at all* to *5 = describes me very well*). Scores on the seven items were averaged for each participant. On average, both women and men reported moderate levels of perspective taking with some variability (M = 3.60, SD =0.73 for men; M = 3.84, SD =0.68 for women). Alphas of .84 for women and .81 for men support reliability of the measure.

Self-Report Outcomes

Outcomes of conflict resolution efficacy were assessed in four ways, as highlighted below. The first three assessments highlight partners' personal evaluations of how the discussion went, their immediate feelings following the discussion, and how close they felt to their partners after the discussion. The final assessment highlights post-discussion evaluations rated by third-party observers.

Post-conflict Appraisals. Using adapted items from the Florida Newlywed Project on Adult Development (McNulty & Karney, 2002), partners' evaluations of the discussion were measured with 11 items assessing the degree to which participants felt satisfied with the discussion they had with their partners (e.g., "*I feel satisfied with how the conversation went; "The conversation helped me and my partner work on our issues").* Targets' evaluations of their partners' behavior during conflict were assessed through 19 additional items inquiring the extent to which targets agreed with specific statements about their partner (e.g., *"During the conversation, my partner behaved positively towards me)* (*see Appendix*). Finally, targets' evaluations of their own behavior during conflict were assessed through another additional 19 items inquiring the extent to which targets agreed with specific statements about themselves (e.g., *"During the conversation, I behaved positively towards my partner"*) (*see Appendix*). Altogether, items across this 49-item measure were scored on a seven-point scale (*1 = not at all* to *7 = extremely*) and averaged for each participant. On average, both women and men reported favorable evaluations of the discussion they had with variability (M = 5.40, SD = 0.72 for men; M = 5.61 SD = 0.76 for women). Alphas of .95 for both women and men support reliability of the measure.

Relationship Quality. Relationship satisfaction, operationalized as partners' global sentiment towards the relationship, was assessed using a combined measure of the Couple Satisfaction Index version 4, Couple Satisfaction Index version 16, and Quality Marriage Index (Funk & Rogge, 2007; Norton, 1983). This combined version is a 12-item measure of satisfaction, with higher scores indicating higher levels of satisfaction. The items assess global satisfaction (e.g., *"I have a good relationship"*) and were rated on a 5 to 7-point Likert scale. Scores on the 12 items were averaged for each participant. On average, both women and men reported high levels of satisfaction in their relationships with ample variability (M = 5.25, SD = 0.76 for men; M = 5.36, SD = 0.67 for women). Alphas of .93 for women and .95 for men support reliability of the measure.

Post-Conflict Evaluations by Independent Raters

Post-discussion evaluations were also assessed through ratings made by independent observers after viewing the videotaped discussions, where outcomes of these interactions were assessed as highlighted below.

Raters' Post-Conflict Appraisals. Mirroring the measure of post-discussion appraisals including items from the Florida Newlywed Project on Adult Development completed by participants (McNulty & Karney, 2002), this measure was adapted to be completed by third-party raters after viewing the videotapes (*see Appendix for complete measure*). For this version, ten items first assessed the degree to which raters felt that participants had a satisfying discussion, understood their partner's point of view, and were able to resolve their disagreements (e.g., "*The target felt satisfied with how the conversation went"; "The conversation was productive").* Items were scored on a seven-point scale (*1 = not at all* to *7 = extremely*). Following these items, raters also made an overall global assessment of the interaction through one additional item (i.e., *"Overall, what is your evaluation of the target's degree of connection to their partner throughout the conversation?"*), scored on a 6-point scale (*1 = extremely disconnected* to *7 = extremely connected*). Three or more raters completed this 11-item measure for each participant and their interrater reliability was calculated for each item, ranging from 0.67-0.97 with an average interrater reliability of 0.79 across all items (see *Appendix* for specific interrater reliabilities of each separate item). Following interrater reliability calculations, scores were averaged across all raters for each item. On average, observers had moderately favorable evaluations of the discussions across both men (M = 3.40, SD = 1.18) and women (M = 3.50, SD = 1.13), with ample variability. Reliability for internal consistency across the 11 items was also assessed, where alphas of 0.98 for both men and women support reliability of this measure.

Analytic Plan

Data corresponding to all aims in this study were analyzed using multilevel modeling (MLM). Across all analyses, both partners from each couple were included in the same model to account for interdependence in the dyadic data. All variables in the model were first z-scored to ensure measurement on comparable scales. Analyses were conducted in SAS version 9.4 using the Proc Mixed procedure.

Revisiting Aim 1

Do greater degrees of neural synchrony in mentalizing regions correspond with partners' post-conflict assessments, relationship satisfaction, and third-party observer ratings?

Aim 1a Analyses: Indistinguishable Dyads Across the Entire Sample

Between-person models were utilized to test whether greater degrees of average synchrony in mentalizing regions predict more positive self-reported post-discussion evaluations, greater relationship satisfaction in study participants, and more positive ratings of the interaction by observers. *Equation 1* depicts an example of the model structure corresponding to this analysis for the outcome of partners' post-conflict appraisals.

Equation 1

Level 1:

$$\text{Post\_Conflict Appraisals}_{id} = \pi_{0d} + e_{id}$$

Level 2:

$$\pi_{0d} = \beta_{00} + \beta_{01}(\text{mPFC synchrony}) + u_{0d}$$

This model utilizes a single-intercept approach, in which the intercept for post-conflict appraisals of an individual "i" in a given dyad "d" is a function of each dyad's initial level of post-conflict appraisals ($\text{Post Conflict Appraisals}_{id}$), in addition to their intra-individual model error (e_{id}). At Level 2, each dyad's initial level of post-conflict appraisals (π_{0d}) is a function of the sample average intercept (β_{00}), controlling for between-dyad differences in neural synchrony (β_{01}) and between-dyad random error (u_{0d}). In this model, if "β_{01}" is significant, greater synchrony in mentalizing regions in dyads is associated with more positive post-conflict appraisals in partners. The decision to implement a single-intercept model stems from the conceptualization of partners as indistinguishable dyads, in which neither partner took on a distinct role from one another while discussing their area of shared conflict. Contrary to common practice in couples' research, couples were not distinguished based on gender because same-gender couples participated in *Study 1*. However, the interdependence between partners within couples was still accounted for through controlling for dyadic variability at Level 2.

Aim 1b Analyses: Distinguished Dyads Based on Gender

As previously addressed, I did not choose to distinguish couples on the basis of gender when analyzing our full sample of couples because there were same-gender couples that participated, for which a gender distinction would not apply. However, much of the existing couples' literature point out differences between how men and women engage in communication tasks (e.g., women have greater tendencies towards demanding behavior while men have greater tendencies towards withdrawal on average) (e.g., Klinetob & Smith, 1996). Considering these previous findings, I also chose to analyze a subset of only different-gender couples to examine whether the associations between neural synchrony and discussion-related outcomes may differ between men and women. To distinguish dyads based on gender, between-person *dual-intercept* *models* were implemented within a subset of only different-gender couples to examine associations between synchrony in brain regions of interest and post-conflict and relationship outcomes. Using this approach, separate intercept estimates were obtained for men and women. These intercepts were obtained by dummy coding male (M) and female (F) roles at Level 2, such that $M = 0$ and $F = 1$ when the individual female; and $M = 1$ and $F = 0$ when the individual is male. *Equation 2* depicts an example of the model structure corresponding to this analysis investigating the effect of mPFC synchrony on partners' post conflict appraisals.

Equation 2:

Level 1: (*Eq. 2)*

$$\text{Post-Conflict Appraisals}_{id} = \pi_{0d} + e_{id}$$

Level 2 (2-intercept approach):

$$\pi_{0d} = P^*[\beta_{00} + \beta_{01}(\text{mPFC synchrony}_d) + u_{0d}] + R^*[\beta_{02} + \beta_{03}(\text{mPFC synchrony}_d) + u_{1d}].$$

Within this model, β_{00} and β_{02} were, respectively, between-dyad intercepts for men and women. β_{01} and β_{03} were, respectively, between-dyad slopes for men's and women's mentalizing synchrony. After controlling for all other variables in the model, covariance estimates for baseline post-conflict appraisals were reflected through u_{0d} and u_{1d}, respectively, whereas correlated error *within* dyads is modeled in the Level 1 error term (e_{id}). Coefficient estimates for β_{01} and β_{03} tested my predictions on the associations between dyadic synchrony on partners' post-discussion outcomes.

Revisiting Aim 2

Is neural synchrony in mentalizing regions associated with the same outcomes, over and above partners' self-reported perspective taking and relationship satisfaction?

Aim 2a Analyses: Indistinguishable Dyads Across the Entire Sample

To address Aim 2, analogous single-intercept *between-person* models were used to test the hypothesis that neural synchrony in mentalizing regions predicts post-conflict outcomes, over and above partners' self-reported perspective-taking and relationship satisfaction. This model is identical to the prior model, with one exception: to test the "over and above" effect of neural synchrony, between-dyad differences in partners' self-reported perspective-taking (PT_{id}) were included as an additional predictor entered first in the model. *Equation 3* depicts an example of the model structure corresponding to this analysis with perspective taking as the control variable.

Equation 3:

Level 1:

$$Post\_Conflict\ Appraisals_{id} = \pi_{0d} + e_{id}$$

Level 2:

$$\pi_{0d} = \beta_{00} + . + \beta_{01}(PT_{id} - PT_{.}) + \beta_{02}(mPFC\ synchrony_{d}) + u_{0d}$$

Most general multilevel models include coefficients from first-stage analyses (i.e., intercepts and slopes), which can vary from group to group. However, Kenny, Kashy, and Cook (2020) assert that with dyadic data, slopes must be constrained to be equal across all dyads because dyads do not have enough lower-level units (i.e., members) to allow for slopes to vary between them. Dyad intercepts, in contrast, may vary, which accounts for how non-independence in members' scores is modeled. Thus, the Level 1 error term (e_{id}) controls for correlations between each dyad member's self-reported perspective taking, by accounting for the correlation between each partner's error. In sum, there is not enough variability to model within-dyad variability at Level 1 with only two dyad members per group, so the Level 1 error term accounts for the fact that each partner's errors will be correlated.

If β_{02} remains significant even after controlling for β_{01}, this model would indicate that the effect of synchrony in mentalizing regions predicts post-support outcomes, over and above partners' self-reported perspective-taking and relationship satisfaction, testing my hypothesis.

Aim 2b Analyses: Distinguished Dyads Based on Gender

Once more, analogous dual-intercept *between-person* models were used to test the hypothesis that neural synchrony in mentalizing and somatosensory regions predicts post-conflict outcomes in men and women, over and above their self-reported perspective-taking, empathic distress, and relationship satisfaction using a subset of data with only different-gender couples. *Equation 4* depicts an example of the model structure corresponding to this analysis with separate intercept estimates for men and women, where the same coefficients as the ones mentioned above test my hypotheses.

Equation 4:

Level 1:

$$\text{Post-Conflict Appraisals}_{id} = \pi_{0d} + e_{id}$$

Level 2 (2-intercept approach):

$\pi_{0d} = M*[\beta_{00} + \beta_{01}(relsat_{.id}) + \beta_{02}(PT_{id}) + \beta_{03}(PD_{id}) + \beta_{04}(mPFC\ synchrony_{d}) + u_{0d}] +$

$F*[\beta_{05} + \beta_{06}(relsat_{id}) + \beta_{07}(PT_{id}) + \beta_{08}(PD_{id}) + \beta_{09}(mPFC\ synchrony_{d}) + u_{1d}].$

Results

Preliminary Analyses and Descriptive Statistics

Table 1 displays descriptive statistics and bivariate correlations among the couple-level neural synchrony predictors. Synchrony values in each region were small and modestly correlated as expected, aside from a stronger correlation between mPFC synchrony and lPFC synchrony ($r = 0.71$), with substantial variability in average degrees of synchrony across different couples. As indicated by the 'Couple N' column, signal loss for specific channels associated with each brain region did not exceed 25% for most couples, lending confidence in statistical power for upcoming data analyses.

Table 1: Correlations and Descriptive Statistics of Couple-level Neural Synchrony Predictors in Conflict

Variable	(1)	(2)	(3)	(4)	Couple N	Couple Mean	Couple SD
(1) mPFC Synchrony		0.49**	0.71***	0.37**	47	0.03	0.15
(2) TPJ Synchrony			0.49**	0.52**	49	0.01	0.12
(3) lPFC Synchrony				0.18	48	0.03	0.16
(4) SPL Synchrony					37	0.01	0.15

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2 displays descriptive statistics and bivariate correlations for participants' self-report assessments and third-party observer ratings in partners as indistinguishable dyads, while *Table 3* displays these same metrics for couples distinguished by gender. As expected in a sample of young, unmarried couples, mean reports of post-conflict appraisals and relationship satisfaction were moderately high with substantial variability regardless of how partners were distinguished. Compared to mean self-reported post-conflict appraisals, mean observer ratings of the conflict discussions were modestly lower. On average, reports of post-conflict positive affect were moderately low and reports of post-conflict negative affect were even lower, with variability.

Correlations between different self-report variables were in expected directions for both partners regardless of how dyads were distinguished. Specifically, relationship satisfaction, post-conflict appraisals, and post-discussion positive affect were modestly to strongly positively correlated with one another, and negatively correlated with post-conflict negative affect, lending confidence that all self-report measures were performing as expected. Observer ratings were positively associated with self-reported post-conflict appraisals and relationship satisfaction, and negatively associated with negative affect. This indicates a degree of general consistency between observer ratings and self-report ratings, though the strength of associations between observer and self-report measures are weaker than associations between self-reported measures themselves. Partners reported modestly high degrees of self-reported perspective taking, which was significantly positively associated with post-discussion appraisals and relationship satisfaction. However, perspective taking was not strongly associated with observer ratings. This may be a reflection of shared method variance commonly observed between self-reported predictors and outcomes (LaGrange & Cole, 2008), in which partners who *perceive themselves* as good perspective-takers are likely to also perceive more positive post-discussion outcomes and evaluations of their relationships, in part due to sentiment override (Hawkins, Carrère, & Gottman, 2002).

Table 2: Correlations and Descriptive Statistics of Continuous Self-report Variables in Conflict for Partners in Indistinguishable Dyads

Variable	(1)	(2)	(3)	(4)	(5)	(6)	Partner 1 N	Partner 1 Mean	Partner 1 SD
(1) Post-Conflict Appraisal		0.61***	-0.50**	0.37**	0.32*	0.54***	55	5.51	0.81
(2) Positive Affect	0.56***		-0.47**	0.35**	0.13	0.24	56	2.78	0.83
(3) Negative Affect	-0.23	-0.21		-0.26	-0.03	-0.28*	56	1.45	0.53
(4) Relationship Satisfaction	0.47***	0.23	-0.04		0.25	0.34*	56	5.27	0.73
(5) Perspective Taking	0.41**	0.08	-0.07	0.30*		0.27	56	3.76	0.73
(6) Post-Conflict Observer Ratings	0.62***	0.29*	-0.08	0.30*	0.21		54	3.49	1.16
Partner 2 N	51	52	52	52	52	48			
Partner 2 Mean	5.64	2.91	1.35	5.35	3.70	3.37			
Partner 2 SD	0.65	0.81	0.37	0.71	0.70	1.12			

Note: Though analyses collapse across all individuals as indistinguishable dyads, partner 1 and partner 2 descriptive data are shown separately above (partner 1) and below (partner 2) the diagonal to ensure unbiased r-values for correlation estimates. * *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

Table 3: Correlations and Descriptive Statistics of Continuous Self-report Variables in Conflict for Partners Distinguished by Gender

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**Male N**	**Male Mean**	**Male SD**
(1) Post-Conflict Appraisal		0.63***	-0.14	0.42**	0.29*	0.58***	51	5.48	0.72
(2) Positive Affect	0.61***		-0.32*	0.40**	-0.01	0.28	51	2.82	0.80
(3) Negative Affect	-0.58***	-0.41**		0.01	0.12	0.02	52	1.39	0.37
(4) Relationship Satisfaction	0.43**	0.25	-0.37**		0.08	0.28	52	5.25	0.76
(5) Perspective Taking	0.37**	0.21	-0.16	0.34*		0.29*	52	3.60	0.73
(6) Post-Conflict Observer Ratings	0.54***	0.28	-0.30*	0.42**	0.19		48	3.40	1.18
Female 1 N	51	52	52	52	52	48			
Female 1 Mean	5.61	2.87	1.44	5.38	3.85	3.44			
Female SD	0.76	0.87	0.54	0.56	0.66	1.18			

Note: Values for men are above the diagonal and below the diagonal for women. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Prior to analysis of neural data, separate models were run as a validity check on our self-report control variables of perspective-taking and relationship satisfaction to examine their independent effects on self-report outcomes. These models were run across indistinguishable dyads using the entire sample and in a subset of different-gender dyads distinguished by gender. As expected, there was a significant main effect of self-reported perspective taking on partners' overall post-conflict appraisals, such that reports of greater perspective taking predicted more favorable post-conflict evaluations ($t = 3.01^{**}$, $SE = 0.07$). Greater perspective-taking was also significantly associated with better relationship satisfaction ($t = 2.17^{*}$, $SE = 0.08$). No associations were found between perspective-taking and post-discussion affect. In dyads distinguished by gender, the same effect emerged significantly for women ($t = 2.12^{*}$, $SE = 0.12$) where reports of greater perspective taking also predicted more favorable post-conflict evaluations. No significant associations were found between perspective-taking and relationship satisfaction, or post-discussion affect across the board. As expected, greater relationship satisfaction was significantly associated with more favorable post-conflict evaluations ($t = 2.73^{**}$, $SE = 0.09$), greater post-conflict positive affect ($t = 2.99^{**}$, $SE = 0.09$), and greater observer evaluations of partners' behaviors ($t = 2.42^{*}$, $SE = 0.08$). Primarily as expected, in dyads distinguished by gender, greater relationship satisfaction was significantly associated with more favorable post-conflict evaluations across men ($t = 2.02^{*}$, $SE = 0.11$) and women ($t = 2.09^{*}$, $SE = 0.14$), greater post-discussion positive affect in men ($t = 2.73^{**}$, $SE = 0.13$), less post-discussion negative affect in women ($t = -3.16^{**}$, $SE = 0.17$), and more favorable observer evaluations of women's behavior ($t = 2.82^{**}$, $SE = 0.13$).

Aim 1a: Neural Synchrony in Partners' Mentalizing Activity and Post-Discussion Evaluations in Couples as Indistinguishable Dyads.

To address these associations, separate single-intercept models were run with all couples included to examine the main effects of neural synchrony in regions associated with mPFC and TPJ on self-reported relationship satisfaction, self-reported post-discussion evaluations, and observer evaluations, controlling for dyadic interdependence. No associations were found between mPFC synchrony and any outcomes of interest. However, contrary to predictions, greater synchrony in channels associated with TPJ activity significantly predicted *less* favorable post-conflict evaluations ($t = -2.04$, $SE = 0.13$*) (see *Table 3*, *Model 1*). No associations were found between TPJ synchrony and other outcomes of interest, and no significant associations were found between our control synchrony regions (i.e., lPFC and SPL synchrony) and any outcomes.

Aim 1b: Neural Synchrony in Partners' Mentalizing Activity and Post-Discussion Evaluations in Couples Distinguished by Gender.

To address these associations, dual-intercept models were run in a subset including only different-gender couples to examine the same associations as above, with partners distinguished by gender while controlling for their dyadic interdependence. Once more, there were no associations found between mPFC synchrony and any outcomes of interest. Greater synchrony in channels associated with TPJ activity marginally predicted less favorable post-conflict evaluations in women only ($t = -1.91$, $SE = 0.16$, $p = 0.06$). Regarding findings for control regions, greater synchrony in channels associated with SPL activity also marginally predicted less favorable post-conflict evaluations for only women ($t = -1.92$, $SE = 0.16$, $p = 0.06$).

Aim 2a: Associations between Neural Synchrony in Partners' Mentalizing Activity and Post-Discussion Evaluations, Over and Above Relationship Satisfaction and Self-Reported Perspective-Taking in Couples as Indistinguishable Dyads.

To address this aim, an additional single-intercept model was run across all couples to assess the robustness of the significant negative association between TPJ synchrony and post-discussion evaluations. As further depicted in *Table 3*, Model 2 below tested this association with relationship satisfaction entered first as a control variable followed by perspective-taking and then neural synchrony. Controlling for these variables, the negative association between TPJ synchrony and post-discussion partner evaluations became marginally significant and remained in the expected direction ($t = -1.93, p = 0.06$).

Aim 2b: Associations between Neural Synchrony in Partners' Mentalizing Activity and Post-Discussion Evaluations, Over and Above Relationship Satisfaction and Self-Reported Perspective-Taking in Couples Distinguished by Gender.

To address this aim, an additional dual-intercept model was run across the subset of only different-gender couples to also assess the robustness of the significant negative association between TPJ synchrony and post-discussion evaluations., over and above relationship satisfaction and perspective-taking. Controlling for these variables, the marginally significant negative association between TPJ synchrony and post-conflict evaluations for women disappeared.

Table 3: Statistical models of associations between TPJ synchrony and post-discussion partner evaluations (Model 1), controlling for relationship satisfaction and perspective-taking (Model 2) in couples as indistinguishable dyads.

Model 1

Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper
Intercept	-0.07(0.13)	-0.49	-0.33	0.20
TPJ Synchrony	-0.27(0.13)*	-2.04	-0.53	-0.003

Model 2

Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper
Intercept	-0.05(0.11)	-0.44	-0.28	0.18
Relationship Satisfaction	0.24(0.09)*	2.60	0.06	0.43
Perspective-Taking	-0.18(0.08)*	2.22	0.02	0.34
TPJ Synchrony	-0.22(0.11)	-1.93	-0.44	0.001

Discussion

Despite the importance of communication for healthy relationship functioning and maintenance, partners often find it difficult to communicate constructively. Empathy has been theorized to be a key facet for predicting the quality of communication, yet it has been difficult to assess in prior research due to response biases associated with self-report measures and the impossibility of using third-party observers to assess partners' internal empathic states.

Key Findings and Implications

To overcome these challenges, this study was the first to analyze real-time dynamics in brain regions associated with empathy while couples engage in conflict discussions. Specifically, we assessed whether greater average degrees of neural synchrony in channels associated with mPFC and TPJ activity between partners predicted their own post-conflict appraisals, post-conflict affect, relationship quality, and post-conflict observer ratings.

Contrary to predictions, greater average synchrony in TPJ activity between partners was significantly associated with *less* favorable perceptions of partners' behaviors during conflict. Though the mPFC and TPJ are commonly referred to as the mentalizing system to imply their function as a unit (Koster-Hale et al., 2017), imaging studies suggest that these regions are associated with attempts to infer others' perspectives through differing mechanisms. A wealth of neuroimaging studies suggests that activity in the mPFC is associated with attempts to understand the mental state of others through self-reflection and introspection (e.g., Mitchell, Banaji, & Macrae, 2005; Somerville & Casey, 2010). In contrast, studies suggest that TPJ activity is associated with attempts to view a situation similarly to others through making attributions about their intentions and beliefs, without the added component of self-knowledge or self-reflection (Saxe & Powell, 2006; Saxe, Schulz, & Jiang, 2006). Thus, it is possible for greater synchrony in channels associated with TPJ activity to simply reflect that partners view one another and their conflict in a similar, shared light, which could be helpful or harmful towards how couples communicate depending on the nature of their shared view. For instance, negative shared views of the conflict at hand through mutual frustration or resentment (which often occurs in conflict when partners have goals that are at odds with one another) will likely lead to less effective communication compared to positive shared views. Therefore, it may be that the associations between TPJ synchrony and behavioral outcomes could depend on both a) the context of the interaction at hand (e.g., a conflict interaction where partners view the situation in a shared positive vs. shared negative light), as well as b) the type of interaction taking place to begin with (e.g., resolving conflict vs. providing encouragement). Considering these possibilities, future research should examine the role of neural synchrony in mentalizing regions on outcomes of interest throughout various communication tasks (e.g., within a social support paradigm in addition to conflict).

Furthermore, neural synchrony in channels associated with mPFC activity did not significantly predict any post-conflict outcomes and the significant finding for TPJ activity became marginal after controlling for self-reported perspective-taking and relationship satisfaction. Given that we examined a sample of young, highly satisfied couples who were unmarried and without children, most partners generally rated their discussions favorably and were largely favorably assessed by third-party observers as well. Though there was some variability, even wider variability in the quality of conflict discussions across couples may have been needed to a) detect potential associations between mPFC synchrony and post-conflict outcomes, as well as to b) determine whether the negative association between TPJ synchrony and post-outcomes will replicate and remain robust. Thus, future research should examine the impact of neural synchrony in conflict across a more diverse sample of married couples who may share conflicts that are greater in severity (e.g., finances, in-laws, children, etc.), in which greater variability in the quality of their discussions will be likely to emerge.

Strengths and Limitations

Our confidence in the findings of this study is enhanced by some strengths in its methodology and design. First, our neural assessment of empathy overcomes existing challenges of self-report and observational methods, such as social desirability biases, sentiment override, and the inability to capture ongoing cognitive states and appraisals through third-party observation alone. Second, through using fNIRS we were able to study couples' conflict in a way that preserved naturalistic features of how conflict interactions organically take place whereas this would not be feasible with other imaging methods. Third, assessing observer ratings in addition to partners' self-reported post-conflict outcomes provided a direct comparison between the types of outcomes that brain synchrony may be more closely associated with (i.e., internal subjective appraisals versus external observable behavior). Fourth, our additional assessments of lPFC synchrony and SPL synchrony as control regions accounted for the potential alternative explanation that synchronous activity in any part of the brain is similarly associated with the same outcomes.

Notwithstanding these strengths, limitations of this study also require that these results should be interpreted with some caution. First, neural synchrony was calculated as singular overall average synchrony values, in which potentially interesting nuances in degrees of synchrony throughout the interaction may get cancelled out. Second, our study of exclusively young dating couples without children limits the generalizability of our findings. Future studies should extend our work by studying more established, long-term couples, in which even greater variability in conflict resolution strategies and relationship quality are likely to emerge. Third, this study only assesses synchrony in regions corresponding to one hypothesized unit (i.e., mentalizing) within only one specific type of interaction (i.e., conflict resolution). Future studies should extend our work by studying and comparing synchrony in multiple regions of the brain within different social contexts.

Conclusion

This study was the first to ever examine links between neural synchrony in regions associated with empathy and the quality of conflict resolution in couples. Our findings provide preliminary evidence to suggest that synchrony in TPJ activity may be maladaptive within certain social contexts such as conflict, in which a shared negative perspective on a situation is more likely to emerge. To further our knowledge regarding associations between neural synchrony in empathy-related regions and relationship functioning, future research should consider examining these associations across diverse couples throughout a wider variety of social contexts.

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Study 2: The Neural Correlates of Emotional Support Provision in Couples

While *Study 1* examined the role of empathy in the form of perspective taking in the context of conflict resolution, *Study 2* expands on *Study 1* by examining and comparing the effects of two forms of empathy (perspective-taking and empathic distress) in emotional support discussions. Exchanging emotional support is a basic process in close relationships. Receiving emotional support is a major determinant of personal wellbeing (Reblin & Uchino, 2008), predicting more adaptive stress management, improvements in global health, and faster recovery from illness (Sarason & Sarason, 2001). Emotional support has also been linked to better relationship outcomes, including greater relationship satisfaction, better conflict-resolution skills, and a decreased likelihood for relationships to dissolve or end in divorce (Cutrona, 1996).

Despite the importance of emotional support provision for individual and relationship functioning, providing support *effectively* can pose a significant challenge. Why can it be so difficult to console others successfully, despite good intentions? Communicating support effectively may require a delicate balance, where partners should attempt to understand each other's needs, while not empathizing in such a way that their shared emotional distress hinders helping (Bloom, 2017; Ryan, 2018). In other words, it may require emphasizing certain empathic processes (e.g., perspective taking and attempting to understand the other person) while inhibiting others (e.g., internalizing another's distress as one's own distress). Considering the theoretical tension between the functions of perspective taking and empathic distress on the potential efficacy of consolation, implementing an emotional support paradigm was an ideal way to assess the impact of different forms of empathy on the quality of communication in couples.

