INVESTIGATING NEURAL SYNCHRONY IN INTIMATE COUPLES AND ROOMMATES USING ELECTROENCEPHALOGRAPHY DURING NATURALISTIC EMOTIONAL STIMULI

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DEDICATION

To my dear husband, and to my loving family and friends,

Whose unconditional love and support made this journey possible. Thank you for encouraging me and always believing in me. Having you by my side filled this journey with joy, strength, and purpose.

And to my homeland, Iran, and its brave and resilient people.

ABSTRACT

Prior research has suggested that romantic couples exhibit greater inter-brain synchrony than other dyads; however, these findings may be confounded by differences in shared experience. This thesis examined how relationship type, relationship satisfaction, emotional similarity, and social proximity contribute to neural synchrony during naturalistic emotional processing. To address this, the present study compared romantic couples and roommate dyads using electroencephalography (EEG) and phase lag index (PLI) analysis while participants viewed emotionally evocative stimuli with positive, negative, and neutral valence. Results provided limited support for the relationship-type differences in neural synchrony. Although some effects suggested greater synchrony in couples, particularly in frontal regions during emotionally arousing conditions, these effects were not robust and did not survive correction for multiple comparisons. Relationship satisfaction and emotional similarity were also not consistently associated with neural synchrony. In contrast, relationship duration was positively correlated with neural synchrony in both couples and roommates, with significant associations observed in the theta band that survived correction for multiple comparisons. These findings suggest that neural synchrony during naturalistic experiences may be better explained by shared experience and social proximity rather than relationship category alone. The results highlight the importance of considering interaction history and familiarity when interpreting inter-brain synchrony and contribute to a more nuanced understanding of the mechanisms underlying neural alignment in social contexts.

ETHICS STATEMENT

Work described in this thesis received research ethics approval from the University of Alberta Research Ethics Board for the project title "Investigating Neural Synchrony Between Romantic Couples vs Roommates Using EEG", No. Pro00146663, November 12, 2024.

USE OF GENERATIVE AI

I used generative AI tools in a limited capacity to support the writing of this thesis. Their primary role was to assist with improving grammar, clarity, and the overall flow of the text, helping to make the writing more academically refined. This was particularly valuable as English is my second language. In some instances, AI was used to rephrase sentences and enhance the organization of paragraphs. However, AI was not used to generate research ideas, design the study, conduct analyses, or interpret the results. All research decisions, analyses, and conclusions are entirely my own. I carefully reviewed and edited any AI-assisted content to ensure it accurately reflects my work and intended meaning. I take full responsibility for the content of this thesis, including the accuracy of all information and citations.

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Chapter 3: Results

LIST OF ABBREVIATIONS

EEG	Electroencephalography
EOG	Electrooculogram
FDR	False Discovery Rate
FIR	Finite Impulse Response
fNIRS	Functional Near-Infrared Spectroscopy
fMRI	Functional Magnetic Resonance Imaging
ICA	Independent Component Analysis
IFG	Inferior Frontal Gyrus
INS	Inter-brain Neural Synchrony
Mod Diff	Modified Differential Emotions Scale Score
mPFC	Medial Prefrontal Cortex
PLI	Phase Lag Index
ROI	Region of Interest
RSAT	Burns' Relationship Satisfaction Scale
VTA	Ventral Tegmental Area

CHAPTER 1: INTRODUCTION

1.1 Social Relationships and Health

To solve the problem of survival and reproduction, like many other primates, humans have adapted group living and deep investments in social bonds (Caporael, 1997; Dunbar, 1998; Taylor & Gonzaga, 2006). Social bonds refer to existing connections between individuals (Wang et al., 2022) and can be formal or informal, active or passive, positive or negative, and include varying degrees of exchange (e.g., seller-buyer) and equality (e.g., teachers-peers; X. Cheng et al., 2025). Further, the quantity and quality of an individual's social relationships can affect their mental health, health behaviour (i.e., a wide range of personal behaviours that influence health, morbidity, and mortality, such as exercise, drug abuse, etc.), physical health, and mortality risk (Umberson & Karas Montez, 2010). For example, adults with more social ties experience better health and live longer than their isolated peers (Haslam et al., 2016; Umberson & Karas Montez, 2010). Further, previous research has found a link between low quality or quantity of social ties to a host of conditions, including development and progression of cardiovascular disease, atherosclerosis, recurrent myocardial infarction, high blood pressure, autonomic dysregulation, cancer and delayed cancer recovery, slower wound healing, inflammatory biomarkers and impaired immune function (Ertel et al., 2009; Everson-Rose & Lewis, 2005; Kiecolt-Glaser et al., 2002; Robles & Kiecolt-Glaser, 2003; Uchino, 2006). Thus, these findings highlight the critical role of social relationships in shaping both psychological and physical health outcomes.

1.2 Romantic Relationships and Friendships

Romantic relationships and friendships are both meaningful forms of social connection, yet they differ in their structure and function. Humans develop intimate social and personal relationships with their partners (Clore & Byrne, 1974). This enables them to survive, successfully mate, and raise offspring (Cacioppo & Patrick, 2008; Silk, 2007). Romantic relationships are characterized by a deep emotional connection and the potential for long-term commitment and mutual influence (Zhao et al., 2024). They are a primary bond for most adults (Robles & Kiecolt-Glaser, 2003) and an essential resource for exchanging and sharing emotions (Gottman & Levenson, 1988). These characteristics (i.e., deep emotional connection, long-term commitment, mutual influence) make them unique compared to other types of relationships (Zhao et al., 2024).

Friendships are defined as close relationships with people we choose voluntarily and make an effort to stay in contact with (Dunbar, 2018; Näslund & Reinholdsson, 2016). They are conceptualized as serene and secure, involving deep affection and calmness, unlike romantic relationships that are expected to be intense and obsessive (A. Chen, 2020; De Barros et al., 2025; Diamond, 2003). It has been hypothesized that similarity, familiarity, and expressions of esteem and validation — defined as communicating one's worth and signalling the likelihood of help and not harm — will result in friendships (Berscheid, 2010; De Barros et al., 2025). Qualitative research by Adams et al. (2000) shows how friendships differ from other relationships in three main components: emotional (e.g., self-disclosure, sociability, etc.), cognitive (e.g., loyalty, trust, etc.), and behavioural (e.g., compatibility and care). Further, research by De Barros et al. (2025) demonstrates that individuals generally view romantic relationships to be more intimate and interdependent than friendships, often involving sex, and shaped by strong societal norms about how romantic love should be experienced. Thus, while both relationship types involve emotional closeness, romantic relationships tend to be more intensive and interdependent, whereas friendships are more stable and less emotionally intense.

Several brain regions have been associated with romantic love. For example, dopamine-rich reward systems, including the ventral tegmental area (VTA) and the caudate nucleus, are thought to play a key role in arousal and motivation in romantic relationships (Fisher et al., 2005). On this basis, Fisher et al. (2005) characterized romantic love as a motivational system that is distinct from, yet overlapping with, the sex drive, since sexual arousal recruits the same reward circuitry but activates a largely different overall patterns of brain regions. Neuroimaging studies demonstrate that romantic love activates regions associated with reward processing and attachment, like the caudate, nucleus accumbens, and anterior cingulate cortex, reinforcing their role in fostering pair-bonding and energy conservation for mate choice (Acevedo et al., 2012; Younger et al., 2010). This engagement extends to other brain areas, including the posterior cingulate cortex and globus pallidus, which are thought to be associated with attachment and pair-bonding in longer-term relationships, indicating that the brain systems associated with romantic love may change with time (Acevedo et al., 2012). Therefore, early romantic love seems to be most strongly associated with the ventral tegmental area, caudate nucleus, nucleus accumbens and anterior cingulate cortex, whereas later romantic love is associated with the posterior cingulate cortex and globus pallidus.