To date, behavioral research on emotional support processes has been limited by reliance on a narrow range of assessment methods. For example, self-report measures and observational data can identify supportive behaviors that benefit relationships (i.e. positive affect, concern, & cooperation), but neither of these methods are able to tease apart the cognitive mechanisms that may underlie such behaviors. To overcome these limitations, my study was the first to analyze the real-time brain dynamics underlying the role of empathy in emotional support provision in couples. Specifically, I examined neural synchrony in regions corresponding to two empathic processes that may account for variability in effective emotional support. As in *Study 1*, I first examined synchrony between partners in temporal parietal junction (TPJ) and medial prefrontal cortex (mPFC) activity on post-support outcomes. Activation in these regions may correspond to greater attempts between partners to reach an understanding (e.g., D'Argembeau et al., 2007), and therefore I predicted that greater synchrony in these regions should be associated with more positive post-support appraisals, better relationship quality, and more positive observer assessments of the discussions. Second, I also examined synchrony between partners in somatosensory cortex activity. A recent imaging study suggests that activity in this region is associated with empathic distress in response to negative emotion, but is not associated with empathic care (Ashar et al., 2017). In this case, synchronous activation of the somatosensory cortex may correspond to greater shared distress between partners and hinder abilities to remain partner-centered and helpful, leading to reduced support efficacy. Therefore, I predicted that greater synchrony in this region will be associated with more negative post-support appraisals, poorer relationship quality, and less positive observer assessments of support providers and recipients. Analogous to Study 1, the second aim of Study 2 was to test the robustness of any significant associations between synchrony in brain regions and outcomes of interest by assessing whether they remain significant, over and above any associations with self-reports of relationship satisfaction, perspective-taking, and empathic distress. Relationship satisfaction and perspective-taking were chosen as control variables for analogous reasons to why they were utilized in Study 1. For study 2, I chose to examine empathic distress as an additional control variable given that it assesses empathic distress via self-report and can be compared to neural assessments of somatosensory cortex synchrony.

Method

Sampling

Couples were recruited through flyers posted around the University of California, Los Angeles campus and through the online university study participant recruitment system. Eligibility criteria required that all participants: (a) had been in a relationship for at least 6 months, (b) were at least 18 years of age, (c) were right handed (a common requirement for neuroimaging studies), and (d) were fluent in English. Each partner received either two course credits or $25 as compensation for their participation.

Participants

Our sample consisted of 52 couples, ranging in age from 18 to 30 years old (M = 21 years old), with an average age difference between partners of approximately 2.4 months. Couples were in relationships for an average of 24.12 months. 98.1% were dating and only 1.9% were married. 90.4% of couples identified as different-gender couples and 9.6% of couples identified as same-gender couples. No couples in our sample reported having children. 40.4% of participants identified as Caucasian, 44.2% identified as Asian, 2.9% identified as Black, 31.7% identified as Hispanic or Latino, and 25% identified as Multiracial or Other (note that percentages add up to greater than 100 because some participants identified as multiracial). 71% of couples were same-race couples and 29% were different-race couples. Regarding educational background, 16.3% of participants had a high school degree, 59.6% completed some college credits, 26% had a bachelor's degree, and 6.7% had a graduate school or post-baccalaureate degree. 62% of couples had similar educational backgrounds, whereas 38% had different educational backgrounds.

fNIRS Acquisition and Preprocessing.

See Study 1. The only difference from Study 1 was that in Study 2, the Visual Area (VA) activity was assessed instead of SPL activity as a comparative control region to empathy-associated brain regions.

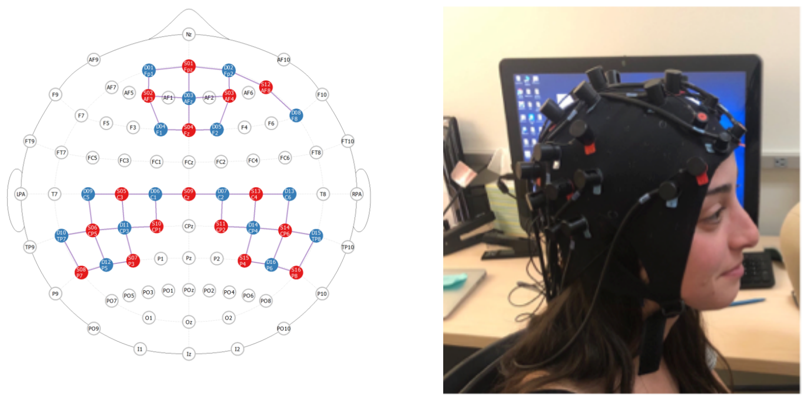

Figure 1. Partial-head layout in the 10-10 system, with 16 sources and 16 detectors comprising 42 data channels.

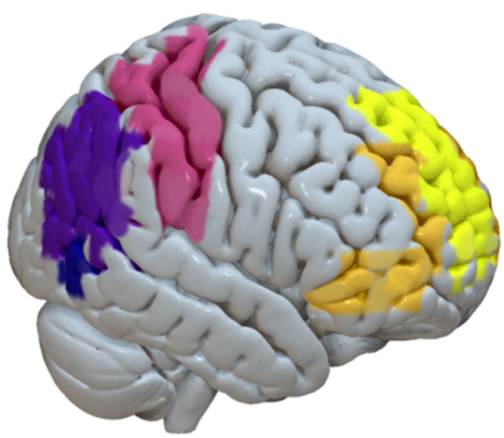

Figure 2. A cortical projection visualizing the mentalizing, somatosensory, and comparison ROIs. The mPFC = yellow, TPJ = purple, somatosensory = pink, lPFC = orange, Visual Association = blue.

Procedure

The procedure for Study 2 followed a nearly identical sequence as the Study 1 procedure, with a few exceptions. First, for counterbalancing purposes, a coin toss was performed in advance to determine the order in which each partner would initially take on roles as support providers or recipients throughout two discussions involving emotional support. Second, participants completed their pre-discussion background questionnaire in lab during the fNIRS cap fitting and calibration process (*see Appendix*). After completing the background questionnaire, couples were provided an overview of their first discussion task, in which recipients were instructed verbatim *to recall and discuss the most emotionally stressful incident or time period in their life that did not involve their partner and was not caused by their partner*, while the listener took on the role of the support provider. The instructions to recall an emotional stressor outside of the romantic relationship ensured that the stressor being discussed did not reflect or prompt an area of conflict between partners. Though their discussion surrounded one partner's topic, couples were encouraged to communicate interactively and conversationally, as opposed to having a one-sided disclosure. The procedure for the second emotional support discussion was identical with partners switched from their previous roles as providers and recipients. Aside from these distinctions, all other procedural details were identical to that of *Study 1*.

Measures

Neural Synchrony

Inter-subject Correlations (ISC). See Study 1. Note that similarly to Study 1, neural synchrony in two additional ROIs including the lateral prefrontal cortex (lPFC) and visual association cortex (VA), were also measured so that they could be assessed as comparative control regions to our brain regions of interest (mPFC, TPJ, and somatosensory cortex synchrony).

Self-report Predictors

Perspective-taking. See Study 1. On average, both women and men reported moderate levels of perspective taking with some variability (M = 3.65, SD = 0.68 for men; M = 3.71, SD = 0.62 for women). Alphas of .78 for women and .79 for men support reliability of the measure.

Empathic Distress. Using items from the Interpersonal Reactivity Index (Davis, 1983), self-reported empathic distress was measured with seven items assessing the degree to which partners report they tend to adopt self-oriented feelings of distress in response to others' pain or misfortune (e.g., "*When I see someone who badly needs help in an emergency, I go to pieces.") (See Appendix for complete measure).* Items were rated on a 5-point scale (*1 = does not describe me well at all* to *5 = describes me very well*). Scores on the seven items were averaged for each participant. On average, both women and men reported moderate levels of empathic distress with variability (M = 2.39, SD = 0.70 for men; M = 2.83, SD = 0.69 for women). Alphas of .76 for women and .80 for men lend support reliability of the measure.

Self-Report Outcomes

Outcomes related to partners' post-support assessments were measured in four ways, highlighted below. The first three assessments highlight partners' personal evaluations of how the discussion went and their immediate feelings following the discussion. The final assessment highlights post-discussion evaluations rated by third-party observers.

Partners' Post-support Appraisals. Using adapted items from the Florida Newlywed Project on Adult Development (McNulty & Karney, 2002) (*see Appendix for complete measure*), recipients' evaluations of the discussion was measured with 10 items assessing the degree to which support recipients felt supported and satisfied with the discussion they had with their partners (e.g., "*How satisfied are you with the conversation?; "How close did the conversation make you feel to your partner?").* Items were scored on a seven-point scale (*1 = not at all* to *7 = extremely*). Scores on the 10 items were averaged for each participant. On average, both women and men reported moderately favorable evaluations of each discussion they had with ample variability (M = 4.74, SD = 1.05 following Discussion 1 and M = 4.93, SD = 1.15 following discussion 2 for men; M = 4.84, SD = 1.15 following Discussion 1 and M = 4.89, SD = 1.10 following discussion 2 for women). Alphas of .91 in Discussion 1 and .89 in discussion 2 for women and .87 in Discussion 1 and .93 in Discussion 2 for men support reliability of the measure.

Post-Support Negative Affect. See *Study 1*. On average, both women and men reported moderately low degrees of negative affect following with the discussion they had with ample variability (M = 2.4, SD = 1.50 in Discussion 1 and M = 2.53, SD = 1.69 in Discussion 2 for men; M = 2.93, SD = 1.53 in Discussion 1 and M = 2.90 SD = 1.53 for women). Alphas of .84 in Discussion 1 and .83 in Discussion 2 for women and .86 in Discussion 1 and .92 in Discussion 2 for men support reliability of the measure.

Post-Support Positive Affect. See Study 1. On average, both women and men reported moderate levels of positive affect following with the discussion they had with ample variability, where women reported lower degrees of positivity on average compared to men (M = 4.08, SD = 1.62 in Discussion 1 and M = 4.16, SD = 1.46 in Discussion 2 for men; M = 3.43, SD = 1.68 in Discussion 1 and M = 3.47, SD = 1.64 in Discussion 2 for women). Alphas of .88 in Discussion 1 and .81 in Discussion 2 for women and .78 in Discussion 1 and .76 in Discussion 2 for men support reliability of the measure.

Relationship Quality. See Study 1. On average, both women and men reported high levels of satisfaction in their relationships with variability (M = 4.95, SD = 0.69 for men; M = 5.07, SD = 0.59 for women). Alphas of .92 for women and .92 for men support reliability of the measure.

Post-Support Evaluations by Independent Raters

Post-discussion evaluations were also assessed through ratings made by independent observers after viewing the videotaped discussions, and outcomes of these interactions were assessed in two ways as highlighted below.

Raters' Post-Support Appraisals. Mirroring the measure of post-discussion appraisals including items from the Florida Newlywed Project on Adult Development completed by participants (McNulty & Karney, 2002), this measure was comparably adapted to be completed by third-party raters after viewing the videotapes (*see Appendix for complete measure*). For this version, five items first assessed the degree to which raters felt that participants had satisfying discussions and understood their partner's point of view (e.g., "*How satisfied was the participant with the conversation?"; "How understood did the participant feel by their partner during the discussion?").* These questions were all identical for both support providers and support recipients aside from one role specific question (i.e., the question was phrased as "*How successfully did the participant provide help or support to their partner?"* for providers but phrased as *"How satisfied did the participant seem with the help or support they received?"* for recipients. Items were scored on a seven-point scale (*1 = not at all* to *7 = extremely*). Following these items, raters also made an overall global assessment of the interaction through one additional item (i.e., *"Overall, what is your evaluation of the target's degree of connection to their partner throughout the conversation?"*), scored on a 6-point scale (*1 = extremely disconnected* to *7 = extremely connected*). Three or more raters completed this 6-item measure for each participant and their interrater reliability was calculated for each item across four metrics: providers in discussion 1, recipients in discussion 1, providers in discussion 2, and recipients in discussion 2. For discussion 1, ICCs ranged from 0.80-0.97 with an average interrater reliability of 0.88 across all items for providers and ranged from 0.71-0.93 with an average interrater reliability of 0.84 across all items for recipients. For discussion 2, ICCs ranged from 0.81-0.97 with an average interrater reliability of 0.89 across all items for providers and ranged from 0.78-0.94 with an average interrater reliability of 0.86 across all items for recipients. (see *Appendix* for specific interrater reliabilities of each separate item). Following interrater reliability calculations, scores were averaged across all raters for each item. On average, observers had moderately favorable evaluations of the discussions across both men ($M = 4.37$, $SD = 0.90$ in Discussion 1, $M = 4.45$, $SD = 0.99$ in Discussion 2) and women ($M = 4.46$, $SD = 0.94$ in Discussion 1, $M = 4.52$, $SD = 1.00$ in Discussion 2), with ample variability. Reliability for internal consistency across the 11 items was also assessed, where alphas of 0.97 for both men and women in Discussion 1 and 0.97 for both men and women in Discussion 2 support reliability of this measure.

Analytic Plan

Data corresponding all aims in this dissertation were analyzed using multilevel modeling (MLM). Across all analyses, both partners from each couple were included in the same model to account for interdependence in the dyadic data. All variables in the model were first z-scored to ensure measurement on comparable scales between neural data and self-report data. Analyses were conducted in SAS version 9.4 using the Proc Mixed procedure.

Revisiting Aim 1

Assess whether greater degrees of neural synchrony in mentalizing and somatosensory regions between partners are associated with partners' post-support evaluations, relationship satisfaction, and third-party ratings.

Aim 1a Analyses: Distinguished Dyads Based on Provider and Recipient Roles

Between-person models were utilized to test whether high degrees of average synchrony in mentalizing regions and low degrees of average synchrony in somatosensory cortex activity in couples may predict more positive post-support evaluations, relationship satisfaction, and more positive third-party ratings. Synchrony in mentalizing and somatosensory cortex regions was modeled at Level 2 to predict post-support appraisal intercepts. Separate models were run to assess other post-support outcomes and relationship satisfaction, along with third-party ratings. *Equation 1* depicts an example of the model structure corresponding to this analysis investigating the effect of mPFC synchrony on partners' post support appraisals.

Equation 1:

Level 1:

$\text{Post-Support Appraisals}_{id} = \pi_{0d} + e_{id}$

Level 2 (2-intercept approach):

$\pi_{0d} = P*[\beta_{00} + \beta_{01}(\text{mPFC synchrony}_{d}) + u_{0d}] + R*[\beta_{02} + \beta_{03}(\text{mPFC synchrony}_{d}) + u_{1d}]$.

In particular, note that this model utilizes a dual-intercept approach; contrary to the single-intercept models from *Study 1*. Unlike in the conflict interaction, partners took turns taking on separate roles as support providers and recipients across two emotional support interactions in *Study 2*, warranting a dual-intercept approach to acquire separate intercept estimates for providers and recipients. These intercepts were obtained by dummy coding support provider (P) and support recipient (R) roles at Level 2, such that $R = 0$ and $P = 1$ when the individual is the support provider; and $R = 1$ and $P = 0$ when the individual is the support recipient. Within this model, β_{00} and β_{02} were, respectively, between-dyad intercepts for support providers and recipients. β_{01} and β_{03} were, respectively, between-dyad slopes for providers' and recipients' mentalizing synchrony. After controlling for all other variables in the model, covariance estimates for baseline post-support appraisals were reflected through u_{0d} and u_{1d}, respectively; whereas correlated error *within* dyads is modeled in the Level 1 error term (e_{id}). Coefficient estimates for β_{01} and β_{03} tested my predictions on the associations between dyadic synchrony on partners' post-discussion outcomes.

Aim 1b Analyses: Distinguished Dyads Based on Gender

Analogous to *Study 1*, I did not choose to distinguish couples on the basis of gender when analyzing our full sample of couples because there were same-gender couples that participated in *Study 2,* for which a gender distinction would not apply. To distinguish dyads based on gender, analogous dual-intercept models were implemented within a subset of only different-gender couples to examine associations between synchrony in brain regions of interest and post-support outcomes. Separate intercept estimates were acquired for men and women rather than providers and recipients. *Equation 2* depicts an example of the model structure corresponding to this analysis investigating the effect of mPFC synchrony on partners' post support appraisals.

Equation 2:

Level 1:

$$\text{Post-Support Appraisals}_{id} = \pi_{0d} + e_{id}$$

Level 2 (2-intercept approach):

$$\pi_{0d} = M*[\beta_{00} + \beta_{01}(\text{mPFC synchrony}_d) + u_{0d}] + F*[\beta_{02} + \beta_{03}(\text{mPFC synchrony}_d) + u_{1d}].$$

Gender intercepts were obtained by dummy coding male (M) and female (F) roles at Level 2, such that $M = 0$ and $F = 1$ when the individual female; and $M = 1$ and $F = 0$ when the individual is male. Identically to the previous equation, coefficient estimates for β_{01} and β_{03} tested my predictions on the associations between dyadic synchrony on partners' post-discussion outcomes.

Revisiting Aim 2

Assess whether neural synchrony in mentalizing and somatosensory regions is associated with the same outcomes, over and above partners' self-reported perspective taking, self-reported empathic distress, and relationship satisfaction.

Aim 2a Analyses: Distinguished Dyads Based on Provider and Recipient Roles

To address Aim 2, analogous dual-intercept *between-person* models were used to test the hypothesis that neural synchrony in mentalizing and somatosensory regions predicts post-support outcomes in providers and recipients, over and above their self-reported perspective-taking, empathic distress, and relationship satisfaction. This model is identical to the prior model, with one exception: to test the "over and above" effect of neural synchrony, between-dyad differences for providers and recipients in self-reported variables (e.g., self-reported perspective-taking exemplified as PT_d) were included as additional predictors entered first in the model. *Equation 3* depicts an example of the model structure corresponding to this analysis with the control variables entered before the neural synchrony predictor.

Equation 3:

Level 1:

Post-Support Appraisals$_{id}$ = π_{0d} + e$_{id}$

Level 2 (2-intercept approach):

π_{0d} = P*[β_{00} + β_{01}(relsat$_{.id}$) + β_{02}(PT$_{id}$) + β_{03}(PD$_{id}$) + β_{04}(mPFC synchrony$_{d}$) + u_{0d}] + R*[β_{05} + β_{06}(relsat$_{id}$) + β_{07}(PT$_{id}$) + β_{08}(PD$_{id}$) + β_{09}(mPFC synchrony$_{d}$) + u_{1d}].

If β_{04} and β_{09} remain significant even after controlling for β_{01}, β_{02}, β_{03}, β_{06}, β_{07}, and β_{08}, this model would test my hypothesis to indicate that the effect of synchrony in mPFC activity predicts post-support outcomes for providers and recipients, over and above their self-reported relationship satisfaction, perspective-taking, and personal distress.

Aim 2b Analyses: Distinguished Dyads Based on Gender

Once more, analogous dual-intercept *between-person* models were used to test the hypothesis that neural synchrony in mentalizing and somatosensory regions predicts post-support outcomes in men and women, over and above their self-reported perspective-taking, empathic distress, and relationship satisfaction using a subset of data with only different-gender couples. *Equation 4* depicts an example of the model structure corresponding to this analysis with separate intercept estimates for men and women, where the same coefficients as the ones mentioned above test my hypotheses.

Equation 4:

Level 1:

Post-Support Appraisals$_{id}$ = π_{0d} + e_{id}

Level 2 (2-intercept approach):

π_{0d} = M*[β_{00} + β_{01}(relsat$_{.id}$) + β_{02}(PT$_{id}$) + β_{03}(PD$_{id}$) + β_{04}(mPFC synchrony$_{d}$) + u_{0d}] + F*[β_{05} + β_{06}(relsat$_{id}$) + β_{07}(PT$_{id}$) + β_{08}(PD$_{id}$) + β_{09}(mPFC synchrony$_{d}$) + u_{1d}].

Results

Preliminary Analyses and Descriptive Statistics

Table 1 displays descriptive statistics and bivariate correlations among the couple-level neural synchrony predictors in Discussion 1 and Discussion 2, along with correlations between Discussion 1 neural synchrony and Discussion 2 neural synchrony. Synchrony values in each region were small as expected, with substantial variability in average degrees of synchrony between different couples. As indicated by the 'Couple N' column, signal loss for specific channels associated with each brain region did not exceed 25% for most couples aside from a lower N for somatosensory cortex synchrony.

As further shown in the table, in Discussion 1 average degrees of mPFC synchrony throughout support conversations are strongly positively associated with TPJ and lPFC synchrony, and both mPFC and TPJ synchrony are moderately positively associated with lPFC synchrony and VA synchrony. In comparison, the magnitudes of these same associations are less strong overall in Discussion 2. Furthermore, associations between Discussion 1 and Discussion 2 neural synchrony within the same brain regions are nonsignificant across mPFC, TPJ, somatosensory cortex, and lPFC activity. These inconsistencies between the two discussions across both degrees of association in different brain regions coupled with nonsignificant associations within the same regions may suggest that the experiences captured by synchrony in Discussion 1 may be largely distinct from that of Discussion 2. Thus, this informed our decision to run separate analyses for each discussion when assessing associations between neural synchrony and support-related outcomes in following sections.

Table 1: Correlations and Descriptive Statistics of Couple-level Neural Synchrony Predictors in Support Discussions 1 and 2.

Variable	(1)	(2)	(3)	(4)	(5)	D1 Couple N	D1 Couple Mean	D1 Couple SD
(1) mPFC Synchrony	**-0.10**	0.73**	0.52**	0.74**	0.34**	40	0.01	0.19
(2) TPJ Synchrony	0.28*	**0.01**	0.38**	0.52**	0.53**	42	0.02	0.14
(3)SMS synchrony	0.09	0.57***	**-0.08**	0.27	0.36**	32	0.04	0.12
(4) lPFC Synchrony	0.42**	0.48***	0.42**	**-0.09**	0.38*	39	0.003	0.16
(5) VA Synchrony	0.46**	0.55***	0.37**	0.37**	**-0.26***	38	0.01	0.14
D2 Couple N	42	46	33	44	47			
D2 Couple Mean	0.02	0.02	-0.02	0.05	-0.01			
D2 Couple SD	1.07	0.72	0.88	0.83	0.53			

Note: Discussion 1 values are above the diagonal, Discussion 2 values are below the diagonal, and correlations between Discussion 1 synchrony and Discussion 2 synchrony are bolded along the diagonal. $* p < 0.05$, $**p < 0.01$, $***p < 0.001$.

Table 2 displays correlations and descriptive statistics for self-reported predictors, outcomes, and third party ratings across providers and recipients in Discussion 1, while *Table 3* displays these same metrics for providers and recipients in Discussion 2. *Table 4* displays correlations and descriptive statistics for self-reported predictors, outcomes, and third party ratings across men and women in Discussion 1, while *Table 5* displays these same metrics for men and women in Discussion 2. As expected in a sample of young, unmarried couples, mean reported relationship satisfaction was moderately high with variability across both providers and recipients in both discussions. Mean reports of post-support positivity and post-support negativity were well distributed, where reports of post-support negativity were lower on average across both discussions for providers and recipients. Both mean post-support appraisals and observer evaluations of both discussions were rated moderately highly across providers and recipients, with ample variability. Across both discussions mean ratings on self-reported perspective-taking were moderate and mean ratings on self-reported empathic distress were moderately low, with variability. Mean reported relationship satisfaction, post-support positive affect, post-support negative affect, post-support appraisals, observer ratings, perspective-taking, and empathic distress across both discussions behaved similarly to metrics addressed above across men and women when dyads were distinguished based on gender.

Correlations between different self-report variables were weakly to modestly correlated with one another in providers and recipients across both discussions in the expected direction (e.g., post-discussion evaluations were positively correlated with positive affect and relationship satisfaction while negatively correlated with negative affect, and positive affect was negatively correlated with negative affect). Correlations between different self-report variables were weakly to modestly correlated with one another in men and women in the first discussion, but in discussion 2 there was no association between post-support appraisals and post-support negative affect in both men and women. Correlations across both discussions were in the expected direction for men and women. The direction of these correlations lend confidence in that these self-report measures were performing as expected. Their weak to moderate magnitude suggests that each variable measures a distinct construct, justifying our decision to examine each as a separate outcome. Observer ratings were modestly correlated with post-discussion evaluations for providers and recipients in Discussion 1 but only for providers in Discussion 2. Observer ratings were modestly correlated with post-discussion evaluations for men and women in Discussion 1 but only for men in Discussion 2. Taken together, this suggests a degree of congruency between third-party assessments and participants' own self-reported assessments of their conversations across most of the conversations. In contrast, observer ratings and post-discussion evaluations were virtually uncorrelated in Discussion 2 specifically for recipients ($r = 0.01$) and for women ($r = 0.06$). Self-report predictors of perspective-taking and empathic distress were weakly associated or completely unassociated with one another across both discussions in providers, recipients, men, and women, suggesting that they reflect distinct and unrelated constructs. Furthermore, both self-report predictors of perspective taking and empathic distress were either largely uncorrelated or only weakly correlated with all self-report outcomes and observer ratings across all roles and genders in both discussions. Follow-up statistical models were additionally run to further test these associations in the following section.

Table 2: Correlations and Descriptive Statistics of Continuous Predictors and Outcomes in Support Discussion 1 Dyads Distinguished as Providers and Recipients.

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**Provider N**	**Provider Mean**	**Provider SD**
(1) Post-Support Appraisal		0.25	-0.19	0.27	0.39**	0.11	0.02	52	4.75	1.06
(2) Positive Affect	0.34*		-0.49***	0.13**	0.20	0.05	0.07	52	3.90	1.50
(3) Negative Affect	-0.35*	-0.32*		-0.09	-0.27	-0.09	0.21	52	2.64	1.48
(4) Relationship Satisfaction	0.24	-0.17	0.19		0.32*	-0.04	0.02	52	4.99	0.67
(5) Observer Ratings	0.40**	0.13	-0.02	0.24		0.11	-0.14	52	4.43	0.99
(6) Perspective-Taking	0.03	0.004	0.10	0.24	-0.12		-0.08	52	3.76	0.65
(7) Empathic Distress	-0.07	-0.04	0.28*	-0.13	0.06	-0.08		52	2.66	0.74
Recipient N	51	51	51	52	52	52	52			
Recipient Mean	4.84	3.52	2.81	5.04	4.40	3.61	2.60			
Recipient SD	1.15	1.83	1.58	0.60	0.86	0.65	0.72			

*Note: Provider values are above the diagonal and recipient values are below the diagonal. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Table 3: Correlations and Descriptive Statistics of Continuous Predictors and Outcomes in Support Discussion 2 Dyads Distinguished as Providers and Recipients

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**Provider N**	**Provider Mean**	**Provider SD**
(1) Post-Support Appraisal		0.55***	-0.10	0.11	0.36**	0.13	0.14	52	4.75	1.06
(2) Positive Affect	0.23		-0.47**	-0.15	0.14	0.08	0.01	52	3.90	1.50
(3) Negative Affect	0.08	-0.44**		0.09	0.09	0.03	0.21	52	2.64	1.48
(4) Relationship Satisfaction	0.25	0.08	-0.09		0.05	0.24	-0.13	52	4.99	0.67
(5) Observer Ratings	0.01	-0.05	-0.34	0.29*		0.10	0.02	52	4.43	0.99
(6) Perspective-Taking	-0.06	-0.03	-0.001	-0.04	0.06		-0.08	52	3.76	0.65
(7) Empathic Distress	0.04	0.12	0.21	0.02	-0.17	-0.08		52	2.66	0.74
Recipient N	51	51	51	52	52	52	52			
Recipient Mean	4.84	3.52	2.81	5.04	4.40	3.61	2.60			
Recipient SD	1.15	1.83	1.58	0.60	0.86	0.65	0.72			

*Note: Provider values are above the diagonal and recipient values are below the diagonal. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Table 4: Correlations and Descriptive Statistics of Continuous Predictors and Outcomes in Support Discussion 1 Dyads Distinguished by Gender

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	Female N	Female Mean	Female SD
(1) Post-Support Appraisal		0.36*	-0.39**	0.37*	0.39**	0.01	0.01	47	4.88	1.21
(2) Positive Affect	0.35*		-0.30**	-0.06	0.11	-0.01	0.21	47	3.59	1.60
(3) Negative Affect	-0.21	-0.41**		-0.07	-0.53	0.09	0.10	47	2.67	1.40
(4) Relationship Satisfaction	0.13	0.06	0.10		0.23	0.10	-0.25	47	5.08	0.63
(5) Observer Ratings	0.37*	0.47*	0.03	0.35*		-0.17	0.09	47	4.41	0.94
(6) Perspective-Taking	0.12	0.10	-0.14	0.04	0.12		0.08	47	3.68	0.60
(7) Empathic Distress	-0.12	-0.11	0.32*	0.05	0.01	-0.25		47	2.85	0.68
Male N	46	46	46	47	47	47	47			
Male Mean	4.74	4.08	2.47	4.95	4.37	3.65	2.39			
Male SD	1.05	1.62	1.50	0.69	0.90	0.68	0.70			

*Note: Women's values are above the diagonal and men's values are below the diagonal. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Table 5: Correlations and Descriptive Statistics of Continuous Predictors and Outcomes in Support Discussion 2 Dyads Distinguished by Gender

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**Female N**	**Female Mean**	**Female SD**
(1) Post-Support Appraisal		0.68**	-0.06	0.18	0.06	0.02	0.25	47	4.87	1.14
(2) Positive Affect	0.19		-0.28	-0.09	-0.03	0.08	0.23	47	3.69	1.46
(3) Negative Affect	0.04	-0.47**		-0.07	-0.32	0.01	0.25	47	2.63	1.69
(4) Relationship Satisfaction	0.21	0.07	0.02		0.13	0.10	-0.25	47	5.08	0.69
(5) Observer Ratings	0.37*	0.19	0.02	0.24		0.16	-0.07	47	4.49	0.99
(6) Perspective-Taking	0.03	0.05	0.02	0.04	0.03		0.09	47	3.68	0.68
(7) Empathic Distress	0.01	-0.01	0.17	0.05	-0.13	-0.25		47	2.85	0.70
Male N	47	47	47	47	47	47	47			
Male Mean	4.93	4.15	2.52	4.95	4.45	3.65	2.39			
Male SD	1.15	1.46	1.69	0.69	0.99	0.68	0.70			

Note: Women's values are above the diagonal and men's values are below the diagonal. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Prior to analyses of the neural data, separate models were run as a validity check between self-report control variables and outcomes to examine the independent effects of perspective taking, empathic distress, and relationship satisfaction on post-discussion affect, post-discussion appraisals, and observer appraisals in couples, controlling for their dyadic interdependence. Contrary to expectations, no significant associations were found between self-reported perspective-taking, personal distress, and any self-reported outcomes across couples in both discussions. As expected, in Discussion 1 relationship quality was significantly associated with better post-discussion evaluations ($t = 2.56, p = 0.01$), such that couples who reported to be in better relationships also rated their discussions more favorably. Relationship quality was also significantly associated with better observer evaluations of couples' behaviors ($t = 2.87, p = 0.005$), such that those who reported to be in better relationships also received more favorable third-party evaluations. Interestingly, these same effects of relationship quality on both post-discussion evaluations ($t = 1.87, p = 0.06$) and third-party evaluations ($t = 1.72, p = 0.09$) became marginal in Discussion 2, although their positive directionality remained consistent. No associations were found between relationship quality and post-discussion affect in either discussion.

Aim 1a: Effect of Neural Synchrony in mPFC, TPJ, and Somatosensory Activity on Self-reported and Observer Post-Discussion Evaluations in Couples Distinguished as Providers and Recipients

To address this aim, separate models were run to examine the main effects of neural synchrony in regions associated with the mPFC, TPJ, and somatosensory cortex activity on self-reported relationship satisfaction, post-discussion affect, post-discussion evaluations, and observer evaluations. Equivalent models were also run to assess the main effects of neural synchrony in control regions (lPFC and visual cortex) on the same outcomes. Separate models were run for each discussion (given their distinct characteristics from one another based on the previous descriptive data), where providers and recipients were included in the same model using the aforementioned dual-intercept approach. As expected, in Discussion 1 there was a significant main effect of mPFC synchrony on support recipients' post-discussion evaluations ($t = 2.90, p = 0.005$) and a marginally significant effect of mPFC synchrony on support providers' evaluations ($t = 1.80, p = 0.077$), such that greater average synchrony in regions associated with mPFC activity between partners predicted more favorable self-reported appraisals of the discussion. Furthermore, as expected, in Discussion 1 there were significant main effects of TPJ synchrony on support providers' ($t = 2.55, p = 0.01$) and support recipients' ($t = 2.53, p = 0.01$) post-discussion evaluations, such that greater average synchrony in regions associated with TPJ activity between partners also predicted more favorable self-reported appraisals of the discussion. No associations were found between synchrony in somatosensory cortex activity and any outcomes. Regarding findings for the control regions, in Discussion 1 lPFC synchrony ($t = -2.82, p = 0.01$) and VA synchrony ($t = -2.06, p = 0.04$) were significantly associated with relationship satisfaction in support providers, such that greater average synchrony between partners in activity associated with those regions predicted lower relationship satisfaction. In Discussion 1, VA synchrony ($t = 1.85, p = 0.07$) was marginally associated with post-discussion evaluations.

Results for the second discussion were much weaker. In Discussion 2, average synchrony in channels associated with mPFC and TPJ activity no longer predicted any outcomes. Somatosensory cortex synchrony was marginally associated with relationship satisfaction ($t = -1.97, p < 0.10$ in providers, such that greater average synchrony between partners in regions associated with somatosensory cortex activity predicted lower pre-discussion relationship quality. Regarding findings for comparative control regions in Discussion 2, lPFC synchrony (*$t = -2.16$, $p = 0.03$*) was significantly associated with observer evaluations for support providers, such that greater average synchrony between partners in activity associated with this region predicted less favorable third-party assessments of provider behaviors.

Aim 1b: Effect of Neural Synchrony in mPFC, TPJ, and Somatosensory Activity on Self-reported and Observer Post-Discussion Evaluations in Couples Distinguished by Gender

As expected within our subset of different-gender couples, in discussion 1 there was a significant main effect of mPFC synchrony on post-discussion evaluations for both women *($t = 2.36$, $p = 0.02$)* and men *($t =2.20$, $p = 0.03$)*, such that greater average synchrony in regions associated with mPFC activity between partners predicted more favorable self-reported appraisals of the discussion. Furthermore as expected, in discussion 1 there were significant main effects of TPJ synchrony on post-discussion evaluations for both women (*$t = 2.09$, $p = 0.04$*) and men (*$t = 3.01$, $p = 0.004$*), such that greater average synchrony in regions associated with TPJ activity between partners also predicted more favorable self-reported appraisals of the discussion. Discussion 1 somatosensory cortex synchrony was marginally associated with observer evaluations of men’s behaviors *($t = -1{,}83$, $p = 0.07$)*, such that greater synchrony between partners in activity associated with this region predicted worse third-party evaluations of men’s behavior. Regarding findings for the comparative control regions, in discussion 1 VA synchrony was significantly associated with post-discussion evaluations for only men *($t = 2.04$, $p = 0.05$)*, such that greater average synchrony between partners in activity associated with this region predicted better post-support evaluations. VA synchrony was also significantly associated with observer evaluations of women ($t = 2.06$, $p = 0.04$), such that greater average synchrony between partners in activity associated with this region predicted more favorable third-party evaluations of women's behavior.

Once more, Discussion 2 findings differed from discussion 1 and were less robust overall. In Discussion 2, mPFC synchrony was significantly associated with women's post-discussion negative affect *($t = 2.24$, $p = 0.03$)*, such that greater average synchrony between partners in areas associated with mPFC activity predicted increased post-discussion negative affect. In Discussion 2, TPJ synchrony was marginally associated with post-discussion positive affect in women *($t = 1.95$, $p = 0.055$)*, such that greater average synchrony between partners in activity associated with this region predicted increased post-discussion positive affect. For the comparative control regions, greater lPFC synchrony was significantly associated with relationship satisfaction in men ($t = -2.23$, $p = 0.03$), such that greater average synchrony between partners in channels associated with lPFC activity predicted lower pre-discussion relationship satisfaction. Analogous findings emerged for VA synchrony in men *($t = -2.93$, $p = 0.005$)*, such that greater average synchrony between partners in channels associated with VA activity also predicted lower pre-discussion relationship satisfaction.

Aim 2a: Effect of Neural Synchrony on Self-reported and Observer Post-Discussion Evaluations, Controlling for Relationship Satisfaction, Perspective-taking, and Empathic Distress in Couples Distinguished as Providers and Recipients

To address this aim, equivalent models to the above were run again, with relationship satisfaction, perspective-taking, and empathic distress entered first as control variables prior to neural synchrony predictors. In Discussion 1, the significant main effect of mPFC synchrony on support recipients' post-discussion evaluations ($t = 3.06$, $p = 0.003$) and marginally significant effect of mPFC synchrony on support providers' evaluations ($t = 1.73$, $p = 0.088$) held, such that greater average synchrony between partners in regions associated with mPFC activity predicted more favorable self-reported appraisals of the discussion, over and above the effects of self-reported relationship satisfaction, perspective-taking, and empathic distress. The same findings held for effects of TPJ synchrony in both providers (*$t = 2.52, p = 0.01$*) and recipients (*$t = 2.59, p = 0.01$*) on post-Discussion 1 evaluations, such that such that greater average synchrony in regions associated with TPJ activity predicted more favorable self-reported appraisals of the discussion over and above the same control variables. Refer to *Table 7* and *Table 8* for further details regarding statistically significant models in primary brain regions of interest corresponding to Aim 1a and Aim 2a. Regarding control regions in Discussion 1, VA synchrony also remained marginally associated with providers' post-discussion evaluations (*$t = 1.73, p = 0.089$*) with the added controls.

In Discussion 2, the association between lPFC synchrony and observer evaluations remained significant for providers (*$t = -2.07, p = 0.04$*), such that greater average synchrony between partners in activity associated with this region predicted less favorable third-party assessments of provider behaviors, over and above effects of relationship satisfaction, perspective-taking, and empathic distress.

Aim 2b: Effect of Neural Synchrony on Self-reported and Observer Post-Discussion Evaluations, Controlling for Relationship Satisfaction, Perspective-taking, and Empathic Distress in Couples Distinguished by Gender

As expected when examining our subset of different-gender couples, the significant main effects of mPFC synchrony between partners on women's post-discussion evaluations (*$t = 2.02, p = 0.03$*) and men's post-discussion evaluations (*$t = 2.42, p = 0.02$*) held, such that greater average synchrony between partners in regions associated with mPFC activity predicted more favorable self-reported appraisals of the discussion, over and above the effects of relationship satisfaction, perspective-taking, and empathic distress for both partners. The same findings held for effects of TPJ synchrony between partners on men's post-discussion evaluations ($t = 3.22$, $p = 0.002$), such that greater average synchrony in regions associated with TPJ activity predicted more favorable self-reported appraisals of the discussion over and above the same control variables. Discussion 1 somatosensory cortex synchrony remained marginally associated with observer evaluations of men ($t = -1,81$, $p = 0.07$), such that greater synchrony between partners in activity associated with this region predicted worse third-party evaluations of men's behavior. See *Tables 6* through *9* for further details regarding statistically significant models in primary brain regions of interest corresponding to Aim 1b and Aim 2b for Discussion 1. Regarding control regions in Discussion 1, VA synchrony was no longer associated with men's post-discussion evaluations after controlling for relationship quality, perspective-taking, and empathic distress. However, the significant association between VA synchrony and observer evaluations of women held ($t = 2.07$, $p = 0.04$), such that greater average synchrony between partners in activity associated with this region predicted more favorable third-party evaluations of women's behavior over and above the added controls.

In Discussion 2, the significant association between mPFC synchrony in partners and women's post-discussion negative affect held ($t = 2.94$, $p = 0.008$), such that greater average synchrony between partners in activity associated with this region predicted increased post-discussion negative affect over and above relationship quality, perspective-taking, and empathic distress. The marginal association between TPJ synchrony and women's post-discussion positive affect also held in Discussion 2 with the added controls ($t = 1.80$, $p = 0.076$). Refer to *Table 10* for further details regarding statistically significant models in primary brain regions of interest corresponding to Aim 1b and Aim 2b for Discussion 2.

Table 6. Independent Effects of mPFC Synchrony on Discussion 1 Self-Reported Post-Support Evaluations for Providers and Recipients (Model 1), Over and Above Relationship Satisfaction, Perspective-Taking, and Empathic Distress (Model 2) in Couples Distinguished as Providers and Recipients

Model 1

	Providers				**Recipients**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	0.10 (0.16)	0.63	-0.1`	0.41	0.03(0.16)	0.16	-0.29	0.34
mPFC Synchrony	0.28(0.16)	1.80	-0.03	0.60	0.48(0.17)**	2.90	0.15	0.81

Model 2

	Providers				**Recipients**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	0.12(0.16)	0.73	-0.20	0.40	0.04(0.16)	0.22	-0.29	0.36
Relationship Quality	0.22(0.13)	1.61	-0.05	0.48	0.31(0.17)	1.82	-0.03	0.64
Perspective-Taking	-0.002(0.16)	-0.01	-0.32	0.31	0.04(0.16)	0.24	-0.29	0.36
Empathic Distress	-0.14(0.16)	-0.86	-0.46	0.18	-0.07(0.16)	-0.43	-0.39	0.25
mPFC Synchrony	0.28(0.16)	1.73	-0.04	0.59	0.51(0.17)**	3.06	0.18	0.84

* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$*

Table 7. Independent Effects of TPJ Synchrony on Discussion 1 Self-Reported Post-Support Evaluations for Providers and Recipients (Model 1), Over and Above Relationship Satisfaction, Perspective-Taking, and Empathic Distress (Model 2) in Couples Distinguished as Providers and Recipients.

Model 1

	Providers				**Recipients**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	0.02(0.15)	0.13	-1.86	1.89	0.01(0.15)	0.04	-1.87	1.89
TPJ Synchrony	0.38(0.15)*	2.55	0.08	0.68	0.38(0.15)*	2.53	0.08	0.67

Model 2

	Providers				**Recipients**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	0.01(0.15)	0.04	-1.90	1.91	-0.02(0.15)	-0.12	-1.91	1.87
Relationship Quality	0.20(0.13)	1.64	-0.04	0.46	0.30(0.16)	1.83	-0.03	0.62
Perspective-Taking	0.14(0.15)	0.92	-0.16	0.44	0.02(0.15)	0.14	-0.27	0.31
Empathic Distress	0.01(0.14)	0.06	-0.27	0.28	-0.13(0.17)	-0.73	-0.46	0.21
TPJ Synchrony	0.38(0.15)*	2.52	0.08	0.68	0.40(0.15)*	2.59	0.09	0.70

* $p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 8. Independent Effects of mPFC Synchrony on Discussion 1 Self-Reported Post-Support Evaluations for Women and Men (Model 1), Over and Above Relationship Satisfaction, Perspective-Taking, and Empathic Distress (Model 2) in Couples Distinguished by Gender.

Model 1

	Women				**Men**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	0.11(0.19)	0.60	-0.26	0.48	0.05(0.19)	0.24	-0.33	0.43
mPFC Synchrony	0.38(0.16)*	2.36	0.06	0.71	0.38(0.17)*	2.20	0.03	0.72

Model 2

	Women				**Men**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	0.10(0.17)	0.59	-0.23	0.43	0.05(0.16)	0.29	-0.29	0.38
Relationship Quality	0.31(0.15)	2.00	-0.0001	0.62	0.22(0.16)	1.37	-0.10	0.54
Perspective-Taking	-0.07(0.19)	-0.40	-0.45	0.30	0.07(0.16)	0.42	-0.25	0.39
Empathic Distress	-0.04(0.18)	-0.24	-0.39	0.31	-0.14(0.17)	-0.81	-0.46	0.20
mPFC Synchrony	0.36(0.16)*	2.20	0.03	0.69	0.42(0.18)*	2.42	0.07	0.78

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9. Independent Effects of TPJ Synchrony on Discussion 1 Self-Reported Post-Support Evaluations for Women and Men (Model 1), Over and Above Relationship Satisfaction, Perspective-Taking, and Empathic Distress (Model 2) in Couples Distinguished by Gender.

Model 1

	Women				**Men**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	0.08(0.16)	0.48	-1.97	2.13	0.03(0.16)	0.18	-2.02	2.08
TPJ Synchrony	0.33(0.15)*	2.09	0.02	0.65	0.48(0.16)**	3.01	0.16	0.80

Model 2

	Women				**Men**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	0.07(0.16)	0.47	-1.93	2.08	0.03(0.16)	0.17	-1.93	2.08
Relationship Quality	0.34(0.16)*	2.17	0.003	0.65	0.23(0.15)	1.50	-0.07	0.53
Perspective-Taking	0.02(0.17)	0.13	-0.31	0.36	0.14(0.16)	0.85	-0.18	0.45
Empathic Distress	0.09(0.19)	0.47	-0.29	0.46	-0.09(0.16)	-0.59	-0.41	0.22
TPJ Synchrony	0.25(0.16)	1.49	-0.08	0.57	0.52(0.16)**	3.22	0.20	0.85

* $p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 10. Independent Effects of mPFC Synchrony on Discussion 2 Post-Support Negative Affect for Women and Men (Model 1), Over and Above Relationship Satisfaction, Perspective-Taking, and Empathic Distress (Model 2) in Couples Distinguished by Gender.

Model 1

	Women				**Men**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	-0.23(0.14)	-1.64	-0.52	0.05	-0.08(0.14)	-0.55	-0.36	0.21
mPFC Synchrony	0.32(0.14)*	2.24	0.03	0.60	0.24(0.14)	1.67	-0.05	0.53

Model 2

	Women				**Men**			
Effect	*b(SE)*	*t*	95% CI Lower	95% CI Upper	*b(SE)*	*t*	95% CI Lower	95%CI Upper
Intercept	-0.27(0.14)	-1.90	-2.11	1.56	-0.06(0.14)	-0.45	-1.89	1.76
Relationship Quality	0.06(0.13)	0.48	-0.20	0.33	0.07(0.14)	0.51	-0.21	0.36
Perspective-Taking	-0.10(0.15)	-0.67	-0.41	0.20	0.05(0.15)	0.36	-0.24	0.35
Empathic Distress	0.34(0.16)*	2.15	0.02	0.65	0.11(0.16)	0.66	-0.21	0.42
mPFC Synchrony	0.41(0.15)**	2.74	0.11	0.72	0.20(0.15)	1.32	-0.10	0.51

$* p < 0.05$, $**p < 0.01$, $***p < 0.001$

Discussion

Key Findings and Implications

Expanding on Study 1, the primary purpose of *Study 2* was to examine and compare the effects of two forms of empathy (perspective-taking and empathic distress) on the quality of emotional support discussions. In line with this aim, I examined effects of activity in channels associated with mPFC synchrony, TPJ synchrony, and somatosensory cortex synchrony between partners on post-support appraisals, post-support affect, relationship quality, and observer assessments of social support discussions between intimate partners. To test the robustness of any significant associations between synchrony in brain regions and outcomes of interest, I further examined the strength of these associations over and above self-reports of relationship satisfaction, perspective-taking, and empathic distress.

Prior to analyzing the neural data, associations between self-reported perspective-taking, empathic distress, and relationship quality on self-reported outcomes were first examined as a validity check. We initially found the lack of association between measures of self-reported empathy and self-report outcomes to be surprising, given the potential for sentiment override to often predict stronger associations between self-report measures in general (e.g., those who perceive themselves as more understanding may have also rated their behaviors following a discussion more favorably). This contrasting finding to the robust associations between perspective-taking and self-reported outcomes in the conflict study may have been due to wider variability in the reported quality of the conflict discussions compared to the support discussions. Post-discussion ratings were more favorable overall following support interactions compared to conflict, which may have led to some ceiling effects on the predictive ability of self-reported empathy measures. Though associations between relationship quality and post-discussion outcomes were in the expected direction across both discussions, they were surprisingly only statistically significant in Discussion 1. These discrepant findings between Discussion 1 and Discussion 2 may support insight into how characteristics of each discussion may be psychologically and methodologically distinct, which will be further discussed in later sections.

Findings for synchrony in channels associated with mPFC and TPJ activity between partners were robust and in the expected direction. Regardless of whether dyads were distinguished by role or gender, greater average synchrony across channels associated with mPFC activity and TPJ activity between partners significantly predicted more favorable self-reported post-discussion appraisals in Discussion 1, and these associations primarily held over and above relationship satisfaction, perspective-taking, and empathic distress. This study is in line with existing research suggesting that activity in these regions may correspond to adaptive attempts to infer the mental states of others (e.g., D'Argembeau et al., 2007). Beyond existing research, this study was the first to demonstrate an association between neural synchrony and discussion-related outcomes within the naturalistic context of communicating emotional support in couples; in which greater average degrees of synchrony in mPFC and TPJ regions between partners may reflect attempts to develop a *shared* understanding to adaptively influence the quality of communication surrounding emotionally distressing topics.

Discussion 2 findings differed from Discussion 1 and were less robust. In Discussion 2, findings for mPFC and TPJ synchrony only emerged when dyads were distinguished by gender, in which average synchrony between partners in channels associated with mPFC activity predicted increased post-discussion negative affect in women. It is worth noting that the function of negative affect following an emotional support interaction is difficult to interpret and may differ greatly from that of conflict. While post-conflict negative affect is likely indicative of a poor-quality interaction due to a heated disagreement and inability to compromise, the interpretation of post-support negative affect is much more nuanced. Indeed, it is also possible for post-support negative affect to analogously reflect a partner's dissatisfaction with the quality of the interaction. However, it is just as possible for post-support negative affect to reflect a person's feelings of distress due to reliving their own painful experience or distress in response to hearing about a painful experience of their partner. Thus, the significant association between mPFC synchrony and women's increased post-support negative affect may reflect multiple potential explanations and caution should be exercised when interpreting this finding.

Findings for synchrony in somatosensory cortex activity were also less robust but in the expected direction. Greater synchrony between partners in channels associated with this region marginally predicted worse third-party evaluations of men's behavior in dyads distinguished by gender in Discussion 1, and greater average synchrony between partners in channels associated with this region predicted marginally lower provider relationship quality in providers in dyads distinguished by role. Though findings for synchrony in channels corresponding to somatosensory cortex activity were either marginal or nonsignificant, all marginal findings for synchronous activity corresponding to this region were in the expected negative direction with post-support outcomes, and remained marginal with added control variables. This provides some preliminary evidence to corroborate existing literature that activity in this region may correspond to shared distress (Ashar et al., 2017), which may lead to maladaptive behaviors.

Based on Discussion 1 and Discussion 2 findings, a key question emerges: why are neural synchrony findings between discussions 1 and 2 so divergent? From a theoretical perspective, one possibility may be that Discussion 1 and Discussion 2 reflect psychologically distinct interactions. For instance, at the beginning of discussion 1 both partners are freshly engaging in an emotional support interaction for the first time in the lab. In contrast, at the beginning of Discussion 2 each partner has either already shared or listened to an emotionally painful event from Discussion 1, in which feelings and recollections from that discussion may spill over to influence the nature of Discussion 2. Furthermore, both the roles that partners serve (i.e., as support providers or recipients) and the topic they discuss are not held constant between the two discussions, in which unaccounted factors such as the traumatic severity of the topic at hand may vary greatly between discussions 1 and 2. From a methodological perspective, participants may have experienced physical discomfort due to wearing the neuroimaging caps for prolonged periods of time, potentially impacting both their area of focus and the nature of their interactions in discussion 2 compared to discussion 1. Supporting this possibility, there were notably greater instances of participant complaints about the caps feeling uncomfortable in videotaped footage from discussion 2 compared to discussion 1. Finally, general fatigue that participants may have experienced during the discussion 2 task due to being in the lab for a longer period of time may have also contributed to discrepancies between discussion 1 and discussion 2 findings. In light of these additional contributors which may impact the nature of Discussion 2 (i.e., emotional spillover from Discussion 1, discomfort from wearing the fNIRS caps for too long, and general experimental fatigue), we have greater confidence in findings from Discussion 1 which are less impacted by extraneous factors.

Taken together, findings from this study suggest that within the context of social support, shared empathy in regions associated with perspective-taking may lead to better overall partner evaluations surrounding how their discussions went compared shared empathy in regions associated with empathic distress.

Strengths and Limitations

Our confidence in the findings of this study is enhanced by some strengths in its methodology and design. First, analogous to Study 1 strengths our neural assessments of empathy overcome existing challenges of self-report and observational methods, preserve naturalistic features of how these interactions may organically take place compared to other imaging methods, assess observer ratings in addition to partners' self-reported post-support outcomes, and additionally assess synchrony in other areas of the brain as control regions. As an additional strength beyond Study 1, Study 2 examined neural assessments in regions associated with two different forms of empathy as points of comparison between one another and to self-reported assessments of perspective-taking and empathic distress. This allowed for complex, multifaceted components of empathy to be more fully captured and examined as a construct (i.e., attempting to develop a shared point of view vs. developing shared feelings of emotional pain).

Notwithstanding these strengths, limitations of this study also require that these results should be interpreted with some caution. Like in Study 1, this study of exclusively young dating couples without children may have impacted the direction of some findings and limits generalizability. Despite having variability across self-reported and third-party evaluations, emotional support interactions were largely favorably evaluated by both partners and observers and potentially limits the scope in which neural synchrony can predict post-support outcomes due to ceiling effects (e.g., where most partners were satisfied with each other's behaviors and rated favorably by third-party observers). Future studies should extend our work by studying more established, long-term couples, in which even greater variability in emotional support behaviors and relationship quality are likely to emerge and more divergent assessments may also emerge between self-report assessments and third-party ratings. Second, neural synchrony values were calculated as singular overall average synchrony values collapsed across a time series, wherein nuances in degrees of synchrony throughout the interactions may get cancelled out. Whereas it is not possible to associate time-dependent, lagged synchrony predictors to the time invariant self-report outcomes in Studies 1 and 2, future work should consider measuring the association between moment-to-moment internal brain dynamics and moment-to-moment shifts in behavioral patterns.

Conclusion

Study 2 was the first study to ever examine links between neural synchrony in regions associated with multiple forms of empathy and the quality of emotional support discussions in couples. My findings provide preliminary evidence to support that greater synchrony in mPFC and TPJ activity between partners may adaptively improve the quality of emotional support discussions through mutual attempts to develop a shared understanding. To further our knowledge regarding associations between neural synchrony in empathy-related regions and relationship functioning, future research should consider examining these associations across diverse couples throughout a variety of contexts using time-dependent analyses.

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Study 3: The Temporal and Interpersonal Dynamics of Empathy in Couples' Communication

Study 1 and Study 2 expand upon theoretical and methodological limitations in existing empathy research, but several important gaps remain. First, both studies and much of the existing literature (Harris & Gordon, 2015) assume that neural synchrony affects communication through direct associations with partners' *behaviors,* and subsequently, partners' evaluations of their discussions. While Study 1 and Study 2 assess associations between neural synchrony and evaluations of the interaction (made by both partners themselves and third-party raters), these associations address the relationship between neural synchrony and *overall evaluations* of the interaction, rather than the direct relationship between neural synchrony and behavioral changes throughout the interaction itself. While limited research has examined associations between neural synchrony and rudimentary behavioral processes (e.g., motor tasks) (Nam, Choo, Huang, & Park, 2020), no study to date has investigated links between neural synchrony and the complex behavioral nuances surrounding communication. To surmount this limitation in the field, the relationship between brain activity between partners and their observed behavior should be assessed directly.

Second, Study 1 and Study 2 assess neural synchrony as inter-subject correlation estimates averaged across the entire discussion, ignoring fluctuations of neural synchrony and behavior within those discussions. Existing research has defined empathy as an "ability" or "capacity" (e.g., Banissy, Kanai, Walsh, & Rees, 2012; Eisenberg & Morris, 2001), implying that empathy operates as a stable, trait-based construct. However, other researchers suggest that empathic abilities may also be context-specific, using terms such as "situational" or "contextual" when describing it (Lishner, Batson, & Huss, 2011; Morelli, Rameson, & Lieberman, 2014). Yet, empathy has primarily been measured as an individual tendency, ignoring it's interpersonal nature, the context in which empathy may change throughout social interactions, and the varying contexts through which empathic processes may operate differently (e.g., in a social support discussion versus a conflict discussion). Although prior research has measured empathy as a stable construct through global self-report assessments, fluid, social, and context-dependent empathy processes have remained largely unexplored. To assess how empathy may unfold as an interpersonal and dynamic construct, state-based measurements of empathy should be implemented through repeated assessments across the entirety of an interaction. Assessing observationally coded videotapes of each partner's behavior in addition to their own neural data will allow me to assess the relationship between these two measures in identical levels of detail over time. Third, though models such as the Biobehavioral Synchrony Model (Feldman, 2012) directly infer the directionality of the relationship between brain activity and behavior (e.g., that shared behavioral cues subsequently lead to neural synchrony), such assumptions have yet to be empirically assessed on a moment-to-moment basis. To offer greater insight into this potential phenomenon, *bidirectional* lagged associations between brain activity and behavior should be directly tested.