The brain regions associated with friendship have also been examined, and include regions related to reward and motivation, such as the ventral striatum and nucleus accumbens, as well as those in the social brain network, such as the medial prefrontal cortex (mPFC), temporoparietal junction, posterior superior temporal sulcus and precuneus (Becht et al., 2021). A review by Güroğlu (2022) highlighted neuroimaging studies focused on friendships and found increased activation in reward and motivational circuitry, such as the ventral striatum including nucleus accumbens, amygdala, hippocampus, and ventromedial prefrontal cortex during interactions between friends compared to interactions between other peers (Güroğlu et al., 2008). These brain regions also show greater activation in young adults when they watch emotional stimuli and believe their friend is watching the same stimuli (Wagner et al., 2015). Further, a neuroimaging study by Becht et al. (2021) looked at the relationship between friendship quality and the structure of the social brain network in 8- to 25-year-olds. They found that individuals showing faster cortical thinning in the mPFC, a marker of accelerated brain maturation and increasing specialization of neural circuits during adolescence, developed higher-quality friendships over time. Thus, both romantic relationships and friendships engage reward-related brain regions, most notably the nucleus accumbens. This shared activation points to a common neural basis for social reward across different types of close relationships, while raising questions about how variations in relationship quality may influence these processes.

1.3 Relationship Satisfaction and Social Relationships

Beyond the type of social relationship, the quality of these relationships plays a critical role in shaping individual well-being and social functioning. The term *relationship satisfaction* in romantic relationships refers to an individual's overall assessment of their romantic relationship (Bühler et al., 2021; Fincham & Bradbury, 1987; Funk & Rogge, 2007; Kamp Dush et al., 2008). Higher relationship satisfaction is characterized by positive attitudes and feelings toward the partner and is often associated with an individual feeling that their needs are being met (Bühler et al., 2021; Fincham & Rogge, 2010). This, in turn, may have a protective effect against various types of emotional distress for individuals in a romantic relationship (Røsand et al., 2012). Importantly, satisfaction in romantic relationships is a far more significant predictor of overall happiness compared to satisfaction in other life domains, such as work or friendships (Bühler et al., 2021; Glenn & Weaver, 1981; Headey et al., 1991; Heller et al., 2004; Umberson et al., 2006). Taken together, these findings suggest that relationship satisfaction plays an important role in individual well-being, beyond the mere presence of social bonds.

Previous research shows the impact of romantic relationships on the subjective well-being and health of individuals. People who are more satisfied in their relationships tend to have greater overall satisfaction in life (Be et al., 2013; Headey et al., 1991; Proulx et al., 2007), experience better overall health (Bookwala, 2005; Bühler et al., 2021; Kiecolt-Glaser & Newton, 2001; Proulx et al., 2007; Robles et al., 2014), and live longer (Sbarra et al., 2011; Whisman et al., 2018) than people in less stable relationships. Likewise, many behavioural studies show that relationship conflict strongly impacts both physical and mental health (Coyne et al., 2001; Greene & Griffin, 1998) and is associated with poorer relationship satisfaction among adults (Gottman, 1994; Greene & Griffin, 1998). Further, previous research suggests that interpersonal conflict may lead to chronic stress (Mayne et al., 1997), which can in turn result in long-term physical and mental health problems (Beach et al., 1998; Mayne et al., 1997). In addition, experiencing conflict negatively impacts relationship quality perception for partners, which leads to poorer relationship satisfaction in distressed relationships (Campbell et al., 2005; Cooper et al., 2018). These findings further emphasize that relationship quality, particularly in the form of low conflict and emotional stability, is associated with both psychological and physiological health outcomes.

Friendship quality is referred to as the nature of friendship interactions that affects individuals' development and adjustment (Akin et al., 2016; Näslund & Reinholdsson, 2016). Friendship quality is characterized by help, loyalty, acceptance and few conflicts and is more important than the number of friends. People with higher friendship quality can cope better with stress, whereas lower friendship quality often leads to feelings of loneliness (Näslund &