Considering these existing gaps in the literature, Study 3 has two primary aims. The first aim of Study 3 is to incorporate time-dependent dynamics by assessing concurrent associations between second-to-second neural synchrony and second-to-second observed behavior (e.g., whether observed behavior at a given moment is associated with neural synchrony at the same point in time). The second aim of Study 3 is to assess lagged associations between neural synchrony and observed behavior at various time-intervals across social support and conflict interactions in couples (e.g., whether observed behavior at a given moment is associated with neural synchrony ‘x’ seconds later and vice versa). This analysis will provide information about associations between brain activity and observable behavior at comparable time-intervals, in which both within-person and between-person assessments can be simultaneously measured while controlling for dyadic interdependence. Specifically, the concurrent analyses determine a) on average, whether partners who show above average behavioral connection concurrently share above average neural synchrony with their partners at the same point in time, and b) on average, whether couples who show greater behavioral connection share greater neural synchrony with their partners across the interaction; whereas the lagged analyses determine a) on average, whether partners who show moments of greater than average behavioral connection share greater than average neural synchrony with their partners ‘x’ seconds later across an interaction and vice versa, along with b) comparable between-person estimates to the concurrent models. Note that I did not choose to control for previous levels of the outcome in these models because it is highly unlikely for a predictor to be associated with an outcome over and above previous levels of that same outcome when examining physiological and neural data at the second-to-second level. Instead, for each aim I chose to run multilevel models with an autoregressive error structure (i.e., ar1). Doing so measures associations between the prior state of the predictor on the current state of the outcome, while accounting for the association between the prior state of the outcome and current state of outcome, above and beyond the effect of prior states of the predictor.

Using a moment-to-moment method of measurement, I was able to capture the stream of interpersonal affect and behavior as it unfolds temporally over the course of the interaction. Doing so afforded a more direct, nuanced measure of behavior than would be offered by a macro-coding system that relies on coder judgment of the entire interaction. Furthermore, having moment-to-moment ratings of behavior allowed for a more direct comparison of real-time observational data to real-time neural activity within partners compared to global ratings of affect, capturing the live, ever-changing context in which degrees of empathy may fluctuate throughout specific moments of social interactions.

In line with Study 1 and Study 2 hypotheses, corresponding to Aim 1, I predicted that on average, moments of greater behavioral connection in partners will be concurrently associated with greater mPFC and TPJ activity between partners at both the within-subjects and between-subjects levels across conflict and social support interactions. On the other hand, I predicted that moments of greater behavioral *disconnection* in partners will be concurrently associated with greater neural synchrony in somatosensory cortex activity between partners at both the within-subjects and between-subjects levels in social support interactions specifically. Corresponding to Aim 2, I predicted that on average, moments of greater behavioral connection in partners will be associated with greater mPFC and TPJ activity between partners at later points in time and vice versa at both the within-subjects and between-subjects levels, across conflict and social support interactions. On the other hand, I predicted that moments of greater behavioral *disconnection* in partners will be associated with greater neural synchrony in somatosensory cortex activity between partners at later points in time and vice versa at both the within-subjects and between-subjects levels in social support interactions specifically.

Method

Sampling and Participants

See Studies 1 and 2.

fNIRS Acquisition and Preprocessing

See Studies 1 and 2.

Observational Coding Procedure

Fluctuations in behavior were assessed using movement of a curser along a single sliding axis by trained observers as they watched each partner's emotional support and conflict interaction tasks on a computer monitor. The Continuous Axis Rating and Media Annotation package (CARMA) developed by Girard (2014) was used to perform these moment-to-moment ratings. CARMA has been designed to be a user-friendly and easily customizable behavioral coding package. Based on Gottman and Levenson's affect rating dial (1985), CARMA enables investigators to provide moment-by-moment ratings of multimedia files using a computer mouse or keyboard. The rating scale can then be configured on certain parameters, such as labels for its upper and lower bounds, its numerical range, and its visual representation.

When each partners' videos were uploaded, their soundtrack simultaneously played through the speakers and the video was visually displayed in the multimedia window. Using a slider, which was controlled with a computer mouse, trained observers rated the selected multimedia file in real-time as it played. As the coding progressed, CARMA sampled the position of the slider 10 times per second and saved second-by-second means of observer ratings. At the conclusion of the video, observers' collected ratings were displayed in the program's Annotation Viewer window *(see Figure 1)*, and observers exported their ratings into an EXCEL file where data were integrated and analyzed.

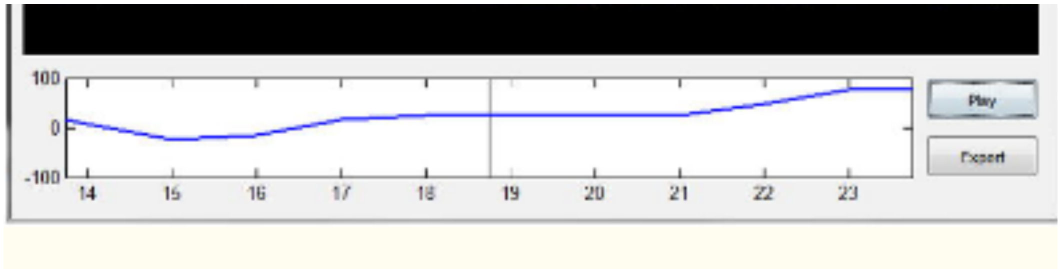

Figure 1. Example time-course of CARMA ratings in Annotation Viewer window collected throughout observational coding sequence.

Over twenty-five undergraduate research assistants were trained in the coding procedures. Each research assistant coded approximately fifteen videos per week. Between 2 to 12 trained observers were assigned to code each video depending on how challenging it was to achieve interrater reliability. Observers were instructed to view each video twice, once without rating, and then once again while performing the rating on a given partner's video footage. Note that each video only contained one partner's face in the frame (i.e., a single video contained an 8-minute emotional support or conflict interaction for one given partner); thus, two separate videos per dyadic interaction were coded. Specifically, there were two videos to code per dyad within the conflict videotapes given that couples only engaged in one conflict discussion, whereas there were four videos to code per dyad within the social support videotapes given that couples engaged in two support discussions and took turns as support providers and recipients. Videos were presented in blocked randomized order so that the order of which partner was rated first in a dyad differed across observers within a block. Reliabilities of each coded time-series were calculated each week and reviewed in weekly observer meetings. As addressed by Girard and Cohn (2016), these meetings were useful to combat observer drift (e.g., error because of fatigue, forgetting, apathy, or the accumulation of bad habits) by collectively analyzing and standardizing the criteria that observers use to assign measurements to items. Inter-rater reliability was assessed using intra-class correlations (McGraw & Wong, 1996), which permitted the inclusion or exclusion of between-rater variance as part of the error variance. ICCs that did not reach at least .60 between the first group of raters for a given video were reviewed and discussed by the observers and me during our weekly meetings to address issues surrounding discrepancies. My decision to aim for ICCs of at least 0.60 aligns with existing research suggesting that the 0.50 to 0.60 cut-off reflects moderate to good reliability across time-varying observational ratings, in which discrepancies between raters are more likely to emerge at more precise, moment-to-moment units of measurement compared to global ratings of interactions (Hallgren, 2012). Videos that did not initially meet the reliability threshold were then reassigned throughout future coding tasks until they became reliable between raters. Across the 108 total conflict videotapes, 96% (104 videotapes) were reliably coded at 0.6 or above, with an average ICC of 0.71 across all videotapes. Of the remaining 4 videotapes, 3 of them (approximately 3% of total tapes) still reached a moderate reliability threshold with an ICC above 0.50, with only 1 videotape (approximately 1% of total tapes) with an ICC below 0.50. Across the 208 total social support videotapes, 93% (194 videotapes) were reliably coded at 0.6 or above, with an average ICC of 0.63 across all videotapes. Of the remaining 14 videotapes, 10 of them (approximately 5% of total tapes) still reached a moderate reliability threshold with an ICC above 0.50, with only 4 videotapes (approximately 2% of total tapes) with an ICC below 0.50. All videotapes were included in final analyses as a conservative approach to determine whether significant associations between neural synchrony and behavior may still emerge over and above any potential noise of the few unreliable videotapes.

Measures

Time-Varying Observed Partner Behavior as Behavioral Connection/Disconnection

Dimensions of behavioral connection and disconnection ranged from -100 (high disconnection) to +100 (high connection) and were rated continuously, sampled at a rate of once per second. A dot moved in accordance with the current position of the cursor displayed on an axis during the coding process to provide visual feedback on current ratings. Observers were instructed to make ratings by moving the cursor in a continuous manner in accordance with the target person's statements, verbal tone, and nonverbal behaviors, of which constituted any change in degrees of behavioral connection and/or disconnection. Raters kept the cursor in place for a given behavioral rating until they noticed an observable change that warranted a new rating.

Moment-to-moment observed behavior was captured and assessed through a novel coding scheme using the behavioral connection/disconnection spectrum. This spectrum was broadly operationalized as the degree to which targets demonstrated understanding, validation, and alignment with their partners versus misunderstanding, invalidation and misalignment with partners. Throughout social support and conflict interactions, mild behavioral connection was broadly characterized as targets' maintenance of general attentiveness to their partners through nonverbal cues such as seeking/maintaining eye contact, nodding, etc. Moderate behavioral connection was characterized by targets' verbal demonstration of attempting to understand partners through behaviors such as acknowledging a partner's point of view and validating a partner's feelings. High behavioral connection was broadly characterized by targets' attempts to cooperatively problem-solve and/or directly offer statements of comfort, support, and love to partners. In contrast, mild behavioral disconnection was categorized by a temporary lack of attentiveness and engagement with partners demonstrated through nonverbal cues such as a temporary decrease in eye contact (e.g., looking down at the floor) and appearing temporarily distracted from the conversation (e.g., fidgeting with hoodie strings). Moderate behavioral disconnection was characterized by targets' verbal lack of understanding and validation for their partners (e.g., directly invalidating a partner's statement, making statements showing a lack of consideration for a partner's feelings, etc.). High behavioral disconnection was characterized through behaviors demonstrating a lack of understanding, care, and respect for partners, such as harsh criticism and contempt, placing blame on partners, overtaking the conversation (e.g., frequent interruptions), and withdrawal from the conversation (e.g., stonewalling). See *Figure 2* below for a visual depiction of the broad behavioral connection versus disconnection spectrum, in which the midpoint reflected a zero-point for behavioral neutrality.

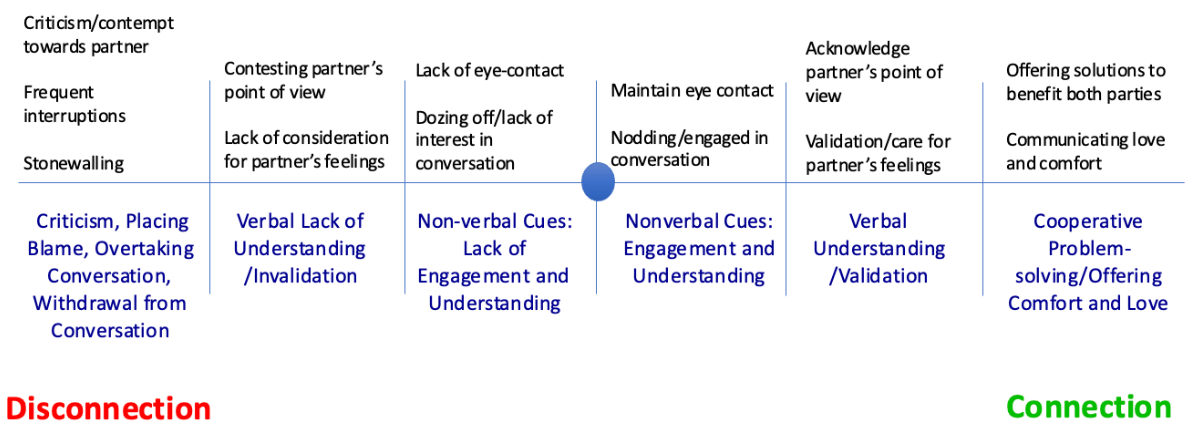

Figure 2. Diagram of the Behavioral Connection-Disconnection Spectrum.

The diagram of the behavioral connection-disconnection spectrum above was used to familiarize coders with the general coding scheme across social support and conflict interactions. Following their initial orientation, coders were divided into separate teams of social support raters and conflict raters, where members of each team specialized on coding more detailed moment-to-moment nuances within the specific type of interaction they were assigned to. These detailed codes are more extensively described in the following sections, and they were chosen based on both existing patterns of behavior frequently documented by couples' researchers (e.g., criticism and withdrawal) (e.g., Williamson, Bradbury, Trail, & Karney, 2011), as well as recurring behavioral patterns I observed myself within each type of interaction while viewing the tapes (e.g., support providers frequently asking recipients about their feelings surrounding the emotionally distressing topic of discussion). It is also worth noting that both the broader axis described above, and the detailed codes described below, served as a *general guide* to help standardize the way in which observers assessed the degree that certain behaviors may have reflected either side of the spectrum. However, each coding guideline was not necessarily all-encompassing, in which there were 1) many instances where multiple codes within the spectrum occurred simultaneously to additively affect the degree of behavioral connection/disconnection ratings (e.g., nonverbal cues occurring in conjunction with verbal behaviors), and 2) unique contextual nuances within certain interactions which may have additionally contributed to coding decisions following group discussions.

Codes for Behavioral Connection

Refer to the lefthand side of *Figure xx* below for detailed point-based coding guidelines of behavioral connection across social support interactions and the lefthand side of *Figure xx* below for the detailed coding guidelines for conflict interactions. Refer to the *Appendix* for an in-depth description of coding for behavioral connection based on these guidelines. Across conflict and social support interactions, behavioral connection was assessed through five categories including 'Nonverbal Cues', 'Asking Questions', 'Storytelling and Disclosure', 'Empathy, Agreeableness, and Validation', and 'Affection and Positivity'. Concrete examples of various behaviors falling under each category were provided, along with a general guideline for the degree of behavioral connection each code would generally be rated as based on a 0 to 100 scale.

Codes for Behavioral Disconnection

Across guidelines for both conflict and support, behavioral disconnection was assessed through four categories encompassed by 'Nonverbal Cues', 'Asking Questions', 'Storytelling and Disclosure', and 'Critical and Defensive Commentary'. Concrete examples of various behaviors falling under each category were provided, along with a general guideline for the degree of behavioral disconnection each code would generally be rated as based on a 0 to -100 scale. Refer to the righthand side of *Figure 3* below for the detailed coding guidelines for social support interactions and the righthand side of *Figure 4* below for the detailed coding guidelines for conflict interactions. Refer to the *Appendix* for an in-depth description of coding for behavioral disconnection based on these guidelines.

Connection

Nonverbal Cues

- Shifty eye-contact but engaged in convo → +5
- Maintained eye-contact → +15
- Leaning in/nodding → +20 to +25
- Making empathetic face on behalf of partner who is also feeling the same way (e.g., shared disgust over something bad that happened) → +30 to +35
- Genuine/positive laughter (e.g., expressing shared humor rather than shared uncomfortable feelings) → +30 to +40
- Empathetic Crying (own tears in response to partner's tears) → + 100

Asking Questions

- Clarifying questions to show partner is following along/engaged (e.g., oh ok, when was this?) → +40
- Deepening questions (e.g., how you do feel about that now?) → + 50
- Question Asking for Partner's Perspective (e.g., "so how will we reach a resolution?", "did we resolve this?") → +40 to +50

Storytelling and Disclosure

- Openly discussing their topic → neutral at 0 but then refer to nonverbal cues for additional coding
- Talking about own personal experience/example as a way to clarify or illuminate more on discussion → + 40 to +50
- Constructively Getting Discussion Back on Topic (e.g., "Let's get back on track with 'x') → +20 to +30

Empathy, Agreeableness, and Validation

- Mhm/yeahs → +30
- Basic Validation/Agreement (e.g., "you're right", "I get that") → +40
- Concrete Validation (e,g,. "Yeah that must be tough") → +50
- Positive Problem-Solving/Constructive Advice (e.g., "maybe 'x' could help us by…", "lets find a middle ground") → +40 to +60
- Expressing Appreciation (e.g., "Thank you for trying") → +50 to +60
- Praise Validation (e.g., "I'm proud of you for trying to work through this") → + 60
- Accepting Responsibility (e.g., "Yeah you're right") → +50 to +60
- Expressing Proactivity (e.g., "I'll work on this) → +60 to +70

Affection and Positivity

- Touching or verbalizing desire to touch (e.g., "I wish I could hold your hand right now") → +50 to +60

****note: if other partner responds "no" to touching, ignore and do not code as disconnection because they are following experimental guidelines*

- Expressing optimism (e.g., "I think it'll be okay") → +40
- Compliments/Positive Affirmations (e.g., "You're amazing", "I believe in you") → + 60 to +70
- Saying "I love you" → +80

Disconnection

Nonverbal Cues

- Shifty eye-contact and slightly disengaged (e.g., looking away more than looking at partner → -5
- Overall lack of eye-contact/engagement at beginning → -15 (this code should continue to become more negative if convo progresses and lack of eye-contact maintains, see bottom bullet point)
- Non-responsiveness (e.g., awkward silence in response to what partner says) → -30 to -50 (can continue to become more negative if convo progresses this way, see bottom bullet)
- Leaning away/fidgeting and playing with stuff (e.g., with sweatshirt strings) → -20 to - 25
- Nervous laughter showing partner is uncomfortable → - 30 -to- 40
- Making disgusted face showing disagreement with/opposition to partner → -40 to -50
- Bored Yawning → -40 to -50
- Eye-rolling → - 40 to - 50
- Contemptuous/sarcastic laughter, irritated groans/sighs → - 50
- Dominant withdrawal: lack of eye-contact/disengaged throughout all or most of conversation → -80 to -100

Asking Questions

- Defensive questions (e.g., "Well what else was I supposed to do?") → - 30 to -40
- Accusatory/pointed questions (e.g., "Why didn't you just…?")→ -40 to -50
- Question Attempting to End the Conversation (e.g., "Okay can we be done with this conversation now?") → -40 to -50

Storytelling and Disclosure

- Not open to sharing experiences without partners probing → -10 then refer to nonverbal cues for additional coding
- Topic shifting (e.g., going off on a tangent) → -10 to - 20
- Talking about own experience to invalidate partner's (e.g., "Well I was able to do "x" so it shouldn't be that hard for you") → -50

Critical/Defensive Comments

- Nonhostile disagreement → -20
- Expressing pessimism (e.g., "I just don't know if we can resolve this") → -30 to -40
- "Yes, But-ing"/Denial → -30 to -40
- Reluctant/Disingenuous Agreement (e.g., "fine yeah", "yeah whatever") → -30 to -50
- Expressing not being on the same page (e.g., "I just don't understand your point") → - 30 to -50
- Passive Aggressive Remarks (e.g., "Whatever, it's fine") → -40 to -60
- Sarcasm/Hostile Sarcasm (e.g., "yeah bc you're so perfect right") → -40 to -60
- Prescription/Prescriptive Advice (e.g., "You must…", "You need to…") → -40 to -60
- Lecturing/Moralizing (e.g., "You should have known better") → -50 to -60
- Behavior Faulting/Negative Attributions (e.g., "It's bc you're so…") → -50 to- 70
- Prescriptive Threat (e.g., "if you don't do "x", then I'm done") → -70 to -80
- Belligerence/Verbal Attack/Yelling (e.g., "You are terrible at handling this!") → - 90 to - 100

Figure 3. Detailed Codes Across the Connection-Disconnection Spectrum for Conflict Interactions.

Connection

Nonverbal Cues

- Shifty eye-contact but engaged in conversation → +5
- Maintained eye-contact → +15
- Leaning in/nodding → +20 to +25
- Making empathetic face on behalf of partner who is also feeling the same way (e.g., shared disgust over something bad that happened) → +30 to +35
- Genuine/positive laughter (e.g., expressing shared humor rather than shared uncomfortable feelings) → +30 to +40
- Recipient crying adding to greater connection (e.g., paired with openly expressing vulnerability/looking to partner for support) → +10 to +20 **in addition to** previous score
- Empathetic Crying (own tears in response to partner's tears) → + 100

Asking Questions

- Clarifying questions to show partner is following along/engaged (e.g., oh ok, when was this?) → +40
- Deepening questions (e.g., how you do feel about that now?) → +50
- Question about Other Person's Opinion (e.g., what do you think about that?") → +40 to +50

Storytelling and Disclosure

- Support recipients openly sharing their experience → neutral at 0 but then refer to nonverbal cues for additional coding
- Support recipients expressing how they FEEL about situation/feelings of vulnerability (e.g., "this was very difficult for me, "I was scared", etc.) → +30 to +50
- Talking about own personal experience/similar story to validate partner's experiences → + 40 (if story is meant for clarification, e.g., "was this like the time when I…") to +50 (if story is meant to demonstrate how partner directly relates, e.g., "yeah I understand because one time I…")
- Constructively Getting Discussion Back on Topic → +20 to +30

Empathy, Agreeableness, and Validation

- Mhm/yeahs → +30
- Basic Validation/Agreement (e.g., "you're right", "I get that") → +40
- Concrete Validation (e.g., "Yeah that must have been so hard", "I'm sorry you had to deal with that") → +50
- Constructive Advice (e.g., "maybe 'x' could help by…") → +40 - +60
- Expressing Appreciation (e.g., "Thank you for being there for me", "You helped me get through it") → +50 to +60
- Praise Validation (e.g., "I'm proud of you for overcoming this", "You're so strong") → + 60

Affection and Positivity

- Touching or verbalizing desire to touch (e.g., I wish I could hold your hand right now) → +50 to +60

****note: if other partner responds "no" to touching, ignore and do not code as disconnection because they are following experimental guidelines*

- Expressing optimism (e.g., "I think it'll be okay") → +40
- Compliments/Positive Affirmations (e.g., "You're amazing", "I believe in you") → + 60 to +70
- Saying "I love you" → +80

Disconnection

Nonverbal Cues

- Shifty eye-contact and slightly disengaged (e.g., looking away more than looking at partner → -5
- Overall lack of eye-contact/engagement at beginning → -15 (this code should continue to become more negative if convo progresses and lack of eye-contact maintains, see bottom bullet point)
- Non-responsiveness (e.g., awkward silence in response to what partner says) → -30 to -50 (can continue to become more negative if convo progresses this way, see bottom bullet)
- Leaning away/fidgeting and playing with stuff (e.g., with sweatshirt strings) → -20 to -25
- Nervous laughter showing partner is uncomfortable → - 30 -to- 40
- Making disgusted face showing disagreement with/opposition to partner → -40 to -50
- Bored Yawning → -40 to -50
- Eye-rolling → - 40 to - 50
- Contemptuous/sarcastic laughter, irritated groans/sighs → - 50
- Dominant withdrawal: lack of eye-contact/disengaged throughout all or most of conversation → -80 to -100
- Recipient crying adding to greater disconnection (e.g., tears in awkward silence/primarily looking away for extended time) → -10 to -20 **in addition to** previous score

Asking Questions

- Defensive questions (e.g., "Well what else was I supposed to do?") → - 30 to -40
- Accusatory/pointed questions (e.g., "Why didn't you just…?")→ -40 to -50

Storytelling/Disclosure

- Not open to sharing experiences without partners probing → -10 then refer to nonverbal cues for additional coding
- Topic shifting (e.g., going off on a tangent) → -10 to - 20
- Talking about own experience to invalidate partner's (e.g., "Well I was able to overcome "x" so it shouldn't be that hard for you") → -50
- Shutting down conversation (e.g., "I don't have anything else to say") → -30 to -50

Critical/Defensive Comments

- Non-hostile disagreement → -20
- Expressing pessimism (e.g., "I just don't think anything will help") → -30 to -40
- "Yes, But-ing"/Denial → -30 to -40
- Reluctant/Disingenuous Agreement (e.g., "fine yeah", "yeah whatever") → -30 to -50
- Expressing not being on the same page (e.g., "I just don't understand your point") → -30 to -50
- Passive Aggressive Remarks (e.g., "Whatever, it's fine") → -40 to -60
- Sarcasm/Hostile Sarcasm → -40 to -60
- Prescription/Prescriptive Advice (e.g., "You must…", "You need to…") → -40 to -60
- Lecturing/Moralizing (e.g., "You should have known better") → -50 to -60
- Behavior Faulting/Negative Attributions (e.g., "It's because you're so…") → -50 to- 70
- Prescriptive Threat (e.g., "if you don't do "x", then I'm done") → -70 to -80

*Figure 4. Detailed Codes Across the Connection-Disconnection Spectrum for Social Support Interactions. *Black text = applicable codes to both providers and recipients, *Blue text = primarily applicable codes to support providers, *Green text = primarily applicable codes to support recipients.*

Time-varying Neural Synchrony

The simplest approach to computing neural synchrony of hemodynamic neural signals is to calculate the correlation coefficient between the two time series as described in Studies 1 and 2. While Pearson correlations are straightforward measurements of the global synchrony between two signals, they may not capture more nuanced covariation that occurs over time. Computing time-varying neural synchrony with correlation requires dividing neural time series into smaller data windows, sacrificing a degree of accuracy in the correlation value estimate. In contrast, an alternative approach known as Wavelet Transform Coherence (WTC) is available when an estimation of time-varying synchrony is required. To estimate coherence between two signals, WTC first relies on the fact that any time series can be created from the convolution of wavelet functions by varying their amplitude, length, and (unlike sine waves) localized position in time. WTC estimates coherence by decomposing neural signals into their wavelet power spectra, and then identifying where in frequency and time these power spectra are very similar. This enables a moment-to-moment estimation of neural synchrony, which can also be averaged across to obtain similar information as a correlation measure that the ISC method produces. Further, the phase shift of the two time courses do not impact WTC values, so those can be investigated separately to detect any lag in synchrony. For more information on wavelets and WTC, see Graps (1995) and Grinsted, Moore, & Jevrejeva (2004). This approach is unusual in fMRI research on neural synchrony, but common in fNIRS studies. In this dissertation, I used WTC to compute time-varying neural synchrony.

To compare broader areas of interest and increase the signal-to-noise ratio of the neural data, four new time series were created by averaging across active channels within the predetermined ROIs. See Study 1 and Study 2 for ROI descriptions. If a subject lost more than

25% of the channels in a given ROI, further analysis was not conducted for that dyad within that ROI. The wavelet coherence package in MATLAB was used to calculate WTC values for dyadic partner's time series using the default Morlet wavelet for transformation of both time and frequency domain (Grinsted et al. 2004). Statistical significance of coherence values was estimated with the Monte Carlo method and autocorrelation was regressed out with the AR1 model. Two frequency bands of interest (FOI) were chosen based on previous research that has shown differentiation in rest (VLFO = 0.008-0.04) and task based (LFO = 0.04-0.09) neuronal frequencies (Liu et al., 2016; Tan et al., 2016). This choice is also supported by the correlation of higher frequencies with language production and processing while lower frequencies have been related to emotional and non-verbal cognitive processes (Nozawa et al., 2016). An additional power spectral analysis was performed which confirmed that both FOIs predominated the conversational data. After WTC of dyadic partner's ROI time series, coherence values were Fisher's z-scored and averaged across each FOI to provide a single vector of coherence values for each time series. Coherence values for each FOI were also averaged for a singular time invariant WTC value for each ROI within each dyad. Re-sampling of the coherence values was then performed to align with the second-by-second time-scale CARMA ratings of the conversations. Subsequent averaging of WTC values was then performed for each bin of time (i.e., 5s, 15s, and 30s).

Analytic Plan

Data were analyzed using multilevel modeling (MLM). Across all analyses, both partners from each couple were included in the same model to account for interdependence in the dyadic data. All variables in the models were first z-scored to ensure measurement on comparable scales between time-varying neural data and time-varying CARMA ratings. Analyses were conducted in SAS version 9.4 using the Proc Mixed procedure.

Revisiting Aim 1

Assess concurrent associations between second-to-second observed behavior and second-to-second neural synchrony across social support and conflict interactions in couples.

Aim 1 Analyses: Concurrent Models

Within-person models were utilized to test whether moments of above or below average degrees of behavioral connection within partners were *concurrently* associated at the second-to-second level with moments of above or below average degrees of neural synchrony at the same point in time, across social support and conflict interactions. *Equation 1* depicts an example of the single-intercept model structure corresponding to this analysis for conflict and *Equation 2* depicts the dual-intercept model structure for social support with separate provider and recipient intercepts, in which degrees of time-varying mPFC synchrony between partners is concurrently associated with partners' degree of behavioral connection at the same point in time at second-to-second intervals. Note that since neural synchrony is being measured as a dyad-level outcome, longitudinal autoregressive multilevel models were implemented across both social support and conflict interactions, without the need to control for dyadic interdependence.

Equation 1: Concurrent Models for Conflict

Level 1 (WITHIN-PERSON EFFECTS)

$$mPFC\ Synchrony_{dt} = \beta_{0id} + \beta_{1id}(time_{idt} - 1) + \beta_{2id}(Behavioral\ Connection_{idt} - Behavioral\ Connection_{id.}) + \varepsilon_{idt} \quad (1)$$

Level 2 (BETWEEN-DYAD EFFECTS)

$$\beta_{0id} = \gamma_{000} + \gamma_{001}(\mathit{Behavioral\ Connection}_{id.} - \mathit{Behavioral\ Connection}_{..}) + u_{0id} \quad (2)$$

$$\beta_{1id} = \gamma_{10} + u_{1id}$$

(3)

$$\beta_{2id} = \gamma_{20} + u_{2id} \quad (4)$$

Equation 2. Concurrent Models for Social Support

Level 1 (WITHIN-PERSON EFFECTS)

$$\mathit{mPFC\ Synchrony}_{dt} = \beta_{0id} + \beta_{1id}(\mathit{time}_{idt} - 1) + \quad (1)$$

$$\beta_{2id}(\mathit{Behavioral\ Connection}_{idt} - \mathit{Behavioral\ Connection}_{id.}) + \varepsilon_{idt}$$

Level 2: (2-intercept approach): (SEPARATING WITHIN-DYAD EFFECTS)

$$\beta_{0id} = \gamma_{00d}(\mathit{prov}._{d}) + \gamma_{01d}(\mathit{recip}._{d}) \quad (2)$$

$$\beta_{1id} = \gamma_{01d}(\mathit{prov}._{d}) + \gamma_{11d}(\mathit{recip}._{d}) \quad (3)$$

$$\beta_{2id} = \gamma_{20d}(\mathit{prov}._{d}) + \gamma_{21d}(\mathit{recip}._{d}) \quad (4)$$

Level 3: (FIXED AND BETWEEN-DYAD/INDIVIDUAL EFFECTS)

$$\gamma_{00d} = \delta_{000} + \delta_{001}(\mathit{Behavioral\ Connection}_{d.} - \mathit{Behavioral\ Connection}_{..}) + \nu_{001d} \quad (5)$$

$$\gamma_{20d} = \delta_{20} + \nu_{20d} \quad (9)$$

$$\gamma_{01d} = \delta_{000} + \delta_{010}(Behavioral\ Connection_{d.} - Behavioral\ Connection_{..}) + \nu_{010d} \quad (6)$$

$$\gamma_{10d} = \delta_{10} + \nu_{10d} \quad (7)$$

$$\gamma_{11d} = \delta_{11} + \nu_{11d} \quad (8)$$

$$\gamma_{21d} = \delta_{21} + \nu_{21d} \quad (10)$$

For *Equation 1*, the outcome is at the dyad-level. Here, the Level 1 equation corresponds to within-person effects, and equations at Level 2 corresponds to between-dyad effects . At Level 1 in Equation 1, β_{1id} controls for potential linear effects of time ($time_{dt} - 1$) within the time series. β_{2id} reflects the effect of person-mean centered behavioral connection ($Behavioral\ Connection_{idt} - Behavioral\ Connection_{id.}$), for individual, i , in dyad, *d*. Specifically, $Behavioral\ Connection_{id.}$ reflects person-mean scores of partners' degree of behavioral connection. These person-mean scores are then subtracted from observed scores of behavioral connection at a specific measurement occasion ($Behavioral\ Connection_{idt}$) to obtain within-dyad effects (Wang & Maxwell, 2015).

At Level 2, γ_{000} measures the average level of synchrony at Time 1, as well as between-dyad differences in synchrony at Time 1, u_{0id}, after accounting for effects of between-dyad differences in average levels of behavioral connection on synchrony, γ_{001}. Of particular interest were parameters γ_{001} and γ_{20} that provide statistical indexes of (1) estimated average between-dyad differences between behavioral connection and neural synchrony and (2) the estimated average within-dyad association between connection and synchrony.

The dual-intercept model for social support depicted by *Equation 2* utilizes a very similar approach, aside from separating within-dyad effects for providers and recipients at Level

2 to provide separate intercept estimates for each, along with between-dyad differences and individual effects estimated at Level 3. Of particular interest were parameters, δ_{001}, δ_{010}, δ_{20}, and δ_{21} that provide statistical indexes of (1) separate estimates of average between-dyad differences between behavioral connection and neural synchrony for providers and recipients, and (2) separate estimates of average within-dyad associations between connection and synchrony for providers and recipients.

Revisiting Aim 2

Assess lagged associations between neural synchrony and observed behavior at various time-intervals across social support and conflict interactions in couples.

Aim 2a Analyses: Lagged Models with Observed Behavior Associated with Changes in Neural Synchrony across Social Support and Conflict Interactions in Couples

Within-person models were utilized to test whether moments of above or below average degrees of behavioral connection within partners were associated with changes in above or below average degrees of couples' neural synchrony 1, 5, 15, and 30 seconds later, across social support and conflict interactions. *Equation 3* depicts an example of the single-intercept model structure corresponding to this analysis for conflict and *Equation 4* depicts an example of the dual-intercept model structure for social support with separate provider and recipient intercepts. Note that since neural synchrony is still being measured as a dyad-level outcome in these models, lagged autoregressive multilevel models were implemented without the need to control for dyadic interdependence.

Equation 3: Lagged Models for Conflict with Synchrony Outcome

Level 1 (WITHIN-PERSON EFFECTS)

$$mPFC\ Synchrony_{dt} = \beta_{0id} + \beta_{1id}(time_{idt} - 1) + \beta_{2id}\left(Behavioral\ Connection_{id(t-1)} - Behavioral\ Connection_{id.}\right) + \varepsilon_{idt} \tag{1}$$

Level 2 (BETWEEN-DYAD EFFECTS)

$$\beta_{0id} = \gamma_{000} + \gamma_{001}(\ Behavioral\ Connection_{id.} - Behavioral\ Connection_{..}) + u_{001id} \tag{2}$$

$$\beta_{1id} = \gamma_{10} + u_{10id} \tag{3}$$

$$\beta_{2id} = \gamma_{20} + u_{20id} \tag{4}$$

Equation 4. Lagged Models for Social Support with Synchrony Outcome

Level 1 (WITHIN-PERSON EFFECTS)

$$mPFC\ Synchrony_{dt} = \beta_{0id} + \beta_{1id}(time_{idt} - 1) + \beta_{2id}\left(Behavioral\ Connection_{id(t-1)} - Behavioral\ Connection_{id.}\right) + \varepsilon_{idt} \tag{1}$$

Level 2: (2-intercept approach): (SEPARATING WITHIN-DYAD EFFECTS)

$$\beta_{0id} = \gamma_{00d}(prov._{d}) + \gamma_{001d}(recip._{d}) \tag{2}$$

$$\beta_{1id} = \gamma_{01d}(prov._{d}) + \gamma_{11d}(recip._{d}) \tag{3}$$

$$\beta_{2id} = \gamma_{20d}(prov._{d}) + \gamma_{21d}(recip._{d}) \tag{4}$$

Level 3: (FIXED AND BETWEEN-DYAD/INDIVIDUAL EFFECTS)

$$\gamma_{00d} = \delta_{000} + \delta_{001}(Behavioral\ Connection_{d.} - Behavioral\ Connection_{..}) + \nu_{001d} \quad (5)$$

$$\gamma_{01d} = \delta_{000} + \delta_{010}(Behavioral\ Connection_{d.} - Behavioral\ Connection_{..}) + \nu_{010d} \quad (6)$$

$$\gamma_{10d} = \delta_{10} + \nu_{10d} \quad (7)$$

$$\gamma_{11d} = \delta_{11} + \nu_{11d} \quad (8)$$

$$\gamma_{20d} = \delta_{20} + \nu_{20d} \quad (9)$$

$$\gamma_{21d} = \delta_{21} + \nu_{21d} \quad (10)$$

Note that the structure of these models is nearly identical to the previous concurrent models described above for social support and conflict, with one exception. At Level 2, person-mean scores are subtracted from lagged scores of behavioral connection at the previous measurement occasion ($Behavioral\ Connection_{id(t-1)}$) to obtain within-dyad effects so that associations between prior behavioral connection and future neural synchrony could be measured at different time intervals. For *Equation 3*, of particular interest were parameters γ_{001} and γ_{20}, that provide statistical indexes of (1) estimated average between-dyad differences between behavioral connection and neural synchrony and (2) the estimated average within-dyad association between connection and changes in neural synchrony at the following timepoint. For *Equation 4*, of particular interest were parameters δ_{001}, δ_{010}, δ_{20}, and δ_{21} that provide statistical indexes of (1) separate estimates of average between-dyad differences between behavioral connection and neural synchrony for providers and recipients, and (2) separate estimates of average within-dyad associations between connection and changes in neural synchrony at the following timepoint for providers and recipients.

Aim 2b Analyses: Lagged Models with Neural Synchrony Associated with Changes in Observed Behavior across Social Support and Conflict Interactions in Couples

Within-person models were utilized to test whether moments of above or below average degrees of behavioral connection within partners were associated with changes in above or below average degrees of couples' neural synchrony 1, 5, 15, and 30 seconds later, across social support and conflict interactions. *Equation 5* depicts an example of the single-intercept model structure corresponding to this analysis for conflict and *Equation 6* depicts an example of the dual-intercept model structure for social support with separate provider and recipient intercepts. Note that since the behavioral connection outcome is at the individual level, lagged autoregressive multilevel models were implemented controlling for dyadic interdependence. Otherwise, the model structures were nearly identical to the prior models described above. For *Equation 5*, of particular interest were parameters γ_{001} and γ_{20}, that provide statistical indexes of (1) estimated average between-dyad differences between neural synchrony and behavioral connection and (2) the estimated average within-dyad association between neural synchrony and changes in behavioral connection at the following timepoint. For *Equation 6*, of particular interest were parameters δ_{001}, δ_{010}, δ_{20}, and δ_{21} that provide statistical indexes of (1) separate estimates of average between-dyad differences between neural synchrony and behavioral connection for providers and recipients, and (2) separate estimates of average within-dyad associations between neural synchrony and changes in behavioral connection at the following timepoint for providers and recipients.

Equation 5: Lagged Models for Conflict

Level 1 (TIME-LEVEL):

$$Behavioral\ Connection_{idt} = \beta_{0id} + \beta_{1id}(time_{idt} - 1) +$$

$$\beta_{2id}\left(Behavioral\ Connection_{id(t-1)} - Behavioral\ Connection_{id.}\right) +$$

$$\beta_{3id}\left(neural\ synchrony_{d(t-1)} - neural\ synchrony_{d.}\right) + \varepsilon_{idt}$$

Level 2 (Single Intercept Approach): (SEPARATING WITHIN-DYAD EFFECTS)

$$\beta_{0id} = \gamma_{00d} + u_{0d} \tag{2}$$

$$\beta_{1id} = \gamma_{01d} + u_{1d} \tag{3}$$

$$\beta_{2id} = \gamma_{20d} + u_{2d} \tag{4}$$

$$\beta_{3id} = \gamma_{20d} + u_{3d} \tag{5}$$

Equation 6: Lagged Models for Social Support

Level 1: (TIME-LEVEL)

$$Behavioral\ Connection_{idt} = \beta_{0id} + \beta_{1id}(time_{idt} - 1) +$$

$$+ \beta_{2d}\left(neural\ synchrony_{d(t-1)} - (neural\ synchrony_{d.}\right) + \varepsilon_{idt}$$

Level 2: (2-intercept approach): (SEPARATING WITHIN-DYAD EFFECTS)

$$\beta_{0id} = \gamma_{000d}(prov._{d}) + \gamma_{001d}(recip._{d}) \tag{2}$$

$$\beta_{1id} = \gamma_{10d}(prov._{d}) + \gamma_{11d}(recip._{d}) \tag{3}$$

$$\beta_{2id} = \gamma_{20d}(prov._{d}) + \gamma_{21d}(recip._{d}) \tag{4}$$

Level 3: (FIXED AND BETWEEN-DYAD/INDIVIDUAL EFFECTS)

$$\gamma_{00d} = \delta_{000} + \delta_{001}(Behavioral\ Connection_{d.} - Behavioral\ Connection_{..}) + \nu_{001d} \quad (5)$$

$$\gamma_{01d} = \delta_{000} + \delta_{010}(Behavioral\ Connection_{d.} - Behavioral\ Connection_{..}) + \nu_{010d} \quad (6)$$

$$\gamma_{10d} = \delta_{10} + \nu_{10d} \quad (7)$$

$$\gamma_{11d} = \delta_{11} + \nu_{11d} \quad (8)$$

$$\gamma_{20d} = \delta_{20} + \nu_{20d} \quad (9)$$

$$\gamma_{21d} = \delta_{21} + \nu_{21d} \quad (10)$$

Results

Preliminary Analyses and Descriptive Statistics

Given that descriptive information cannot be obtained for time-varying data on a moment-to-moment basis, below I describe descriptive statistics and correlations across time-averaged neural synchrony and time-averaged behavioral connection to understand how these metrics behave overall. However, note that nuances and fluctuations across these metrics over time are not captured here. *Table 1* displays descriptive statistics and bivariate correlations among the averaged time-varying couple-level neural synchrony variables and averaged time-varying individual-level behavioral ratings in partners from conflict interactions, *Table 2* displays these same metrics for providers and recipients from social support Discussion 1, and *Table 3* displays these metrics for providers and recipients from social support Discussion 2. Across all types of interactions, synchrony values in each region were small as expected, with substantial variability in average degrees of synchrony across couples. As indicated by the 'N' column, signal loss for specific channels associated with each brain region did not exceed 25%

for most couples aside from a lower N for somatosensory cortex synchrony in the support data. Averaged time-varying behavioral connection ratings within conflict interactions were close to zero on average leaning towards slight disconnection with substantial variability, suggesting that most couples' conversations averaged out to fairly neutral interactions as expected. Averaged time-varying behavioral connection ratings within social support interactions were higher towards degrees of mild connection with substantial but less variability compared to conflict, suggesting that most couples' conversations averaged out to be more behaviorally connected than couples from conflict interactions. This difference in degrees of connection between conflict and social support discussions was as expected, given that partners are likely more motivated to behave favorably in conversations when their goals are not at odds with one another. However, it is important to note that since this metric of behavioral connection was averaged over time, it is also possible that moments of higher and lower connection or disconnection at specific points in time may have been cancelled out.

As revealed by the table, averaged degrees of time-varying synchrony throughout all interactions were weakly correlated as a whole, aside from a couple of moderate correlations between synchrony in different regions in conflict interactions (e.g., between mPFC synchrony and lPFC synchrony). Across social support and conflict interactions, averaged degrees of time-varying synchrony were largely uncorrelated with averaged degrees of time-varying behavioral connection. However, in conflict interactions averaged time-varying mPFC synchrony and TPJ synchrony were significantly positively correlated with averaged time-varying behavioral connection as expected, but only in one partner at a modest magnitude. Table 4 further displays correlations between averaged time-varying neural synchrony in the same regions across social support Discussions 1 and 2, in which only averaged time-varying mPFC synchrony was significantly correlated between Discussion 1 and Discussion 2. These nonsignificant associations within the same regions between the two discussions once more suggest that the experiences captured by synchrony in Discussion 1 may be largely distinct from that of Discussion 2. Thus, this informed our decision to run separate analyses for each discussion when assessing associations between neural synchrony and support-related behavioral connection in following sections.

Table 1: Correlations and Descriptive Statistics of Averaged Time-Varying Couple-level Neural Synchrony Predictors and Averaged Time-varying Individual-Level Behavioral Ratings for Partners in Indistinguishable Dyads

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**P1 N**	**P1 Mean**	**P1 SD**
(1) mPFC Synchrony		0.20	0.35*	-0.05	0.27*	53	0.27	0.06
(2) TPJ Synchrony	0.20		0.09	0.21	0.32*	51	0.27	0.07
(3) lPFC Synchrony	0.35**	0.09		0.10	0.12	51	0.29	0.08
(4) SPL Synchrony	-0.05	0.21	0.10		-0.03	45	0.26	0.07
(5) Behavioral Rating	0.03	0.29*	0.01	0.29		52	-4.06	20.94
P2 N	53	51	51	45	51			
P2 Mean	0.27	0.27	0.29	0.26	-4.67			
P2 SD	0.06	0.07	0.08	0.07	22.00			

Note: Though analyses collapse across all individuals as indistinguishable dyads, partner 1 and partner 2 descriptive data are shown separately above (partner 1) and below (partner 2) the diagonal to ensure unbiased r-values for behavioral rating correlation estimates.

** $p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

Table 2: Correlations and Descriptive Statistics of Averaged Time-Varying Couple-level Neural Synchrony Predictors and Averaged Time-varying Individual-Level Behavioral Ratings Across Providers and Recipients in Support Discussion 1.

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**Provider N**	**Provider Mean**	**Provider SD**
(1) mPFC Synchrony		-0.12	0.15	-0.13	0.02	0.05	46	0.27	0.71
(2) TPJ Synchrony	-0.12		0.22	0.02	0.10	-0.15	50	0.27	0.79
(3) SMS synchrony	0.15	0.22		0.03	0.05	-0.01	38	0.26	0.82
(4) lPFC Synchrony	-0.13	0.02	0.03		0.25	-0.23	46	0.28	0.07
(5) VA Synchrony	0.02	0.10	0.05	0.25		0.01	48	0.28	0.08
(6) Behavioral Rating	0.06	0.03	0.07	-0.29*	0.01		52	17.52	8.67
Recipient N	46	50	38	46	48	52			
Recipient Mean	0.27	0.27	0.26	0.28	0.28	16.30			
Recipient SD	0.07	0.08	0.08	0.07	0.08	10.26			

Note: Provider values are above the diagonal, recipient values are below the diagonal, and correlations between provider and recipient synchrony are bolded along the diagonal. * $p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 3: Correlations and Descriptive Statistics of Averaged Time-Varying Couple-level Neural Synchrony Predictors and Averaged Time-varying Individual-Level Behavioral Ratings in Support Discussion 2.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	Provider N	Provider Mean	Provider SD
(1) mPFC Synchrony		0.18	0.28	0.10	0.07	-0.04	46	0.27	0.19
(2) TPJ Synchrony	0.18		0.14	0.16	0.15	0.18	50	0.27	0.14
(3) SMS synchrony	0.28	0.14		0.02	0.09	-0.01	38	0.27	0.12
(4) lPFC Synchrony	0.10	0.16	0.02		0.14	-0.06	46	0.28	0.16
(5) VA Synchrony	0.07	0.15	0.09	0.14		-0.04	48	0.28	0.14
(6) Behavioral Rating	-0.20	0.01	0.07	-0.04	0.08		52	15.84	8.74
Recipient N	42	46	33	44	47	51			
Recipient Mean	0.02	0.02	-0.02	0.05	-0.01	17.68			
Recipient SD	1.07	0.72	0.88	0.83	0.53	7.38			

*Note: Provider values are above the diagonal, recipient values are below the diagonal, and correlations between provider and recipient synchrony are bolded along the diagonal. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.*

Table 4: Correlations Between Discussion 1 and Discussion 2 Averaged Time-Varying Couple-level Neural Synchrony

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
(1) mPFC Synchrony	0.28*				
(2) TPJ Synchrony		-0.04			
(3) SMS Synchrony			0.16		
(4) lPFC Synchrony				0.04	
(5) VA Synchrony					-0.17

* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$*

Aim 1: Concurrent Associations Between Second-to-Second Observed Behavior and Second-to-Second Neural Synchrony across Social Support and Conflict Interactions in Couples

Within-person single-intercept models were utilized to test whether moments of above or below average degrees of behavioral connection within partners were *concurrently* associated at the second-to-second level with moments of above or below average degrees of neural synchrony across conflict interactions, and *within-person* dual-intercept models with separate provider and recipient estimates tested these same concurrent associations across social support interactions. All Study 3 analyses were conducted via SAS Version 9.4 using the proc mixed procedure. Note that in the findings described below, greater *connection* refers to scores closer to +100 on the connection-disconnection spectrum and greater *disconnection* refers to scores closer to -100 on the connection-disconnection spectrum.

In conflict interactions, a significant within-person effect emerged when examining concurrent associations between time-varying behavioral connection and time-varying TPJ synchrony, such that in moments when partners were rated above average in degrees of behavioral *disconnection*, they concurrently had above average levels of synchronous TPJ activation at the second-to-second level, contrary to what was expected ($t = -5.93, p < 0.001$). A marginally significant within-person effect emerged for concurrent associations between behavioral connection and mPFC synchrony, such that in in moments when partners were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous mPFC activation as expected. Regarding conflict control regions, when partners were rated above average in degrees of behavioral *disconnection*, they concurrently had greater than average levels of synchronous lPFC activation ($t = -9.32, p < 0.001$), and when partners were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous SPL activation ($t = 5.36, p < 0.001$). No significant between-couple concurrent associations emerged between behavioral connection and neural synchrony across conflict interactions, such that couples who were more disconnected on average across the sample did not have above average degrees of neural synchrony. See *Appendix* for tables depicting each of these associations.

In the first social support discussion, a significant within-person effect emerged when examining concurrent associations between time-varying behavioral connection and time-varying mPFC synchrony, such that in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous mPFC activation with their partners at the second-to-second level as expected ($t = 5.01, p < 0.001$ for providers, $t = 6.75, p < 0.001$ for recipients). A significant within-person effect emerged when examining concurrent associations between time-varying behavioral connection and time-varying TPJ synchrony, such that in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous TPJ activation with their partners as expected ($t = 3.26, p < 0.001$ for providers, $t = 3.41, p < 0.001$ for recipients). A significant within-person effect emerged when examining concurrent associations between time-varying behavioral connection and time-varying somatosensory cortex synchrony, such that in moments when providers were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous somatosensory activation with their partners, contrary to what was expected ($t = 13.89, p < 0.001$). Regarding social support control regions, when providers were rated above average in degrees of behavioral *disconnection*, they concurrently had greater than average levels of synchronous lPFC activation ($t = -8.44, p < 0.001$). and when recipients were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous VA activation ($t = 4.22, p < 0.001$).

In the second social support discussion, a significant within-person effect emerged when examining concurrent associations between time-varying behavioral connection and time-varying mPFC synchrony, such that in moments when providers were rated above average in degrees of behavioral *disconnection*, they concurrently had greater than average levels of synchronous mPFC activation with their partners at the second-to-second level, contrary to what as expected ($t = -6.50, p < 0.001$). A significant within-person effect emerged when examining concurrent associations between time-varying behavioral connection and time-varying TPJ synchrony, such that in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous TPJ activation with their partners as expected ($t = 6.45, p < 0.001$ for providers, $t = 13.48, p < 0.001$ for recipients). A significant within-person effect emerged when examining concurrent associations between time-varying behavioral connection and time-varying somatosensory cortex synchrony, such that in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous somatosensory activation with their partners, contrary to what was expected ($t = 12.50, p < 0.001$ for providers, $t = 15.11, p < 0.001$ for recipients). Regarding social support control regions, when recipients were rated above average in degrees of behavioral *disconnection*, they concurrently had greater than average levels of synchronous lPFC activation ($t = -6.93, p < 0.001$), and when providers and recipients were rated above average in degrees of behavioral *connection*, they concurrently had greater than average levels of synchronous VA activation ($t = 4.67, p < 0.001$ for providers, $t = 8.72, p < 0.001$ for recipients).

No significant between-couple concurrent associations emerged between behavioral connection and neural synchrony across concurrent analyses, in which couples who were more disconnected on average across the sample did not have above average degrees of neural synchrony.

See *Appendix* for models of each concurrent association described above. Refer to *Table 5* for a comprehensive breakdown of all concurrent associations across conflict and social support described above.

Table 5. Breakdown of all Within-Person Concurrent Associations Between Behavioral Connection and Neural Synchrony Across Conflict and Social Support Interactions.

	mPFC	**TPJ**	**SMS**
Conflict	0	- ***	N/A
Social Support D1	+ *** for providers and recipients	+ *** for providers and recipients	+ *** for providers
Social Support D2	- *** for providers	+ *** for providers and recipients	+ *** for providers and recipients

Note: "+" = significant positive association, "-*" = significant negative association, "0" = no significant association, "N/A" = not applicable (i.e., conflict interactions that did not examine somatosensory activity), * = p < 0.05, **p < 0.01, ***p < 0.001*

Aim 2a: Lagged Associations with Observed Behavior Predicting Changes in Neural Synchrony across Conflict and Social Support Interactions in Couples

Within-person single-intercept models were utilized to test whether moments of above or below average degrees of behavioral connection within partners were associated with changes in degrees of neural synchrony 1, 5, 10, and 15 seconds later across conflict interactions, and *within-person* dual-intercept models with separate provider and recipient estimates tested these same lagged associations across social support interactions. All lagged analyses also accounted for the fact that fNIRS uses the BOLD signal to measure net increases in blood oxygenation following neural activity that has already occurred (Logothetis & Wandell, 2004), in which time-varying measures of neural synchrony are assessed at a slight delay after neural activity has already happened by approximately 5 seconds. Given this inherent time-lead of the BOLD signal, I ensured that measures of time-varying brain activity and behavior were more precisely aligned by matching measures of behavior at second 5 to measures of neural synchrony at second 1 as the starting points in time across all lagged analyses.

In conflict interactions, a significant within-person effect emerged when examining lagged associations between time-varying behavioral connection and changes in time-varying TPJ synchrony, such that in moments when partners were rated above average in degrees of behavioral *disconnection*, they shared greater than average levels of synchronous TPJ activation 1 second later ($t = -5.81, p < 0.001$) and 5 seconds later ($t = -2.38, p < 0.05$) with their partners, contrary to what was expected. No associations were found at 15 and 30 second intervals. No associations were found for mPFC synchrony at any time intervals. Regarding Study 1 control regions, when partners were rated above average in degrees of behavioral *disconnection*, they shared greater than average levels of synchronous lPFC activation 1 second later ($t = -9.21, p <$

0.001), 5 seconds later ($t = -3.99$, $p < 0.001$), and 15 seconds later with their partners ($t = -2.08$, $p < 0.05$). This association disappeared at 30 second intervals. Regarding SPL synchrony, when partners were rated above average in degrees of behavioral *connection*, they shared greater than average levels of synchronous SPL activation 1 second later ($t = 5.39$, $p < 0.001$) and 5 seconds later ($t = 2.50$, $p < 0.05$) with their partners. No significant between-couple associations emerged between behavioral connection and neural synchrony across these lagged models, in which couples who were more disconnected on average across the sample did not have above average degrees of neural synchrony.