Reinholdsson, 2016). A systematic review by Alsarrani et al. (2022) showed a positive association between friendship quality and happiness, self-esteem, life satisfaction and subjective well-being. This may be explained by the fact that high-quality friendships involve positive interpersonal interactions that fulfill basic psychological needs, such as autonomy, competence, and relatedness (i.e., the feeling of meaningful connection with others; M. Li et al., 2024). The role of social support within high-quality friendships can also reduce perceived stress during different life events and influence psychological processes such as mood and self-esteem, ultimately contributing to better overall well-being (Uchino et al., 1999). Additionally, research suggests that high-quality friendships contribute to individuals' social functioning by enhancing their success in peer interactions and promoting prosocial behaviour (Berndt, 2002; Clapham et al., 2025). Thus, in both romantic relationships and friendships, higher satisfaction and quality have been positively linked to happiness, life satisfaction and subjective well-being and negatively associated with perceived loneliness (Näslund & Reinholdsson, 2016). These findings highlight that relationship quality not only shapes individual well-being but also reflects the extent to which individuals are emotionally and cognitively aligned with one another.

1.4 Inter-Brain Neural Synchrony and Closeness in Relationships

In addition to better health and well-being outcomes, previous research also suggests that increased closeness in relationships (whether romantic or non-romantic) is associated with more similar brain activity patterns, particularly inter-brain neural synchrony (INS). INS refers to the alignment of neural activity between individuals involved in an interactive task, such as cooperative tasks (Pan et al., 2017), or conversations (Djalovski et al., 2021; Long et al., 2022), as well as non-interactive tasks, such as watching movie clips (Chen et al., 2024; Parkinson et al., 2018). INS can be quantified using techniques that are correlation-based (e.g., Pearson correlation), Coherence-based (e.g., Fourier Transform Coherence, Imaginary Part of Coherence) or Phase-based (Chen et al., 2024; Hakim et al., 2023). Measures of INS quantify the magnitude of neural coupling between individuals, and the degree of INS may change depending on task demands, the nature of the dyadic relationship, and moment-to-moment engagement (Azhari et al., 2025). Importantly, INS reflects dynamic coupling between individuals over time, rather than identical neural responses (Hakim et al., 2023). These patterns of neural coupling are thought to reflect shared attention, emotional attunement, coordinated behaviour and successful interpersonal communication (Azhari et al., 2025).

A common technique used to measure neural synchrony is electroencephalography (EEG), which provides high temporal resolution and allows researchers to track dynamic changes in neural activity over time (Dmochowski et al., 2012). The Phase Lag Index (PLI) is a widely used connectivity measure in EEG and INS studies (I.-C. Chen et al., 2025; Chen et al., 2024; Stam et al., 2007). The PLI measures whether one signal consistently leads or lags another signal. Because it discards zero-lag phase relationships, it is robust against volume conduction and common-source effects, which produce spurious zero-lag coupling, making it an effective tool for revealing authentic functional connectivity (Aydore et al., 2013; Chen et al., 2024; Stam et al., 2007).

EEG signals can be broken down into different frequency bands (e.g., *theta, alpha, beta, gamma)*. As described by Kraus et al. (2020) and X. Zhang et al. (2021) *theta* (4~7 Hz) oscillations have been associated with partner attachment and romantic rejection from the potential partner. *Alpha* (8~12 Hz) oscillations were found to be associated with individuals engaging in positive mental imagery within romantic relationships (Cannas Aghedu et al., 2021). *Beta* (13~30 Hz) oscillations are involved in emotion regulation (Díaz et al., 2019), and play a key role in recognizing emotions and responding to social stimuli (Mishra et al., 2022). Finally, *gamma* (31~49 Hz) oscillations are related to social interactions and emotional processing, specifically during natural interactions and mutual gazing between romantic partners (Başar, 2013; Kinreich et al., 2017). Together, these features make EEG-based measures of INS particularly suitable for examining shared neural dynamics underlying social and emotional experiences.

A growing number of studies demonstrate that higher levels of INS during cooperative interactions are associated with improved task performance, particularly in joint goal achievement, both in adults and adult-child pairs (Hoehl et al., 2021). Inter-brain synchrony is also thought to facilitate the interpersonal transmission of data through verbal and nonverbal communication (Dumas et al., 2011; Hasson et al., 2012). For example, Nguyen et al. (2020) observed neural synchrony in mother-child pairs during cooperative problem solving. They found higher synchrony in the temporo-parietal and lateral prefrontal areas within mother-child dyads. Increased neural synchrony in temporal areas has been associated with effective cooperation, potentially allowing mother-child pairs to understand each other with less effort (Jiang et al., 2021; Keller et al., 2014; Koban et al., 2019; Miller et al., 2019). Further, increased neural synchrony in frontal areas of the brain within mother-child pairs is also associated with interactive social decision making and effective communication (M. Zhang et al., 2017).