In the first social support discussion, a significant within-person effect emerged when examining lagged associations between time-varying behavioral connection and changes in time-varying mPFC synchrony, such that in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they shared greater than average levels of synchronous mPFC activation 1 second later ($t = 6.61$, $p < 0.001$ for providers, $t = 4.82$, $p < 0.001$ for recipients) and 5 seconds later ($t = 2.81$, $p < 0.01$ for providers, $t = 1.78$, $p < 0.10$ for recipients) with their partners as expected. At 15 second intervals, a marginally significant association remained for providers only ($t = 1.65$, $p < 0.10$) and disappeared for recipients. All associations disappeared at 30 second intervals. A significant within-person effect emerged when examining lagged associations between time-varying behavioral connection and changes in time-varying TPJ synchrony, such that in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they shared greater than average levels of synchronous TPJ activation 1 second later as expected ($t = 3.43$, $p < 0.001$ for providers, $t = 3.00$, $p < 0.01$ for recipients). This association disappeared at 5 second intervals and reappeared at 15 second intervals for providers ($t = 2.19$, $p < 0.05$) and marginally for recipients ($t = 1.81$, p

< 0.10). All associations disappeared at 30 second intervals. A significant within-person effect emerged when examining lagged associations between time-varying behavioral connection and changes in time-varying somatosensory cortex synchrony, such that in moments when partners were rated above average in degrees of behavioral *connection*, they shared greater than average levels of synchronous somatosensory activation with their partners 1 second later for recipients only ($t = 13.70, p < 0.001$), 5 seconds later for recipients only ($t = 5.91, p < 0.001$), 15 seconds later for providers only ($t = 3.04, p < 0.01$), and 30 seconds later for recipients only ($t = 2.52, p < 0.01$), contrary to what was expected. Regarding Study 2 control regions, when providers and recipients were rated above average in degrees of behavioral *connection*, they had greater than average levels of synchronous lPFC activation 1 second later ($t = 11.28, p < 0.001$ for providers, $t = 7.99, p < 0.001$ for recipients), 5 seconds later ($t = 3.17, p < 0.01$ for providers, $t = 3.92, p < 0.001$ for recipients), and 15 seconds later ($t = 2.86, p < 0.01$ for providers, $t = 2.30, p < 0.01$ for recipients) with their partners. These associations became marginal at 30-second intervals ($t = 1.73, p < 0.10$ for providers, $t = 1.90, p < 0.10$ for recipients). When providers only were rated above average in degrees of behavioral *connection*, they had greater than average levels of synchronous VA activation 5 seconds later ($t = 2.13, p < 0.05$).

In the second social support discussion, a significant within-person effect emerged when examining lagged associations between time-varying behavioral connection and changes in time-varying mPFC synchrony, such that in moments when recipients were rated above average in degrees of behavioral *disconnection*, they shared greater than average levels of synchronous mPFC activation with their partners 1 second later ($t = -6.58, p < 0.001$), contrary to what was expected. At 5 second intervals, associations for recipients remained significant, such that in moments when recipients were rated above average in degrees of behavioral *disconnection*, they shared greater than average levels of synchronous mPFC activation with their partners 5 seconds later ($t = -2.98, p < 0.01$), contrary to what was expected. No associations emerged at 15 and 30 second intervals. A significant within-person effect emerged when examining lagged associations between time-varying behavioral connection and changes in time-varying TPJ synchrony, such that in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they shared greater than average levels of synchronous TPJ activation with their partners 1 second later ($t = 13.31, p < 0.001$ for providers, $t = 6.41, p < 0.001$ for recipients), 5 seconds later ($t = 5.84, p < 0.001$ for providers, $t = 2.90, p < 0.001$ for recipients), and 15 seconds later ($t = 3.23, p < 0.01$ for providers, $t = 2.10, p < 0.05$ for recipients), and 30 seconds later for recipients ($t = 2.47, p < 0.01$). A significant within-person effect emerged when examining lagged associations between time-varying behavioral connection and changes in time-varying somatosensory cortex synchrony, such that in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they shared greater than average levels of synchronous somatosensory activation with their partners 1 second later ($t = 14.93, p < 0.001$ for providers, $t = 12.20, p < 0.001$ for recipients) and 5 seconds later ($t = 6.71, p < 0.001$ for providers, $t = 5.05, p < 0.001$ for recipients) and 15 seconds later ($t = 4.06, p < 0.001$ for providers, $t = 2.44, p < 0.05$ for recipients), contrary to what was expected. This association remained significantly positive at 30 second intervals for recipients only ($t = 2.76, p < 0.01$).

No between-couple differences emerged across any of the models. See *Appendix* for tables of each lagged model described above and refer to *Table 6* below for a comprehensive breakdown of all lagged associations between behavioral connection and neural synchrony across social support and conflict described above.

Table 6. Breakdown of all Within-Person Lagged Models of Behavioral Connection Associated with Changes in Neural Synchrony Across Conflict and Social Support Interactions.

	mPFC	TPJ	SMS
Conflict			
1s	0	- ***	N/A
5s	0	- *	N/A
15s	0	0	N/A
30s	0	0	N/A
Support D1			
1s	+*** for providers and recipients	+*** for providers and recipients	0 for providers and +*** for recipients
5s	+** for providers	0 for providers and recipients	0 for providers and +*** for recipients
15s	0 for providers and recipients	+* for providers and recipients	+***for providers and 0 for recipients
30s	0 for providers and recipients	0 for providers and recipients	0 for providers and +* for recipients
Support D2			
1s	0 for providers and -*** for recipients	+*** for providers and recipients	+*** for providers and recipients
5s	0 for providers and - ** for recipients	+*** for providers and recipients	+*** for providers and recipients
15s	0 for providers and recipients	+** for providers and +* for recipients	+*** for providers and recipients
30s	0 for providers and recipients	0 for providers and +* recipients	0 for providers and +* for recipients

Note: "+" = significant positive association, "-*" = significant negative association, "0" = no significant association, "N/A" = not applicable (i.e., conflict interactions that did not examine somatosensory activity), * = p < 0.05, **p < 0.01, ***p < 0.001*

Aim 2b: Lagged Associations with Neural Synchrony Predicting Changes in Observed Behavior across Social Support and Conflict Interactions in Couples

Within-person single-intercept models were utilized to test whether moments of above or below average degrees of behavioral connection within partners were associated with changes in degrees of behavioral connection 5, 10, and 15 seconds later across conflict interactions, and *within-person* dual-intercept models with separate provider and recipient estimates tested these same lagged associations across social support interactions. Note that I attempted to also run models testing these associations at 1 second intervals. However, they were unable to converge because SAS version 9.4 could not support such large file sizes when running lagged models that additionally required more complicated model specifications to control for dyadic variability (i.e., an additional 'repeated' line in the code).

No significant within-couple lagged association emerged between behavioral connection and neural synchrony emerged in conflict discussions across any timewaves. In the first social support discussion, a significant within-couple lagged association emerged between behavioral connection and neural synchrony, in which recipients who shared above average TPJ synchrony with their partners showed above average behavioral *connection* 15 seconds later as expected ($t = 1.98, p < 0.05$). Contrary to expectations, recipients who shared above average somatosensory synchrony with their partners also showed above average behavioral *connection* 15 seconds later ($t = 3.21, p < 0.01$).

In the second support discussion, a significant within-couple lagged association emerged between behavioral connection and neural synchrony, in which recipients who shared above average TPJ synchrony with their partners showed above average behavioral *connection* 5 seconds later ($t = 2.01, p < 0.05$) and 30 seconds later as expected ($t = 1.98, p < 0.05$). Contrary to expectations, recipients who shared above average somatosensory synchrony with their partners also showed above average behavioral *connection* 15 seconds later ($t = 2.97, p < 0.01$) and 30 seconds later ($t = 3.21, p < 0.01$).

No significant between-couple lagged associations emerged between behavioral connection and neural synchrony across these analyses either. See *Appendix* for tables of each lagged model described above and refer to *Table 7* below for a comprehensive breakdown of all lagged associations between behavioral connection and neural synchrony described above across social support and conflict.

Table 7. Breakdown of all Within-Person Lagged Models of Neural Synchrony Associated with Changes in Behavioral Connection Across Conflict and Social Support Interactions.

	mPFC	TPJ	SMS
Conflict			
5s	0	0	N/A
15s	0	0	N/A
30s	0	0	N/A
Support D1			
5s	0 for providers and recipients	0 for providers and for recipients	0 for providers and recipients
15s	0 for providers and recipients	0 for providers and +* for recipients	0 for providers and +* for recipients
30s	0 for providers and recipients	0 for providers and recipients	0 for providers and recipients
Support D2			
5s	0 for providers and recipients	0 for providers and +* for recipients	0 for providers and 0 for recipients
15s	0 for providers and recipients	0 for providers and 0 for recipients	0 for providers and +** for recipients
30s	0 for providers and recipients	0 for providers and +* for recipients	0 for providers and +** for recipients

Note: "+" = significant positive association, "-*" = significant negative association, "0" = no significant association, "N/A" = not applicable (i.e., conflict interactions that did not examine somatosensory activity), * = $p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

The findings described above provide insight into average within-person and between-person differences in concurrent and lagged associations between neural synchrony and behavioral connection over time. Extending on these findings, I further examined whether between-couple differences existed within the sample by examining covariance parameter estimates across each model. The same pattern of significant effects emerged across every analysis investigating concurrent associations between time-varying behavioral connection and time-varying neural synchrony in each region (i.e., mPFC synchrony, TPJ synchrony, somatosensory cortex synchrony, and synchrony in all control regions) across all types of discussions (i.e., conflict, social support discussion 1, and social support discussion 2). First, the variance around the intercept (u_{0d}) was significant across all models, indicating significant between-couple differences in neural synchrony, over and above degrees of partners' behavioral connection. Second, the variance surrounding the effect of time on degrees of neural synchrony in couples (u_{1d}) was significant across all models, indicating significant between-couple differences in the degree to which neural synchrony changes across the timeseries. This suggests that the strength of the time effect on neural synchrony varies across different couples, in which the linear effect of time on neural synchrony might be stronger for some couples and weaker for others. Taken together, these findings point to the relevance of examining moderators to account for between-couple variability in future research, which will be elaborated on in the discussion.

Discussion

Key Findings and Implications

Expanding on Studies 1 and 2, the primary purpose of Study 3 was to capture and assess more nuanced, time-dependent dynamics between neural synchrony and observed behavior throughout couples' conflict and social support interactions as they unfold. In line with this aim, I assessed concurrent associations between second-to-second neural synchrony and second-to-second observed behavior as well as bidirectional lagged associations between neural synchrony and observed behavior at various time-intervals. Akin to conclusions drawn from Study 2 regarding theoretical and methodological issues with the second social support discussion (i.e., emotional spillover from Discussion 1, physical discomfort from wearing the fNIRS caps for too long, and general experimental fatigue), conclusions drawn from Study 3 primarily summarize and compare conflict findings to findings from the first social support discussion.

Prior to analyzing the time-varying data, descriptive data indicated that time-averaged neural synchrony in empathy-associated brain regions and time-averaged behavioral connection were overall weakly correlated. This supported my justification to examine associations between neural synchrony and observed behavior at the moment-to-moment level, as potential fluctuations and nuances driving these associations were likely washed out by collapsing across the timeseries.

In both conflict and social support, only significant within-person associations emerged in the absence of between-person associations across all concurrent and lagged models. This indicates that akin to the descriptive data, time-dependent nuances in behavior within partners and synchrony within couples were the major underlying factors driving associations between brain activity and behavior, where these associations disappear when those nuances get washed out. Though between-person differences were nonsignificant, significant between-dyad differences emerged between different couples both in their degrees of neural synchrony along with the degree to which their neural synchrony changed across the timeseries. Future research should consider examining moderators which may account for some of this between-dyad variability (e.g., whether couples who have been in relationships for longer periods of time, couples in more securely attached relationships, etc., have greater degrees of neural synchrony and stronger associations between synchrony and behavior over time).

Across conflict and social support, significant associations most consistently emerged when examining the relationship between neural synchrony and behavioral connection at concurrent and narrower time intervals (i.e., at concurrent, 1 second, and 5 second lags). This finding indicates that dynamic associations between shared neural activity and behavior likely occur rapidly throughout the course of conversations, as opposed to delayed associations over longer periods of time. Furthermore, behavioral connection was consistently associated with changes in neural synchrony at 1 and 5 second intervals, but this was rarely the case vice versa when neural synchrony was associated with changes in behavioral connection across conflict and social support. This finding provides limited preliminary evidence in support of the Biobehavioral Synchrony model, in which behavior *may* predict changes in neural synchrony based on these findings. However, caution should be exercised regarding how the directionality of associations are interpreted. Though findings indicate that there are strong associations between brain activity and behavior, causal inferences cannot be made regarding the relationship between the two, in which additional unaccounted factors could be driving changes in both neural synchrony and behavioral connection over time.

Across interactions in the first social support discussion, in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they also shared greater than average levels of synchronous mPFC activation with their partners concurrently, 1 second later, and 5 seconds later. These findings were as expected and support my hypotheses that greater synchronous activity in these regions may relate to more adaptive communication in real-time, in which partners may actively attempt to develop a shared understanding of each other and their discussion. However, when examining conflict, there were neither any significant concurrent nor lagged associations between behavioral connection and greater mPFC synchrony in couples. Moreover, contrary to predictions, in moments when partners were rated above average in degrees of behavioral *disconnection*, they also shared greater than average levels of synchronous TPJ activation with their partners concurrently, 1 second later, and 5 seconds later. Though these findings across the conflict interactions were initially surprising, taken together, findings from conflict and social support interactions provide some preliminary evidence to support a novel framework that has been recently proposed in the field of social neuroscience regarding how mPFC and TPJ activity may function *cohesively* to impact the quality of social interactions (Lieberman, 2022). This theory posits that simultaneous activity in the mPFC and TPJ must occur in order for mentalizing (i.e., actively inferring the mental states of other people, such as their beliefs, intentions, and feelings) to take place within an individual (or between partners in the case of neural synchrony). Within this framework, TPJ activity alone may reflect a perceptual, automatic cue for attributions made towards other people and situations. In order for those cues to lead to mentalizing, this theory suggests that mPFC activity must simultaneously occur, and is thought to involve a more effortful, self-reflective mechanism of processing social situations. Consistent with this theory and with discussion points already addressed in Study 1, it is possible that in the absence of mPFC synchrony, greater synchrony in TPJ activity alone may reflect that partners attend to their conflict in a similar, shared light, which may be harmful towards how they behave in real time if that shared view is negative (which often is the case in conflict). Given that concurrent and lagged effects between mPFC synchrony and behavioral connection were nonsignificant in conflict, this may in part explain why concurrent and lagged associations between behavioral connection and TPJ synchrony were negative. In contrast, significant positive concurrent and lagged associations emerged between behavioral connection and both mPFC and TPJ synchrony in the first social support discussion. This finding further supports the theory since greater TPJ synchrony was positively associated with concurrent and lagged behavior in the presence of mPFC synchrony having the same significant positive associations. Taken together, these positive time-dependent associations in both mPFC and TPJ synchrony may suggest that moments in which partners were able to mutually mentalize were associated with greater behavioral connection in social support. To better understand this phenomenon, in future research I plan to investigate associations between brain state synchrony across entire default mode network (DFN, i.e., a neural synchrony measure that combines across mPFC and TPJ activity between partners) (Mars et al., 2012; Raichle, 2015) and behavioral connection. If positive associations emerge between greater DFN synchrony and increased behavioral connection but negative associations emerge when there is less DFN synchrony, it would offer additional evidence to support that the function of TPJ synchrony may only be adaptive in the presence of mPFC synchrony.

Across interactions in the first social support discussion, in moments when providers and recipients were rated above average in degrees of behavioral *connection*, they also shared greater than average levels of synchronous somatosensory cortex activation with their partners concurrently and 1 second through 30 seconds later. These findings did not support my initial predictions that bidirectional time-dependent associations between somatosensory cortex synchrony and behavioral connections would be negative. In contrast, concurrent and lagged associations between behavioral connection and somatosensory cortex activity were robustly positive, where behavioral connection was positively associated with synchrony at every time interval in only this region. While there is consensus that witnessing another person’s suffering elicits brain activity in the somatosensory cortex which are also active when we ourselves are in pain (Ashar et al., 2017; O'Connell et al., 2019), the function of this pain has been understudied and is up for debate in the social neuroscience literature. While more studies suggest that associations between somatosensory activity and empathic distress may lead to inaction or maladaptive behaviors due to feelings of personal discomfort (e.g., Ashar et al., 2017; Decety & Lamm, 2011; Tice, Bratslavsky, & Baumeister, 2001), others also suggest that these very feelings of pain may adaptively *motivate* people to engage in more prosocial helping behaviors (e.g., Gallo et al., 2018). My findings for somatosensory cortex synchrony are more in support of the latter. However, it is also worth noting that though greater somatosensory cortex synchrony is associated with increased behavioral connection in romantic couples, the same may not be the case for people in other types of relationships (e.g., friends, acquaintances, strangers, etc.). Because romantic partners already know each other well and presumably care deeply for one another, the feelings of discomfort that a partner feels in response to the other's pain may motivate prosocial behavior more readily than for a partner in a different type of relationship (e.g., where those same feelings of discomfort may lead someone to pull away or not know the right thing to say if their relationship is not as deep or personal). To better understand the function of empathic distress, future research should examine associations between synchrony in somatosensory cortex activity and behavioral outcomes across diverse types of relationships.

Strengths and Limitations

Our confidence in the findings of this study is enhanced by strengths in its methodology and design. In addition to strengths already addressed throughout Study 1 and Study 2 (i.e., overcoming challenges of self-report and observational methods, preserving naturalistic features of interactions, etc.), this study expanded upon them further by investigating empathy as a fluid, dynamic construct to capture neural and behavioral nuances surrounding communication as they unfold. Second, measuring neural synchrony and observed behavioral connection at the moment-to-moment level allowed for more direct comparisons to be made between brain activity and behavior at comparable levels of detail. Third, the varied pattern of findings that emerged between synchrony in different brain regions (across both empathy-associated regions and control regions) with respect to their magnitude and directionality mitigate the alternative explanation that brain activity in any region is similarly associated with behavior over time.

Notwithstanding these strengths, limitations of this study also require that these results should be interpreted with some caution. First, synchrony in somatosensory cortex activity was only measured in couples from the social support study but it was not assessed in conflict. Though findings from this dissertation suggest that greater somatosensory cortex synchrony relates to greater behavioral connection in support providers, the implications of synchronous activity in this region may differ across conflict interactions. For example, shared empathic distress may be more strongly associated with maladaptive behaviors (e.g., withdrawal from the conversation in response to feeling uncomfortable) during a heated argument. To overcome this limitation, future research should examine and compare synchrony in mPFC, TPJ, and somatosensory cortex activity across social support and conflict interactions. Second, as already addressed above, direct causal inferences cannot be made regarding the directionality of the association between brain activity and behavior. Future research may consider controlling for previous levels of the outcome when examining lagged associations between neural synchrony and behavior to get closer towards inferring causality. However as previously noted, with second-to-second data it is highly unlikely that a predictor will significantly account for changes in an outcome, over and above previous levels of that outcome within the same individuals.

Conclusion

Study 3 was the first study to ever examine time-varying associations between neural synchrony in regions associated with empathy and observed behavior throughout communication. My findings provide preliminary evidence to support that contrary to initial predictions, greater somatosensory cortex activity may motivate couples to behave more adaptively (e.g., act in prosocial ways, provide consolation to recipients, etc.) across social support interactions. Findings across social support and conflict interactions provide preliminary evidence to support that greater TPJ synchrony between partners may be beneficial for communication in the presence of mPFC synchrony but harmful for communication in the absence of mPFC synchrony. To further our knowledge of time-dependent associations between neural synchrony in empathy-related regions and observed behavior, future research should consider examining associations between behavior and brain-state synchrony across the default mode network to better understand how simultaneous synchrony in mPFC and TPJ activity across time may be associated with behaviors throughout communication.

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General Discussion

Key Findings and Implications

The purpose of this dissertation was to examine the role of neural synchrony in empathy-associated brain regions on couples' communication throughout social support and conflict interactions. Towards this end, the primary aim of Study 1 was to examine associations between neural synchrony in regions corresponding with perspective taking and post-conflict outcomes in couples. Expanding on Study 1, the primary purpose of *Study 2* was to examine and compare effects of neural synchrony corresponding to two different forms of empathy (perspective-taking and empathic distress) on post-support outcomes in couples. Expanding on Studies 1 and 2, the primary aim of Study 3 was to capture and assess more nuanced, time-dependent dynamics between neural synchrony and observed behavior throughout couples' conflict and social support interactions as they unfold. In line with this aim, I assessed concurrent associations between second-to-second neural synchrony and second-to-second observed behavior as well as bidirectional lagged associations between neural synchrony and observed behavior at various time-intervals.

Key Takeaways for Findings on mPFC and TPJ Synchrony. Across conflict interactions, greater average synchrony in channels associated with TPJ activity between partners was significantly associated with *less* favorable self-reported post-discussion appraisals in Study 1. Consistently in Study 3, when partners were rated above average in degrees of behavioral *disconnection*, they also shared greater than average levels of synchronous TPJ activation with their partners concurrently and over time. Moreover, across both studies, there were neither significant associations between time-averaged mPFC synchrony and self-report outcomes, nor were there any concurrent or time-lagged associations between time-varying mPFC synchrony and observed behavior. Across the first social support interactions, greater average synchrony across channels associated with mPFC activity and TPJ activity between partners was significantly associated with *more* favorable self-reported post-discussion appraisals in Study 2. Consistently in Study 3, in moments when partners were rated above average in degrees of behavioral *connection*, they also shared greater than average levels of synchronous mPFC and TPJ activation with their partners concurrently and over time. The consistent findings between Studies 1 and 3 and between Studies 2 and 3 further support the potential framework in which TPJ synchrony may be primarily adaptive for communication in the presence of mPFC synchrony, with respect to both partners' own evaluations of their interactions and observers' moment-to-moment evaluations of partners' behavior. Once more, investigating associations between brain state synchrony across the entire default mode network and these outcomes may offer additional insight into this phenomenon.

Key Takeaways for Findings on Somatosensory Cortex Synchrony. Across the first social support interactions, no significant associations emerged between synchrony in channels associated with somatosensory cortex activity and self-reported post-discussion appraisals in Study 2. However, in moments when couples were rated above average in degrees of behavioral *connection*, they also shared greater than average degrees of synchronous somatosensory cortex activation with their partners concurrently and over time, across both shorter and longer time intervals in Study 3. Taken together, these findings may suggest that greater somatosensory synchrony motivated partners to engage in more prosocial behaviors, which could be detected by third-party raters viewing their interactions. Though greater synchrony in this region may have prompted partners to become more behaviorally connected, their internalized feelings of pain and distress from listening to recipients describe past traumatic experiences may have been their most salient takeaway from the discussion. Thus, the very pain that may have motivated providers to behave in more compassionate ways may have also prompted them to perceive the quality of their discussions, along with their own behaviors within those discussions, in a less adaptive light compared to third-party observers who were farther removed from the conversations as outsiders to the relationships. This is consistent with existing research suggesting that activity in this region may motivate prosocial decision-making and behavior (Gallo et al., 2018).

Taken together, findings across the three studies may suggest that shared empathic processes across both perspective-taking and empathic distress may adaptively influence the quality of communication in social support. However, the impact of perspective-taking on the quality of conflict resolution may be more complex, in which partners who perceive each other and their conflicts in a similar manner may communicate *less* effectively if they are unable to effortfully evaluate and reflect on those automatic perceptions. However, I recognize that this latter interpretation is not definitive and plan to test these assumptions more directly in future research by comparing couples who had simultaneous high mPFC and TPJ synchrony to couples with only high TPJ synchrony in conflict within both time-invariant and time-varying contexts.

More broadly speaking, this work lends insight to suggest that contrary to prior research on neural synchrony, the presence of greater neural synchrony between partners is not always associated with positive outcomes across relationships and social interactions. While existing research has found greater neural synchrony between partners in different brain regions to be associated with deeper social bonds, more satisfying relationships, and amelioration of pain, findings from this dissertation highlight that even within the same brain region, the impact of neural synchrony on communication and relationship functioning may also be negative depending on 1) the context in which it is measured (e.g., a social support context that generally encourages greater closeness between partners versus a conflict context that generally creates distance between partners with opposing viewpoints), and potentially 2) the simultaneous strength of neural synchrony in other regions of the brain (e.g., the implications of high TPJ synchrony in couples may be positive or negative depending on whether their degrees of mPFC synchrony are simultaneously high).

Strengths and Limitations

Our confidence in findings from this dissertation is enhanced by some strengths in its methodology and design, in addition to strengths already highlighted in discussions from each of the three studies. First, this dissertation included the first research to ever offer insight into how neural synchrony in empathy-associated regions relates to communication, a much more complicated and nuanced social processes compared to social situations that have been examined to date in relation to neural synchrony (e.g., motor task coordination, kissing, handholding, etc.) (e.g., Anders, Heinzle, Weiskopf, Ethofer, & Haynes, 2011; Kinreich, Djalovski, Kraus, Louzoun, & Feldman, 2017). Second, across all three studies, this dissertation utilized a mixed methods approach to examine associations between neural synchrony, self-reported survey outcomes, and time-lagged observer outcomes involving highly meticulous qualitative moment-to-moment assessments of couples' behavior across different brain regions and diverse types of interactions. This rigorous approach allowed me to compare and corroborate findings between couples' own sentiments and observers' evaluations of their interactions, findings between time-invariant data and time-varying data, findings between social support and conflict interactions, and findings between synchrony in different brain regions. Taken together, implications across all these different domains offer a more holistic view into how neural synchrony in empathy-associated regions relates to couples' communication.

Notwithstanding these strengths, additional limitations beyond what was already addressed in each study also require that these results should be interpreted with caution. First, though the Intimacy Process Model has been the leading theoretical framework for which I based my hypotheses surrounding the function of neural synchrony in couples, the Social Ecological Model offers an alternative explanation that should not be ignored. This model highlights the impact of environmental and macro-societal forces on partners, describing close relationships to be embedded within larger spheres of influence (Huston, 2000). Specifically, partners are embedded in and influenced by the larger communities and societies of which they are a part. From this perspective, neural synchrony may also be driven by those larger spheres of influence, such as a shared stimulus, experience, or environment. To the extent that this alternative is plausible, it follows that *the presence of neural synchrony does not necessarily imply coregulation between partners*, i.e., correlated fluctuations in any affective or physiological marker between partners do not necessarily imply that couples causally regulate each other's behaviors or states. Second, all studies in this dissertation examined cross-sectional associations between neural synchrony in empathy-related regions and different outcomes of interest. Without longitudinal data, it cannot be determined as to whether neural synchrony (or dyadic covariation of any kind for that matter) is a symptom of relationship outcomes or a cause. Future research should consider a longitudinal approach, in which sequences of neural synchrony measured in the lab may be used to predict relationship outcomes over the course of longitudinal follow-ups over time. Third, though this dissertation utilized a rigorous mixed method framework within cross-sectional bounds, future research should utilize mixed methods designs across both cross-sectional and longitudinal frameworks (e.g., combining in-lab, daily diary, and longitudinal survey methods) in which neural synchrony can be studied within the sample couples under varying contexts and periods of time. More causal inferences may be drawn if neural synchrony can someday be studied in relation to outcomes across multiple timeframes (e.g., minutes and days) and multiple contexts (e.g., negative and positive situations) within the same sample of participants.

Conclusion

This dissertation was the first to examine links between neural synchrony in regions associated with multiple forms of empathy and couples' communication throughout social support and conflict discussions. Taken together, findings from this work provide preliminary evidence to support that the impact of synchrony in regions associated with perspective-taking on the quality of communication may be nuanced, in which it may be helpful for communication if synchrony is simultaneously high across brain regions associated with both automatic and reflective processes, but unhelpful if synchrony in regions associated with reflective processing is not present. Findings further support that greater synchrony in the brain region associated with empathic distress may adaptively influence the quality of support provision, contrary to predictions. Findings from the dissertation overall shed light on the complicated nature of empathy and how it may impact communication and close relationships, in which separate facets of empathy relate to communication in different ways and behave differently across various social contexts. Only thinking of empathy as a stable, trait-based construct is likely an oversimplification, as this research shows that it's dynamic shifts throughout communication in real time that correspond to changes in behavior. To further our knowledge regarding associations between neural synchrony in empathy-related regions and relationship functioning, future research may consider examining these associations across diverse couples using a mixed methods approach with both cross-sectional and longitudinal methods.

Appendix

SECTION 1: STUDY 1 MATERIALS

B-IRI	**Brief Form of the Interpersonal Reactivity Index**
Please indicate how well each statement describes you:	
BIRI_1	I often have tender, concerned feelings for people less fortunate than me.
BIRI_2	Sometimes I don’t feel very sorry for other people when they are having problems.
BIRI_3	When I see someone being taken advantage of, I feel kind of protective towards them.
BIRI_4	Other people’s misfortunes do not usually disturb me a great deal.
BIRI_5	When I see someone being treated unfairly, I sometimes don’t feel very much pity for them.
BIRI_6	I am often quite touched by things that I see happen.
BIRI_7	I would describe myself as a pretty soft-hearted person.
BIRI_8	I sometimes find it difficult to see things from the “other person's” point of view.
BIRI_9	I try to look at everybody’s side of a disagreement before I make a decision.
BIRI_10	I sometimes try to understand my friends better by imagining how things look from their perspective.

BIRI_11	If I'm sure I'm right about something, I don't waste much time listening to other people's arguments.
BIRI_12	I believe that there are two sides to every question and try to look at them both.
BIRI_13	When I'm upset at someone, I usually try to "put myself in their shoes" for a while.
BIRI_14	Before criticizing somebody, I try to imagine how I would feel if I were in their place.

Relationship History

1. How long have you been with your romantic partner? _________ Years __________ Months

2. Are you married to your romantic partner? ______Yes ______ No

If yes, please provide your wedding date ________/_________/__________

3. Are you and your romantic partner currently living together? ______ Yes ______ No

If yes, approximately how long have you been living together? ___________ Years __________ Months

4. Are you romantically involved with any other people right now (besides your romantic partner)?

______ Yes _______ No

5. Do you have any children with your romantic partner? ______ Yes ________ No

If yes, how many children do you have? ____

6. How many serious relationships have you had in the past? ______________

Demographics

1. Age:______

2. Gender: _____ Female _____ Male _____ Other

3. Education (please check one):

_____ did not complete high school

_____ completed high school

_____ some college credits

_____ Associate's degree

_____ Bachelor's degree

_____ some graduate school

_____ professional degree (e.g., M.S., M.D., Ph.D. etc.)

4. Your race (please check as many as apply):

_____ American Indian/ Alaska Native

_____ Asian

_____ Black or African American

_____ Native Hawaiian or Pacific Islander

_____ White (Caucasian)

_____ Other (please specify____________

5. Your ethnicity:

_____ Not Hispanic or Latino

_____ Hispanic or Latino

6. Your Major (if applicable):

____

PANAS	**The Positive and Negative Affect Schedule**
Please indicate how you are feeling right now -- that is, at the present moment. At this moment, I feel...	
C1_PANAS_1	Happy
C1_PANAS_2	Sad
C1_PANAS_3	Anxious

C1_PANAS_4	Angry
C1_PANAS_5	Irritated
C1_PANAS_6	Stressed Out
C1_PANAS_7	Content
C1_PANAS_8	Upset
C1_PANAS_9	Excited
C1_PANAS_10	Calm

Relationship Satisfaction

(from Couple Satisfaction Index and Quality Marriage Index; 12 items including everything from QMI, CSI4, CSI16)

Now I am going to ask you some questions about how you feel about your relationship with your partner. Let me remind you that all of your answers are strictly private. Your partner will not ever see them.

RELSAT1

All things considered, how happy are you in your relationship with [PARTNER'S NAME].

1 Extremely unhappy

2 Fairly unhappy

3 A little unhappy

4 A little happy

5 Fairly happy

6 Extremely happy

7 Perfect

RELSAT2

In general, how often do you think that things between you and your partner are going well?

0 Never

1 Rarely

2 Occasionally

3 More often than not

4 Most of the time

5 All of the time

RELSAT3

How much do you agree with these statements:

Our relationship is strong.

0 Not at all true

1 A little true

2 Somewhat true

3 Mostly true

4 Almost completely true

5 Completely true

RELSAT4

My relationship with my partner makes me happy.

0 Not at all true

1 A little true

2 Somewhat true

3 Mostly true

4 Almost completely true

5 Completely true

RELSAT5

I have a warm and comfortable relationship with my partner.

0 Not at all true

1 A little true

2 Somewhat true

3 Mostly true

4 Almost completely true

5 Completely true

RELSAT6

I really feel like part of a team with my partner.

0 Not at all true

1 A little true

2 Somewhat true

3 Mostly true

4 Almost completely true

5 Completely true

RELSAT7

We have a good relationship.

0 Not at all true

1 A little true

2 Somewhat true

3 Mostly true

4 Almost completely true

5 Completely true

RELSAT8

My relationship with my partner is very stable.

0 Not at all true

1 A little true

2 Somewhat true

3 Mostly true

4 Almost completely true

5 Completely true

RELSAT9

How rewarding is your relationship with your partner?

0 Not at all

1 A little

2 Somewhat

3 Mostly

4 Almost completely

5 Completely

RELSAT10

How well does your partner meet your needs?

0 Not at all

1 A little

2 Somewhat

3 Mostly

4 Almost completely

5 Completely

RELSAT11

How much has your relationship met your expectations?

0 Not at all

1 A little

2 Somewhat

3 Mostly

4 Almost completely

5 Completely

RELSAT12

In general, how satisfied are you with your relationship?

0 Not at all

1 A little

2 Somewhat

3 Mostly

4 Almost completely

5 Completely

SSE	Post: Conflict Evaluations
Please answer the following questions with respect to the conversation you just had..	
A2_SSE_1	How important did your partner think this topic was to you?
A2_SSE_2	How important do you think this topic was to your partner?
In thinking about the conversation you just had, please indicate the extent to which you agree with each of the following statements.	
A2_SSE_3	I feel satisfied with how the conversation went.
A2_SSE_4	I feel satisfied with how much my partner and I accomplished during the conversation.
A2_SSE_5	I enjoyed the conversation.
A2_SSE_6	The conversation was productive.
A2_SSE_7	The conversation was pleasant.
A2_SSE_8	The conversation brought my partner and me closer together.
A2_SSE_9	The conversation helped my partner and me work on our issues.
A2_SSE_10	The conversation made me feel satisfied with my relationship.
A2_SSE_11	The conversation was similar to conversations that my partner and I have at home.
In thinking about the conversation you just had, please indicate the extent to which you agree with each of the following statements about your partner *During the conversation, my partner...*	
A2_SSE_12	Behaved positively towards me.
A2_SSE_13	Behaved negatively towards me.
A2_SSE_14	Listened to me.
A2_SSE_15	Was defensive.
A2_SSE_16	Avoided our issues.
A2_SSE_17	blamed/criticized me for our issues.
A2_SSE_18	Tried to change topics

A2_SSE_19	Took responsibility for our issues
A2_SSE_20	Expressed positive emotions.
A2_SSE_21	Hurt my feelings.
A2_SSE_22	Discussed the possibility of breaking up.
A2_SSE_23	Withdrew from the conversation.
A2_SSE_24	Contributed productively to the conversation.
A2_SSE_25	Seemed to care about the topic being discussed
A2_SSE_26	Interrupted me
A2_SSE_27	Asked me to change
A2_SSE_28	Was engaged
A2_SSE_29	Expressed affection.
A2_SSE_30	Understood my point of view.

In thinking about the conversation you just had, please indicate the extent to which you agree with each of the following statements about yourself

During the conversation, I...

A2_SSE_31	Behaved positively toward my partner.
A2_SSE_32	Behaved negatively toward my partner.
A2_SSE_33	Listened to my partner.
A2_SSE_34	Was defensive.
A2_SSE_35	Avoided our issues.
A2_SSE_36	blamed/criticized my partner for our issues.
A2_SSE_37	Tried to change topics.
A2_SSE_38	Took responsibility for our issues.
A2_SSE_39	Expressed positive emotions.
A2_SSE_40	Hurt my partner’s feelings.
A2_SSE_41	Discussed the possibility of breaking up.

A2_SSE_42	WIthdrew from the conversation.
A2_SSE_43	Contributed productively to the conversation.
A2_SSE_44	Seemed to care about the topic being discussed.
A2_SSE_45	Interrupted my partner.
A2_SSE_46	Asked my partner to change.
A2_SSE_47	Was engaged.
A2_SSE_48	Expressed affection.
A2_SSE_49	Understood my partner's point of view.

SSE	**Post: Conflict Evaluations Made By Independent Raters**
Please answer the following questions with respect to the conversation you just watched.	
A2_SSE_1	How important did the conversation seem to the target?
In thinking about the conversation you just watched, please indicate the extent to which you agree with each of the following statements.	
A2_SSE_2	The target felt satisfied with how the conversation went.
A2_SSE_3	The target felt satisfied with how much he/she accomplished with his/her partner during the conversation.
A2_SSE_4	The target enjoyed the conversation.
A2_SSE_5	The conversation was productive.
A2_SSE_6	The conversation was pleasant.
A2_SSE_7	The conversation brought the target closer together with his/her partner.
A2_SSE_8	The conversation helped the target work on issues with his/her partner.
A2_SSE_9	The conversation made the target feel satisfied with his/her relationship.

SCRIPT INTRODUCING CONFLICT DISCUSSION TO PARTICIPANTS

"For the next phase, you two will be having a conversation together. For this conversation, we would like the two of you to identify and work through a topic of disagreement that you haven't resolved yet. This should be an area in your relationship where you two have different opinions and feelings, in which you may have had a

previous argument or fight about. It is important to us that you choose an area where you really do disagree, and that you feel like you can talk about this area for 8 minutes. However, it is also important to us that you both feel comfortable talking about the area you choose."

"Can either of you think about a topic you both would feel comfortable discussing in this conversation?" Pause to see if the couple has a topic.

[IF THE COUPLE ASKS IF THEIR TOPIC CHOICE IS OK] **"As long as the topic you choose is an unresolved disagreement in which you two have different opinions and feelings, and you feel that you can talk about it for at least 8 minutes, then it works for the purposes of this discussion. If you aren't sure that the area of unresolved disagreement will last eight minutes, you can come up with a couple of areas you disagree upon."**

…

[IF UNABLE TO IDENTIFY A TOPIC] **"If you would like, we can give you a couple minutes alone to come up with a topic. We can also provide you with a list of common disagreements couples face in relationships to look over."**

1. Grab the "Common Disagreements" lists from shelf and hand to each participant.

"One of you can ring the bell when you have picked a topic. We'll check in on you in a couple minutes if we haven't heard a bell. To give you additional privacy, we will turn on a white noise machine while you choose a topic."

COMMON DISAGREEMENTS LIST

MAPC	**Marital Agendas Protocol - College (MAP-C)**
Consider the list below of common issues that romantic relationships face. Please rate how much of a problem each area currently is in your relationship by moving the slider from 0 (not at all a problem) to 100 (a severe problem). For example, if "money" is somewhat of a problem, you might enter 25 below "money". If money is not a problem in your relationship, you might enter a 0 below "money". If money is a severe problem, you might enter 100. Be sure to rate all areas.	
MAPC_1	Alcohol and/or Drugs
MAPC_2	Annoying Habits / Pet Peeves
MAPC_3	Attention Needs
MAPC_4	Behaviors(s) Around Others
MAPC_5	Cleaning Up

Conflict: Item by Item Interrater Reliability for Observer Evaluation Measure

A	B	C	D	E	F	G	H	I	J	K	L	M
Row	Post1	Post2	Post3	Post4	Post5	Post6	Post7	Post8	Post9	Post10	OverallConnect	TypeDisconnect
r-value	0.827198817	0.807067018	0.80776971	0.670895579	0.793835838	0.825403867	0.67435797	0.790856563	0.742303243	0.831907881	0.973339495	0.942533942
p-value	0	0	0	3.33733E-13	0	0	1.99396E-13	0	0	0	0	0
F-value	5.786997409	5.183146976	5.202093807	3.038549271	4.850503545	5.7275037	3.070856669	4.781407502	3.880530018	5.949118904	37.5086667	17.40157636
CI-LB	0.76422659	0.73675836	0.737717126	0.550963308	0.718705471	0.761777524	0.555687465	0.714640488	0.648393362	0.770651733	0.963623871	0.921592154
CI-UB	0.875990774	0.861543369	0.862047649	0.763821151	0.85204813	0.874702644	0.766305905	0.84991008	0.815066224	0.879370192	0.980867327	0.958759997
df1	107	107	107	107	107	107	107	107	107	107	107	107
df2	251.6481481	251.6481481	251.6481481	251.6481481	251.6481481	251.6481481	251.6481481	251.6481481	251.6481481	251.6481481	251.6481481	251.6481481

SECTION 2: STUDY 2 MATERIALS

Interpersonal Reactivity Index

The following statements inquire about your thoughts and feelings in a variety of situations. For each item, indicate how well it describes you by choosing the appropriate letter on the scale at the top of the page: A, B, C, D, or E. When you have decided on your answer, fill in the letter next to the item number. READ EACH ITEM CAREFULLY BEFORE RESPONDING. Answer as honestly as you can. Thank you.

ANSWER SCALE:

(ABCDE) DOES NOT DESCRIBE ME WELL TO DESCRIBES ME VERY WELL

1. I daydream and fantasize, with some regularity, about things that might happen to me. (FS)

2. I often have tender, concerned feelings for people less fortunate than me. (EC)

3. I sometimes find it difficult to see things from the "other guy's" point of view. (PT) (-)

4. Sometimes I don't feel very sorry for other people when they are having problems. (EC) (-)

5. I really get involved with the feelings of the characters in a novel. (FS)

6. In emergency situations, I feel apprehensive and ill-at-ease. (PD)

7. I am usually objective when I watch a movie or play, and I don't often get completely caught up in it. (FS) (-)

8. I try to look at everybody's side of a disagreement before I make a decision. (PT)

9. When I see someone being taken advantage of, I feel kind of protective towards them. (EC)

10. I sometimes feel helpless when I am in the middle of a very emotional situation. (PD)

11. I sometimes try to understand my friends better by imagining how things look from their perspective. (PT)

12. Becoming extremely involved in a good book or movie is somewhat rare for me. (FS) (-)

13. When I see someone get hurt, I tend to remain calm. (PD) (-)

14. Other people's misfortunes do not usually disturb me a great deal. (EC) (-)

15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (PT) (-)

16. After seeing a play or movie, I have felt as though I were one of the characters. (FS) 17. Being in a tense emotional situation scares me. (PD)

18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them. (EC) (-)

19. I am usually pretty effective in dealing with emergencies. (PD) (-)

20. I am often quite touched by things that I see happen. (EC)

21. I believe that there are two sides to every question and try to look at them both. (PT)

22. I would describe myself as a pretty soft-hearted person. (EC)

23. When I watch a good movie, I can very easily put myself in the place of a leading character. (FS)

24. I tend to lose control during emergencies. (PD)

25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while. (PT)

26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me. (FS)

27. When I see someone who badly needs help in an emergency, I go to pieces. (PD)

28. Before criticizing somebody, I try to imagine how I would feel if I were in their place. (PT)

Relationship History

7. How long have you been with your romantic partner? _________ Years __________ Months

8. Are you married to your romantic partner? ______Yes ______ No

If yes, please provide your wedding date ________/_________/__________

9. Are you and your romantic partner currently living together? ______ Yes ______ No

If yes, approximately how long have you been living together? ___________ Years __________ Months

10. Are you romantically involved with any other people right now (besides your romantic partner)?

______ Yes _______ No

11. Do you have any children with your romantic partner? ______ Yes _______ No

If yes, how many children do you have? ____

12. How many serious relationships have you had in the past? ______________

Demographics

4. Age:______

5. Gender: _____ Female _____ Male _____ Other

6. Education (please check one):

_____ did not complete high school

_____ completed high school

_____ some college credits

_____ Associate’s degree

_____ Bachelor’s degree

_____ some graduate school

_____ professional degree (e.g., M.S., M.D., Ph.D. etc.)

4. Your race (please check as many as apply):

_____ American Indian/ Alaska Native

_____ Asian

_____ Black or African American

_____ Native Hawaiian or Pacific Islander

_____ White (Caucasian)

_____ Other (please specify____________

5. Your ethnicity:

_____ Not Hispanic or Latino

_____ Hispanic or Latino

6. Your Major (if applicable):

____

Post-discussion Questionnaires

PANAS

adapted from PANAS-X (Watson and Clark, 1994).

In thinking about **the discussion you just had**, indicate the extent to which the following words describe your current mood. Please be honest about how you truly feel.

At this moment in time I feel . . . strongly
strongly
agree
disagree

Cheerful	O O O O O O O
Sad	O O O O O O O
Anxious	O O O O O O O
Angry	O O O O O O O
Irritated	O O O O O O O
Enthusiastic	O O O O O O O

Post-discussion Evaluations of Social Support (The one below is shown for recipients, the only difference for providers was that one of the questions was alternatively phrased as "How much did you feel like you helped for supported your partner")

(Adapted from Florida Study)

Please answer the following questions about **the conversation you just had**.

not at all extremely

How satisfied are you with the conversation?	O O O O O O O
How much did you enjoy the conversation	O O O O O O O

How close did the conversation make you feel to your partner? O O O O O O O

How much did you feel like your partner helped or supported you? O O O O O O O

How satisfied were you with the tone of the conversation? O O O O O O O

How satisfied are you with how much the conversation helped to address the problem? O O O O O O O

How satisfied are you with how much you accomplished during the conversation? O O O O O O O

How similar was the conversation to conversations you have at home? O O O O O O O

How much do you think YOUR PARTNER understood your point of view during the discussion? O O O O O O O

How much did you understand YOUR PARTNER'S point of view during the discussion? O O O O O O O

Independent Raters' Post-discussion Attributions
(Adapted from Florida Study)

Please answer the following questions about **the conversation you just watched**.

not at all extremely

How satisfied was the target with the conversation? O O O O O O O

How much did the target enjoy the conversation? O O O O O O O

How close did the target feel towards their partner after having the conversation? O O O O O O O

How much did the target's partner help or support them? O O O O O O O

How satisfied was the target with
the tone of the conversation? O O O O O O O

How satisfied was the target with how much the
conversation helped to address their problem? O O O O O O O

How satisfied was the target with how much
they accomplished during the conversation? O O O O O O O

How much did the LISTENER understand the target's point of view during the discussion? O O O O O O O

How much did the TARGET understand the listener's point of view during the discussion? O O O O O O O

Consenting and Conveying Overview of Study to Participants

Experimenter A will then go over the consent information sheet and bill of rights with both participants:

"Now, I want to go over what you will be doing in the study today and give you an opportunity to ask any questions. Here is a print-out copy of the consent information sheet. This is for you to keep. Within it is a statement of UCLA's official participant bill of rights so that you know the rights that you have as a participant in this study.

We want to let you both know in advance that this study is straightfoward and does not involve deception. The purpose of our research is to better understand how the brain processes information during conversations about personal topics. During today's session, you will answer questions, have two conversations with each other, and then answer follow-up questions.

During the conversations, we will be measuring activity from both of your brains at the same time. We will be using a technology called functional near infrared spectroscopy. It sounds fancy, but its really just a non-invasive device that measures changes in blood flow in the brain. It does this by shining near infrared light onto your head, using the same technology that is used in a pulse oximeter at the doctor's office, so it has absolutely no adverse effects on your body and there are no health risks. At the end of the study, you will receive $25 each (or two sona credits) as compensation for your participation.

I just want to emphasize that we don't think that there is any one right way that people need to be thinking, feeling, or behaving in their relationships. Different things work for different people. So, as you participate in the study, please don't feel that there is any one correct way to behave or to respond to any of the questions we ask you. Just answer honestly, and don't spend too much time on any one question.

As stated on the information sheet, we will be recording your conversation with your partner on a set of video cameras. These film recordings will be archived in digital form, and are subject to review for scientific purposes only by the investigators and their immediate staff. Along these lines, the data from your videos will only be coded and analyzed as an average across all couples, so you will never be singled out as a particular couple or participant and your identities will always remain anonymous within the lab.

On the third page, please put a checkmark next to the appropriate answer to indicate whether or not you would like to be contacted for future studies. Please put your initials next to the checkmark. Also please go ahead and silence your cell phones for the duration of this study.

Do you have any questions?

If participant asks about what they will discuss during the conversation, inform them that for the purposes of the study, it important that they wait to find out the specifics of what they will be discussing until it is the right time. (If participant notices that there is a line on the bill of rights about "medical studies" and asks about it: *"Our study is not a medical study, but the board that reviews our research also reviews medical studies, and so some of the language used on the document is more applicable to those other studies.")*

Ok, great! If you have any questions after you leave today, you may contact the researchers at the study email address or using the contact information on the sheet here. We have also provided you with additional contact information in case you have concerns or suggestions and you want to talk to someone other than the researchers about the study."

Pre-Scanning Intro and Questionnaire: Social Support Discussion 1

Flip a coin to determine which partner's topic will be discussed first. Heads for person at computer, Tails for person at laptop.

Experimenter A: ***"Thanks for completing that! For the next phase, you will be having two discussions together, and when the time comes we will help each of you rotate your chairs to face one-another. For the topics of these two discussions, we ask each of you to recall and discuss the most emotionally stressful incident or period of time that you experienced in your life that did not involve your partner and was not caused by your partner. This is meant to be a personal conversation between the two of you, and we want to assure you that none of the researchers will be listening to your conversations while you are having them. Would each of you feel comfortable coming up with a topic like this that you would be willing to discuss here together?***

Get each partner to announce the topics. If they don't feel comfortable announcing their topic out loud, also let them know that they have the option to write their topics on a post-it note that they can fold in half and pass to their partners so that the experimenters do not see it.

"Great. So, your first discussion together will be about {Person who won the coin toss]'s topic. Now, even though this is a discussion of one person's topic, we do emphasize the importance of this being a conversation between the two of you, so try to make it interactive and conversational as opposed to only a one-sided disclosure. We also ask again that you please try to limit head movement throughout the

discussion. You don't need to be completely rigid or still to the point that it feels unnatural, just try to limit movement as much as possible. We also ask that you please do not touch each other during the discussion. Any questions so far?

Great! Also don't worry about explaining things to us or to the camera. We don't need to know any background about this – all we want is a sample of the way the two of you communicate naturally. So talk to each other, not to us. Pretend like the camera isn't even there, and again, we are not going to be listening to your conversation while you discuss.

Please stay on this topic for the entire 8 minutes, and do not move on to the next topic until time is up.

You can start as soon as I close the door, and then please discuss the topic together until I knock on the door in 8 minutes. Do you have any questions?

<u>Item by Item Interrater Reliability for Support Observer Measures:</u>

- Provider D1:

A	B	C	D	E	F	G	H
Row	Post1	Post2	Post3	Post4	Post5	OverallConnect	TypeDisconnect
r-value	0.838367824	0.889369414	0.876900502	0.810251404	0.805519644	0.968266878	0.993695662
p-value	0	0	0	0	1.11022E-16	0	0
F-value	6.186886966	9.039091604	8.12350997	5.270131221	5.141907489	31.51281509	158.6209359
CI-LB	0.755731503	0.832808246	0.813964458	0.713240237	0.70608931	0.952042952	0.990472496
CI-UB	0.898919344	0.930814442	0.923016701	0.881336048	0.878376926	0.980154912	0.996057427
df1	51	51	51	51	51	51	51
df2	189.2884615	189.2884615	189.2884615	189.2884615	189.2884615	189.2884615	189.2884615

- Recipient D1:

A	B	C	D	E	F	G	H
Row	Post1	Post2	Post3	Post4	Post5	OverallConnect	TypeDisconnect
r-value	0.754716023	0.831955582	0.834432228	0.805135561	0.706127375	0.931665131	0.994858378
p-value	4.77218E-12	0	0	6.66134E-16	1.84313E-09	0	0
F-value	4.07690715	5.950807607	6.039822759	5.131772657	3.402834821	14.63381742	194.4911523
CI-LB	0.626021114	0.743786509	0.747562594	0.702894634	0.551939112	0.895811383	0.992160686
CI-UB	0.847465068	0.895498091	0.897038244	0.878819504	0.817249209	0.957504543	0.996802576
df1	51	51	51	51	51	51	51
df2	163.7884615	163.7884615	163.7884615	163.7884615	163.7884615	163.7884615	163.7884615

- Provider D2

A	B	C	D	E	F	G	H
Row	Post1	Post2	Post3	Post4	Post5	OverallConnect	TypeDisconnect
r-value	0.848834825	0.874760279	0.879955852	0.806968271	0.918248175	0.994355331	0.956131652
p-value	0	0	0	3.10862E-15	0	0	0
F-value	6.61528029	7.984687211	8.330268608	5.180495487	12.23214285	177.1583171	22.79547866
CI-LB	0.767708183	0.807547191	0.815531101	0.703372875	0.874373975	0.991325976	0.932588585
CI-UB	0.906458901	0.922501587	0.92571661	0.880551853	0.949411923	0.996507076	0.97285424
df1	51	51	51	51	51	51	51
df2	146.1346154	146.1346154	146.1346154	146.1346154	146.1346154	146.1346154	146.1346154

- Recipient D2

A	B	C	D	E	F	G	H
Row	Post1	Post2	Post3	Post4	Post5	OverallConnect	TypeDisconnect
r-value	0.861964733	0.887923652	0.842493145	0.85418018	0.775230603	0.937065823	0.973524464
p-value	0	0	0	0	1.07692E-14	0	0
F-value	7.244525418	8.922489131	6.34893004	6.857778301	4.449004242	15.8896176	37.77071744
CI-LB	0.792409729	0.831449165	0.763126544	0.780702593	0.661970878	0.905353733	0.960183626
CI-UB	0.913406077	0.929690934	0.901190929	0.908522578	0.858994992	0.960519385	0.983391052
df1	51	51	51	51	51	51	51
df2	206.9423077	206.9423077	206.9423077	206.9423077	206.9423077	206.9423077	206.9423077

SECTION 3: STUDY 3 MATERIALS

Detailed Codes for Behavioral Connection

Within the 'Nonverbal Cues' category across social support and conflict, mild behavioral connection ranging from +5 to +25 on the connection spectrum included behaviors indicative of basic conversational engagement, such as maintained eye contact, leaning in, and nodding. Moderate behavioral connection ranging from +30 to +40 on the spectrum included examples such as jovial laughter, and high connection at the far end of the scale included behaviors such as empathetic crying (i.e., a target crying in response to a partner's tears and/or open disclosure of vulnerability).

Within the 'Asking Questions' category, moderate behavioral connection at around +40 included asking clarifying questions (e.g., "oh ok, when did this happen?"), indicating that targets were following along and engaged in their conversations. Higher behavioral connection at around +50 involved a target asking deepening questions demonstrating attempts to better understand their partner's outlook (e.g., "how do you feel about that now?"). Within conflict interactions specifically, questions asking for a partner's perspective (e.g., "so how will we reach a resolution?") were rated as moderately connected and within social support interactions, questions asking for a partner's opinion or advice (e.g., "what are your thoughts about that?") were also rated as moderately connected.

Within the 'Storytelling and Disclosure' category, coders of conflict interactions were instructed to rate behaviors at 0 (the point of behavioral neutrality) if targets followed basic experimental guidelines to openly discuss their shared area of conflict. Within those moments, coders were instructed to rate targets as additionally more behaviorally connected versus disconnected based on nonverbal cues and/or verbal expressions of emotional sentiment regarding their topic of discussion. Targets were further rated towards moderate to high connection at around +40 to +50 if they openly shared personal experiences as a way to illuminate further on the discussion and/or convey their understanding of partners' situations (e.g., "Yeah I experienced 'x' too so I get where you're coming from"). Within social support interactions, coders were instructed to rate behaviors at a neutral 0 for support recipients if they followed basic experimental guidelines and openly shared their experiences with partners and at a neutral 0 if support providers followed basic experimental guidelines by listening to recipients share their stories. Within those moments, coders were instructed to rate targets as more behaviorally connected vs. disconnected based on additional nonverbal cues and/or verbal expressions of emotional sentiment regarding their topic. For example, open expressions of vulnerability throughout recipients' disclosures (e.g., "This was very difficult for me", "I felt so scared", etc.,) were assigned codes ranging from around +30 to +50. Across both conflict and social support interactions, targets were given additional connection ratings ranging from +20 to +30 if they constructively attempted to get their discussions back on track due to topic-shifting (e.g., "Let's get back to talking about 'x'").