Among the four frequency bands, *alpha* oscillations are most strongly associated with social behaviours (Liu et al., 2018). For example, *alpha* oscillations in frontal regions show greater differences across conditions during social bargaining (Billeke et al., 2014). They are also associated with musicians' empathic responses when watching recordings of their own quartet performances (Babiloni et al., 2012). Additionally, significant *alpha* synchronizations have been observed during turn-taking verbal interactions (Ahn et al., 2018) and direct eye contact between infants and adults (Leong et al., 2017). This synchrony might reflect their shared emotional experience (Babiloni et al., 2012; Goldstein et al., 2018), which leads to a stronger emotional bond. Romantic couples also tend to show higher neural synchronization when processing negative emotions rather than positive emotions (Anderson et al., 2003; Chen et al., 2024; Costa et al., 2006). Together, these findings highlight INS as a neural framework for studying shared emotional processing, while also raising questions about how synchrony may differ across relationship types.

1.5 Emotion Processing in Different Relationships

Emotions are a key element in social relationships and deeply tangled with interpersonal dynamics (Nummenmaa et al., 2012). Previous literature has shown the profound impact of relationship type on emotional processing, and among these, romantic relationships receive particular attention (Clark & Finkel, 2005; Fehr & Harasymchuk, 2005). Romantic relationships can be a great context to investigate emotions since they will enhance our understanding of how love and connection shape emotional experiences and expression (Davila et al., 2017; Leach, 2016). The findings suggest a reciprocal relationship between emotions and relationships, whereby relationships shape emotional experiences while emotions, in turn, influence relational processes and outcomes. These processes and outcomes include conflict resolution, emotional support, and interpersonal cognition (Butler, 2017; Guerrero & La Valley, 2006; Larson & Almeida, 1999; Lopes et al., 2005; Randall et al., 2013).

Previous research highlights how expressing emotions varies in different relationships, likely due to different levels of intimacy (Clark & Finkel, 2005; Fehr & Harasymchuk, 2005; Fischer et al., 2003; Fischer & Van Kleef, 2010). Emotional responses tend to be more evident when the presumed partner was a friend compared to an acquaintance (Kimura et al., 2008). Further, emotions in romantic relationships (particularly negative emotions) play a critical role in shaping attachment and relational dynamics (Creasey et al., 1999). At the same time, the transmission of emotions across individuals appears to depend on relationship context, with evidence suggesting that negative emotions may spread more between strangers than between friends (Joiner & Katz, 1999). These findings highlight that emotional expression and emotional influence are shaped by the nature of the relationship, underscoring the importance of considering the relationship type when examining emotional processes. These differences in emotional expression and interpersonal dynamics suggest that individuals in different types of relationships may not only experience emotions differently, but may also exhibit differences in how their neural activity aligns during shared experiences.

Consistent with this idea, several neuroimaging studies have investigated how differing levels of closeness in relationships, both romantic and non-romantic, can influence synchronous brain activity. For example, Parkinson et al. (2018) used fMRI to examine INS among friends during movie watching. The results showed greater INS between friends who are closely connected in the real-world social network compared to those who were not, particularly in regions linked to reward processing (i.e., nucleus accumbens, caudate nucleus, putamen), emotional interpretation (i.e., amygdala), and attentional and social-cognitive functions (i.e., superior and inferior parietal lobules). These results suggest that friends may interpret experiences more similarly, which in turn may help foster empathy and understanding between peers. In another fNIRS neuroimaging study, INS between mother-child pairs was examined during proximal movie co-watching (with the child sitting on the mother's lap), distal movie co-watching (with the child sitting next to the mother) and free play (Nguyen et al., 2021). INS was highest during free play and proximal movie co-watching in brain regions such as bilateral dorsolateral prefrontal cortex and mPFC. Thus, INS is thought to be a biomarker of interaction quality (Nguyen et al., 2021).