Within the ‘Empathy, Agreeableness, and Validation’ category across social support and conflict interactions, targets expressing basic verbal cues to demonstrate following along with a conversation (e.g., saying “mhm” and “yeah” in response to a partner) were rated as mildly connected at around +30. Statements demonstrating basic validation and agreement (e.g., “Yeah I get that”) were rated as more connected at around +40, and statements demonstrating concrete validation paired with a target’s added sentiment (e.g., “Yeah that must have been so tough”, “I’m sorry you had to deal with that”, etc.) were rated as moderately to highly connected at around +50. Providing validation through praise (e.g., “I’m proud of you for trying to work through this”, “You’re so strong to have overcome so much”, etc.) and open expressions of appreciation (e.g., “Thank you for trying” in the context of conflict, “Thank you for being here for me” in the context of support, etc.) were rated as highly connected at around +60. Within conflict interactions specifically, targets who accepted responsibility their actions (e.g., “Yeah you’re right, that one’s on me”) and who expressed future intentions of proactivity (e.g., “I’ll work on being better at ‘x’”) were additionally rated as highly connected ranging from +50 to +70. Within social support interactions specifically, support providers who offered direct, constructive advice (e.g., “Maybe ‘x’ could help by…”) were additionally coded as moderately to highly connected ranging from +40 to +60.

Within the final ‘Affection and Positivity’ category across social support and conflict, targets who verbally expressed feelings of optimism (e.g., “I think things will be okay”) were rated as moderately connected at around +40. Targets who verbally expressed their desire to touch partners to offer comfort and closeness (e.g., “I wish I could hold your hand right now”) were rated as highly connected between +50 to +60, targets who offered compliments/positive affirmations to partners (e.g., “You’re amazing”, “I believe in you”, etc.) were rated as highly connected between +60 to +70, and targets who openly said “I love you” were rated even more highly at around +80.

Detailed Codes for Behavioral Disconnection

Within the ’Nonverbal Cues’ category across social support and conflict, mild behavioral disconnection beginning at around -5 on the spectrum included behaviors such as shifty, inconsistent eye contact demonstrating slight disengagement (e.g., targets who look at the ground slightly more often than they look at their partners). From there, targets demonstrating an overall lack of eye-contact and engagement from the beginning of the conversation were rated as more disconnected at around -15, where the code could become progressively more disconnected if the lack of eye contact and engagement continued throughout the majority of the conversation, up to the point of predominant withdrawal (e.g., a target demonstrating general disengagement and lack of eye-contact throughout most or all of the conversation), which ranged from approximately -80 to -100 in ratings. Other instances of mild to moderate behavioral disconnection included targets leaning away, fidgeting (e.g., playing with sweatshirt strings), and engaging in uncomfortable nervous laughter, ranging in codes around -30 to -40. Other examples of moderate to high behavioral disconnection included behaviors such as bored yawning, eye-rolling, contemptuous/sarcastic laughter, making disgusted facial expressions showing disagreement/direct opposition, and irritated groans and sighs, ranging in codes around -40 to -50.

Within the ‘Asking Questions’ category across social support and conflict interactions, defensive questions (e.g., “Well what else was I supposed to do?”) were rated as moderately disconnected between -30 and -40. Moderate to highly disconnected behaviors included asking accusatory/pointed questions (e.g., “Well why didn’t you just handle it better?”) and asking questions attempting to shut partners down and end the conversation (e.g., “Okay can we just be done with this now?”), ranging in codes around -40 to -50.

Within the ‘Storytelling and Disclosure’ category across social support and conflict interactions, targets were rated as mildly disconnected at around -10 if they demonstrated a lack of openness to initiate discussions of their topic without partners probing. This rating could subsequently become even more disconnected or connected depending on additional nonverbal or verbal behaviors occurring simultaneously. Topic shifting (e.g., one partner going on a tangent) was rated as mildly disconnected, ranging in codes around -10 to -20. Moderate to highly disconnected behaviors included targets sharing their own experiences to *invalidate* their partners (e.g., “Well I was able to overcome ‘x’ so it shouldn’t be too hard for you”) and targets attempting to shut down the conversation (e.g., “I don’t have anything else to say), ranging in codes around -40 to -50.

Within the ‘Critical and Defensive Comments’ category across social support and conflict interactions, examples of mild disconnection coded at around -20 included expressions of nonhostile disagreement (e.g., “I see this differently than you do”). Moderate disconnection coded around -30 to -40 included verbal expressions of pessimism (e.g., “I just don’t know if we can resolve this” in conflict or “I just don’t think anything will help” in support), expressions of denial (e.g., “No I didn’t”), and “Yes-buting” (e.g., “Yes but I don’t think that’s the case because..”). Moderate to high disconnection coded around -40 to -60 included verbal expressions of not being on the same page (e.g., “I just don’t see your point”), passive aggressive remarks (e.g., “Whatever, it’s fine”), hostile sarcasm (e.g., “Yeah because you’re so perfect right”), prescription/prescriptive advice (e.g., “You must..”, “You need to…”), and lecturing/moralizing to partners (e.g., “You should have known better”). Very high disconnection coded around -80 to -100 included expressions of prescriptive threat (e.g., “If you don’t do ‘x’, then I’m done), direct behavioral faulting and making negative attributions (e.g., “It’s because you’re so…”), belligerence and yelling (e.g., “You are terrible at this!”), and direct insults (e.g., “You’re so stupid”).

<u>Concurrent Analyses SAS Output for Significant Associations:</u>

- TPJ Conflict Study

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept	4.5061	5.3651	98.2	0.84	0.4030	0.05	-6.1404	15.1527
timec	-0.02014	0.002918	46E3	-6.90	<.0001	0.05	-0.02586	-0.01442
pmcarma	-0.04276	0.007214	46E3	-5.93	<.0001	0.05	-0.05690	-0.02862
gmcarma	0.1135	0.06276	95	1.81	0.0737	0.05	-0.01111	0.2381

- TPJ Concurrent Support Discussion 1

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	2.3880	13.2677	97.3	0.18	0.8575	0.05	-23.9436	28.7195
recip	2.2461	13.2676	97.3	0.17	0.8659	0.05	-24.0853	28.5776
prov*timec	-0.01017	0.04013	98	-0.25	0.8004	0.05	-0.08981	0.06946
recip*timec	-0.00871	0.04013	98	-0.22	0.8286	0.05	-0.08834	0.07092
prov*pmcarma_a	0.02217	0.006789	47E3	3.26	0.0011	0.05	0.008859	0.03547
recip*pmcarma_a	0.02248	0.006590	47E3	3.41	0.0006	0.05	0.009563	0.03539
prov*gmcarma_a	-0.05267	0.1445	96	-0.36	0.7163	0.05	-0.3395	0.2341
recip*gmcarma_a	-0.05677	0.1445	96	-0.39	0.6953	0.05	-0.3436	0.2300

- TPJ Concurrent Support Discussion 2

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-13.7645	14.2886	98.7	-0.96	0.3377	0.05	-42.1175	14.5885
recip	-13.5279	14.1452	98.6	-0.96	0.3412	0.05	-41.5966	14.5407
prov*timec	0.05656	0.04639	99.9	1.22	0.2257	0.05	-0.03549	0.1486
recip*timec	0.05267	0.04577	98.9	1.15	0.2526	0.05	-0.03815	0.1435
prov*pmcarma_a	0.04662	0.007228	47E3	6.45	<.0001	0.05	0.03245	0.06079
recip*pmcarma_a	0.08903	0.006607	47E3	13.48	<.0001	0.05	0.07608	0.1020
prov*gmcarma_a	0.1095	0.1426	97.2	0.77	0.4444	0.05	-0.1735	0.3926
recip*gmcarma_a	0.1371	0.1420	96.7	0.97	0.3367	0.05	-0.1448	0.4191

- mPFC Concurrent Support Discussion 1

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-11.7949	13.8805	83.9	-0.85	0.3979	0.05	-39.3985	15.8088
recip	-11.9436	13.8805	83.9	-0.86	0.3920	0.05	-39.5472	15.6601
prov*timec	0.05188	0.05369	90.2	0.97	0.3365	0.05	-0.05479	0.1585
recip*timec	0.05416	0.05369	90.2	1.01	0.3158	0.05	-0.05250	0.1608
prov*pmcarma_a	0.03546	0.007083	43E3	5.01	<.0001	0.05	0.02158	0.04935
recip*pmcarma_a	0.04377	0.006488	43E3	6.75	<.0001	0.05	0.03105	0.05649
prov*gmcarma_a	0.1418	0.1372	88.3	1.03	0.3043	0.05	-0.1309	0.4145
recip*gmcarma_a	0.1351	0.1372	88.3	0.98	0.3274	0.05	-0.1375	0.4078

- mPFC Concurrent Support Discussion 2

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-15.7333	13.6194	90.5	-1.16	0.2510	0.05	-42.7884	11.3218
recip	-9.3936	13.4710	90.4	-0.70	0.4874	0.05	-36.1545	17.3673
prov*timec	0.05454	0.04904	93.7	1.11	0.2689	0.05	-0.04283	0.1519
recip*timec	0.03862	0.04829	92.7	0.80	0.4259	0.05	-0.05728	0.1345
prov*pmcarma_a	-0.04600	0.007074	44E3	-6.50	<.0001	0.05	-0.05987	-0.03214
recip*pmcarma_a	-0.01141	0.006518	44E3	-1.75	0.0801	0.05	-0.02418	0.001369
prov*gmcarma_a	-0.1835	0.1642	90.3	-1.12	0.2666	0.05	-0.5096	0.1426
recip*gmcarma_a	-0.1898	0.1635	89.8	-1.16	0.2489	0.05	-0.5146	0.1351

- SMS Concurrent Support Discussion 1

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-8.1190	16.3857	73.6	-0.50	0.6217	0.05	-40.7713	24.5333
recip	-9.4768	16.3857	73.6	-0.58	0.5648	0.05	-42.1291	23.1754
prov*timec	0.03303	0.05603	74	0.59	0.5573	0.05	-0.07862	0.1447
recip*timec	0.04090	0.05603	74	0.73	0.4678	0.05	-0.07075	0.1525
prov*pmcarma_a	0.09800	0.007054	36E3	13.89	<.0001	0.05	0.08417	0.1118

)wnloads/SupportD1LaggedSyntax1s-results (7).html

Results: SupportD1LaggedSyntax1s.sas

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
recip*pmcarma_a	-0.00665	0.006395	36E3	-1.04	0.2985	0.05	-0.01918	0.005885
prov*gmcarma_a	0.07285	0.1759	72	0.41	0.6800	0.05	-0.2779	0.4236
recip*gmcarma_a	0.05097	0.1759	72	0.29	0.7728	0.05	-0.2997	0.4017

- SMS Concurrent Support Discussion 2

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-1.7731	16.1908	74.6	-0.11	0.9131	0.05	-34.0295	30.4833
recip	-2.8220	15.9845	74.6	-0.18	0.8603	0.05	-34.6674	29.0233
prov*timec	0.01617	0.04913	75.7	0.33	0.7430	0.05	-0.08169	0.1140
recip*timec	0.005091	0.04818	74.8	0.11	0.9161	0.05	-0.09089	0.1011
prov*pmcarma_a	0.09064	0.007252	36E3	12.50	<.0001	0.05	0.07642	0.1049

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
recip*pmcarma_a	0.1160	0.007674	36E3	15.11	<.0001	0.05	0.1009	0.1310
prov*gmcarma_a	-0.01124	0.2353	73.9	-0.05	0.9620	0.05	-0.4801	0.4576
recip*gmcarma_a	0.06338	0.2338	72.9	0.27	0.7870	0.05	-0.4025	0.5293

<u>Lagged Analyses SAS Output with Prior Behavior Predicting Changes in Synchrony for Significant Associations:</u>

- Conflict TPJ 1s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept	4.1611	5.3711	98.3	0.77	0.4404	0.05	-6.4974	14.8196
timec	-0.01902	0.002926	46E3	-6.50	<.0001	0.05	-0.02476	-0.01329
pmycarma	-0.04196	0.007223	46E3	-5.81	<.0001	0.05	-0.05612	-0.02780
gmcarma	0.1131	0.06283	95	1.80	0.0750	0.05	-0.01164	0.2378

- Conflict TPJ 5s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept	2.7379	5.5784	112	0.49	0.6245	0.05	-8.3147	13.7906
timec	-0.01456	0.006643	9019	-2.19	0.0284	0.05	-0.02759	-0.00154
pmycarma	-0.03921	0.01646	9019	-2.38	0.0172	0.05	-0.07147	-0.00695
gmcarma	0.1111	0.06287	95	1.77	0.0805	0.05	-0.01373	0.2359

- Support D1 mPFC 1s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-11.8611	13.9383	83.9	-0.85	0.3972	0.05	-39.5795	15.8573
recip	-11.7898	13.9383	83.9	-0.85	0.4000	0.05	-39.5082	15.9286
prov*timec	0.05376	0.05383	90.2	1.00	0.3206	0.05	-0.05318	0.1607
recip*timec	0.05189	0.05383	90.2	0.96	0.3376	0.05	-0.05504	0.1588
prov*pmycarma_a	0.04289	0.006488	43E3	6.61	<.0001	0.05	0.03017	0.05561
recip*pmycarma_a	0.03424	0.007104	43E3	4.82	<.0001	0.05	0.02032	0.04817
prov*gmcarma_a	0.1345	0.1374	88.3	0.98	0.3305	0.05	-0.1386	0.4075
recip*gmcarma_a	0.1408	0.1374	88.3	1.02	0.3083	0.05	-0.1322	0.4138

- Support D1 mPFC 5s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-11.5323	14.0991	83.9	-0.82	0.4157	0.05	-39.5705	16.5058
recip	-11.6318	14.0986	83.9	-0.83	0.4117	0.05	-39.6691	16.4055
prov*timec	0.2640	0.2721	90.2	0.97	0.3345	0.05	-0.2766	0.8047
recip*timec	0.2584	0.2722	90.2	0.95	0.3449	0.05	-0.2822	0.7991
prov*pmycarma_a	0.04257	0.01513	8528	2.81	0.0049	0.05	0.01291	0.07222
recip*pmycarma_a	0.02910	0.01636	8547	1.78	0.0752	0.05	-0.00296	0.06116
prov*gmcarma_a	0.1297	0.1362	88.3	0.95	0.3436	0.05	-0.1410	0.4004
recip*gmcarma_a	0.1353	0.1362	88.3	0.99	0.3234	0.05	-0.1354	0.4060

- Support D1 TPJ 1s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	2.5094	13.3181	97.3	0.19	0.8509	0.05	-23.9221	28.9410
recip	2.5958	13.3181	97.3	0.19	0.8459	0.05	-23.8358	29.0275
prov*timec	-0.00958	0.04024	98	-0.24	0.8123	0.05	-0.08944	0.07028
recip*timec	-0.01077	0.04024	98	-0.27	0.7895	0.05	-0.09063	0.06909
prov*pmycarma_a	0.02258	0.006591	47E3	3.43	0.0006	0.05	0.009658	0.03550
recip*pmycarma_a	0.02042	0.006808	47E3	3.00	0.0027	0.05	0.007076	0.03377
prov*gmcarma_a	-0.05678	0.1446	96	-0.39	0.6954	0.05	-0.3438	0.2302
recip*gmcarma_a	-0.05275	0.1446	96	-0.36	0.7161	0.05	-0.3398	0.2343

- Support D1 TPJ 15s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Prov	-3.7172	16.0245	98.3	-0.23	0.8170	0.05	-35.5159	28.0816
Recip	-2.0717	16.3069	101	-0.13	0.8992	0.05	-34.4195	30.2762
Prov*timec	0.7123	1.5901	98.6	0.45	0.6551	0.05	-2.4429	3.8675
Recip*timec	0.6953	1.6211	101	0.43	0.6689	0.05	-2.5202	3.9109
Prov*pmycarma_a	0.09635	0.04406	1469	2.19	0.0289	0.05	0.009928	0.1828
Recip*pmycarma_a	0.08319	0.04591	1472	1.81	0.0702	0.05	-0.00687	0.1733
Prov*gmcarma_a	0.1310	0.1332	96.2	0.98	0.3279	0.05	-0.1334	0.3953
Recip*gmcarma_a	0.1033	0.1339	96.8	0.77	0.4424	0.05	-0.1625	0.3690

- Support D1 Somatosensory Synchrony 1s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-9.3391	16.4085	73.6	-0.57	0.5710	0.05	-42.0367	23.3586
recip	-8.0639	16.4085	73.6	-0.49	0.6246	0.05	-40.7616	24.6338
prov*timec	0.04043	0.05612	74	0.72	0.4736	0.05	-0.07140	0.1523
recip*timec	0.03292	0.05612	74	0.59	0.5593	0.05	-0.07891	0.1447
prov*pmycarma_a	-0.00681	0.006398	36E3	-1.06	0.2870	0.05	-0.01935	0.005728

wnloads/SupportD1LaggedSyntax1s-results (6).html

Results: SupportD1LaggedSyntax1s.sas

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
recip*pmycarma_a	0.09696	0.007078	36E3	13.70	<.0001	0.05	0.08308	0.1108
prov*gmcarma_a	0.05105	0.1759	72	0.29	0.7725	0.05	-0.2996	0.4017
recip*gmcarma_a	0.07253	0.1759	72	0.41	0.6814	0.05	-0.2782	0.4232

- Support D1 Somatosensory Synchrony 5s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-8.8030	16.4136	73.6	-0.54	0.5934	0.05	-41.5108	23.9048
recip	-7.6715	16.4135	73.6	-0.47	0.6416	0.05	-40.3790	25.0361
prov*timec	0.1947	0.2822	74.1	0.69	0.4923	0.05	-0.3676	0.7571
recip*timec	0.1589	0.2822	74.1	0.56	0.5752	0.05	-0.4035	0.7212
prov*pmycarma_a	-0.00788	0.01499	7034	-0.53	0.5993	0.05	-0.03726	0.02151

nloads/SupportD1LaggedSyntax5s-results (24).html

Results: SupportD1LaggedSyntax5s.sas

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
recip*pmycarma_a	0.09663	0.01636	7044	5.91	<.0001	0.05	0.06456	0.1287
prov*gmcarma_a	0.05077	0.1734	72	0.29	0.7705	0.05	-0.2949	0.3964
recip*gmcarma_a	0.07154	0.1734	72.1	0.41	0.6812	0.05	-0.2741	0.4172

- Support D1 Somatosensory Synchrony 15s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Prov	5.1124	17.8664	75	0.29	0.7756	0.05	-30.4791	40.7039
Recip	7.9733	18.2584	77.6	0.44	0.6635	0.05	-28.3791	44.3256
Prov*timec	-0.7297	1.6784	75.4	-0.43	0.6650	0.05	-4.0730	2.6136
Recip*timec	-0.4086	1.7175	77.2	-0.24	0.8126	0.05	-3.8285	3.0113

wnloads/SupportD1LaggedSyntax15s-results (21).html

Results: SupportD1LaggedSyntax15s.sas

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Prov*pmycarma_a	0.1681	0.05527	1102	3.04	0.0024	0.05	0.05966	0.2766
Recip*pmycarma_a	0.06022	0.04656	1092	1.29	0.1962	0.05	-0.03114	0.1516
Prov*gmcarma_a	0.05036	0.2201	74.1	0.23	0.8196	0.05	-0.3881	0.4889
Recip*gmcarma_a	-0.04247	0.2218	74.8	-0.19	0.8487	0.05	-0.4843	0.3994

- Support D1 Somatosensory 30s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Prov	-7.1992	16.1690	73.6	-0.45	0.6574	0.05	-39.4197	25.0212
Recip	-7.2542	16.1627	73.5	-0.45	0.6549	0.05	-39.4630	24.9546
Prov*timec	1.0439	1.7385	74	0.60	0.5500	0.05	-2.4200	4.5079
Recip*timec	0.9305	1.7382	74	0.54	0.5940	0.05	-2.5329	4.3940
Prov*pmycarma_a	0.01469	0.04799	1078	0.31	0.7597	0.05	-0.07948	0.1089

vnloads/SupportD1LaggedSyntax30s-results (33).html

Results: SupportD1LaggedSyntax30s.sas

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Recip*pmycarma_a	0.1207	0.04784	1075	2.52	0.0118	0.05	0.02683	0.2146
Prov*gmcarma_a	0.03826	0.1619	72.1	0.24	0.8139	0.05	-0.2845	0.3611
Recip*gmcarma_a	0.06598	0.1622	72.6	0.41	0.6854	0.05	-0.2574	0.3894

- Support D2 mPFC 1s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-9.2939	13.5283	90.4	-0.69	0.4938	0.05	-36.1686	17.5807
recip	-15.6869	13.6773	90.5	-1.15	0.2544	0.05	-42.8571	11.4832
prov*timec	0.03827	0.04842	92.7	0.79	0.4314	0.05	-0.05789	0.1344
recip*timec	0.05419	0.04917	93.7	1.10	0.2732	0.05	-0.04344	0.1518
prov*pmycarma_a	-0.01070	0.006538	44E3	-1.64	0.1016	0.05	-0.02352	0.002111
recip*pmycarma_a	-0.04658	0.007079	44E3	-6.58	<.0001	0.05	-0.06045	-0.03270
prov*gmcarma_a	-0.1897	0.1637	89.8	-1.16	0.2494	0.05	-0.5149	0.1354
recip*gmcarma_a	-0.1832	0.1643	90.3	-1.11	0.2679	0.05	-0.5097	0.1433

- Support D2 mPFC 5s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-8.8130	13.6940	90.3	-0.64	0.5215	0.05	-36.0173	18.3912
recip	-15.3796	13.8570	90.7	-1.11	0.2700	0.05	-42.9058	12.1466
prov*timec	0.03663	0.04901	92.5	0.75	0.4567	0.05	-0.06070	0.1340
recip*timec	0.05447	0.04981	93.6	1.09	0.2769	0.05	-0.04443	0.1534
prov*pmycarma_a	-0.00733	0.01519	8753	-0.48	0.6295	0.05	-0.03710	0.02245
recip*pmycarma_a	-0.04843	0.01627	8759	-2.98	0.0029	0.05	-0.08032	-0.01653
prov*gmcarma_a	-0.1868	0.1615	90.1	-1.16	0.2507	0.05	-0.5077	0.1342
recip*gmcarma_a	-0.1853	0.1622	90.6	-1.14	0.2564	0.05	-0.5076	0.1370

- Support D2 TPJ 5s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-11.9203	14.4732	98.6	-0.82	0.4121	0.05	-40.6398	16.7992
recip	-11.9331	14.6325	99	-0.82	0.4167	0.05	-40.9672	17.1011
prov*timec	0.04803	0.04696	99	1.02	0.3088	0.05	-0.04514	0.1412
recip*timec	0.05218	0.04763	100	1.10	0.2759	0.05	-0.04231	0.1467
prov*pmycarma_a	0.08952	0.01533	9323	5.84	<.0001	0.05	0.05947	0.1196
recip*pmycarma_a	0.04798	0.01652	9333	2.90	0.0037	0.05	0.01559	0.08037
prov*gmcarma_a	0.1347	0.1403	96.6	0.96	0.3394	0.05	-0.1437	0.4131
recip*gmcarma_a	0.1077	0.1409	97.2	0.76	0.4462	0.05	-0.1718	0.3873

- Support D2 SMS 1s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-2.5653	16.0602	74.6	-0.16	0.8735	0.05	-34.5613	29.4307
recip	-1.4783	16.2675	74.7	-0.09	0.9278	0.05	-33.8874	30.9307
prov*timec	0.004425	0.04844	74.8	0.09	0.9275	0.05	-0.09207	0.1009
recip*timec	0.01529	0.04940	75.7	0.31	0.7577	0.05	-0.08309	0.1137
prov*pmycarma_a	0.1148	0.007692	36E3	14.93	<.0001	0.05	0.09977	0.1299

ownloads/SupportD2LaggedSyntax1s-results (11).html

Results: SupportD2LaggedSyntax1s.sas

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
recip*pmycarma_a	0.08840	0.007248	36E3	12.20	<.0001	0.05	0.07419	0.1026
prov*gmcarma_a	0.06187	0.2338	72.9	0.26	0.7921	0.05	-0.4042	0.5279
recip*gmcarma_a	-0.01182	0.2354	73.9	-0.05	0.9601	0.05	-0.4809	0.4572

- Support D2 SMS 5s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-46.4497	11.5525	175	-4.02	<.0001	0.05	-69.2498	-23.6496
recip	-26.6471	11.4419	167	-2.33	0.0211	0.05	-49.2369	-4.0573
prov*timec	0.1420	0.03428	279	4.14	<.0001	0.05	0.07450	0.2095
recip*timec	0.1579	0.03376	271	4.68	<.0001	0.05	0.09139	0.2243
prov*dmsms	0.1043	0.05426	591	1.92	0.0551	0.05	-0.00230	0.2108
recip*dmsms	0.1588	0.05346	581	2.97	0.0031	0.05	0.05383	0.2638
prov*gmsms	-0.03541	0.1254	57.5	-0.28	0.7787	0.05	-0.2865	0.2156
recip*gmsms	0.01960	0.1253	57	0.16	0.8763	0.05	-0.2313	0.2705

- Support D2 SMS 15s

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	2.1976	16.8565	75	0.13	0.8966	0.05	-31.3822	35.7774
recip	3.7967	17.1370	76.1	0.22	0.8253	0.05	-30.3339	37.9272
prov*timec	-0.1957	0.7725	75.2	-0.25	0.8007	0.05	-1.7344	1.3430
recip*timec	-0.03082	0.7884	76.2	-0.04	0.9689	0.05	-1.6010	1.5393
prov*pmycarma_a	0.1387	0.03412	2303	4.06	<.0001	0.05	0.07174	0.2056

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
recip*pmycarma_a	0.07342	0.03011	2298	2.44	0.0148	0.05	0.01437	0.1325
prov*gmcarma_a	0.05347	0.2246	73.4	0.24	0.8125	0.05	-0.3942	0.5011
recip*gmcarma_a	-0.02368	0.2264	74.3	-0.10	0.9170	0.05	-0.4747	0.4274

- Support D1 SMS 15s behavior outcome

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Prov	-46.3915	13.9874	183	-3.32	0.0011	0.05	-73.9888	-18.7942
Recip	-19.3420	11.5561	136	-1.67	0.0965	0.05	-42.1946	3.5105
Prov*timec	4.0435	1.3495	186	3.00	0.0031	0.05	1.3811	6.7058
Recip*timec	4.1242	1.0698	174	3.86	0.0002	0.05	2.0127	6.2356
Prov*dmsms	0.07913	0.05914	518	1.34	0.1815	0.05	-0.03705	0.1953
Recip*dmsms	0.1500	0.04674	527	3.21	0.0014	0.05	0.05816	0.2418
Prov*gmsms	-0.04451	0.1450	88.4	-0.31	0.7596	0.05	-0.3327	0.2437
Recip*gmsms	0.02402	0.1253	54	0.19	0.8487	0.05	-0.2272	0.2753

- Support D2 SMS 30s behavior outcome

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Prov	-46.3915	13.9874	183	-3.32	0.0011	0.05	-73.9888	-18.7942
Recip	-19.3420	11.5561	136	-1.67	0.0965	0.05	-42.1946	3.5105
Prov*timec	4.0435	1.3495	186	3.00	0.0031	0.05	1.3811	6.7058
Recip*timec	4.1242	1.0698	174	3.86	0.0002	0.05	2.0127	6.2356
Prov*dmsms	0.07913	0.05914	518	1.34	0.1815	0.05	-0.03705	0.1953
Recip*dmsms	0.1500	0.04674	527	3.21	0.0014	0.05	0.05816	0.2418
Prov*gmsms	-0.04451	0.1450	88.4	-0.31	0.7596	0.05	-0.3327	0.2437
Recip*gmsms	0.02402	0.1253	54	0.19	0.8487	0.05	-0.2272	0.2753

- Support D2 TPJ 5s behavior outcome

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
prov	-49.3612	10.9478	171	-4.51	<.0001	0.05	-70.9715	-27.7508
recip	-27.4046	11.7687	207	-2.33	0.0208	0.05	-50.6065	-4.2027
prov*timec	0.1444	0.03015	341	4.79	<.0001	0.05	0.08505	0.2037
recip*timec	0.1243	0.03364	337	3.70	0.0003	0.05	0.05813	0.1905
prov*dmtpj	0.01645	0.04199	836	0.39	0.6954	0.05	-0.06598	0.09887
recip*dmtpj	0.09442	0.04707	837	2.01	0.0452	0.05	0.002029	0.1868
prov*gmtpj	0.2211	0.1489	66.3	1.49	0.1423	0.05	-0.07613	0.5183
recip*gmtpj	0.01502	0.1545	76.7	0.10	0.9228	0.05	-0.2926	0.3226

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