Recent research has increasingly focused on neural dynamics in romantic couples. Azhari et al. (2020) used neuroimaging to measure INS in parents while listening to different audio stimuli, including infant cries. Their findings showed increased INS in attention and cognitive control areas with the spouse present, suggesting enhanced attentional regulation towards social stimuli. These brain areas included left inferior frontal gyrus (IFG), left middle frontal gyrus and bilateral anterior prefrontal cortex. In another study, Li et al. (2022) used neuroimaging techniques to examine neural activity in couples as they watched two movie types: marital content (e.g., relationship with in-laws, intimacy) and non-marital content (e.g., science, food). The study assessed brain synchronization to observe how couples responded to these distinct themes. Results showed that couples exhibited greater neural synchrony when watching marital movies than non-marital ones. Real couples also showed higher neural synchronization compared to randomly paired couples. Additionally, couples who reported higher marital satisfaction displayed even greater synchronization than those with lower satisfaction. In addition to the observed INS at the whole-brain level, specific brain areas predictive of marital satisfaction were also identified, including the posteromedial and temporoparietal cortex, as well as lateral frontoparietal cortex and language systems.

Further, a study conducted by Chen et al. (2024) examined how different social relationships (i.e., romantic relationships and close friendships) influenced emotion processing and neural synchrony. Using EEG hyperscanning and Phase Lag Index (PLI), they compared romantic couples and close friends during emotional processing tasks and examined both behavioural emotional synchronization and neural synchronization across frequency bands and brain regions. Results from this study showed that romantic couples exhibited greater behavioural synchrony than friends, particularly during negative emotional experiences, with sadness emerging as the primary emotion distinguishing the two groups. At the neural level, romantic couples showed greater INS than friends, particularly within the prefrontal cortex. This effect was most pronounced in the alpha frequency band during the processing of sadness. In contrast, friends showed greater interbrain synchronization than couples in the right temporal region in the beta band.

Further, in couples, higher relationship quality was positively associated with emotional behavioural synchronization, whereas lower relationship quality was associated with increased prefrontal neural synchronization, In addition, when couples were divided into high- and low-quality groups, both groups exhibited greater prefrontal interbrain synchronization than friends, with low-quality couples showing the highest level of neural synchronization, followed by high-quality couples, indicating that elevated neural synchrony is not exclusive to high-quality relationships. In contrast, only high-quality couples exhibited significantly greater behavioural synchronization than friends, whereas low-quality couples did not differ from friends. Together, these findings indicate that relationship quality modulates both neural and behavioural synchronization but not always in the same direction. Chen et al. (2024) further showed that interbrain synchronization partially mediates the relationship between relationship quality and behavioural emotional synchronization in romantic couples. Notably, this mediation effect was negative in direction, suggesting that lower relationship quality was associated with increased neural synchronization, which then contributed to behavioural synchronization. This pattern supports the idea that increased INS may reflect compensatory mechanisms when perceived relationship quality is lower. In addition, Chen et al. (2024) demonstrated that prefrontal neural synchronization distinguished romantic couples from friends more strongly than behavioural synchronization alone, highlighting the prefrontal cortex as an important region for understanding relationship-specific neural coordination.

Together, these findings suggest that emotional coordination in romantic relationships reflects a dynamic interplay between relationship quality, neural synchronization, and emotional experience. By using a non-interactive emotional paradigm, Chen et al. (2024) showed that heightened interbrain synchronization in couples arises from shared emotional processing rather than interaction demands. Further, prefrontal alpha-band synchronization appears to support shared emotional experience and emotion regulation, while reduced right temporal synchronization in couples may reflect decreased reliance on explicit mentalizing due to relational familiarity. Importantly, lower-quality couples appear to compensate for relational instability through increased interbrain synchronization. These interpretations highlight the complexity of emotional coordination in close relationships and position interbrain synchronization as a sensitive marker of relational dynamics beyond observable behaviour alone.

1.6 Limitations of Previous Literature

Despite these contributions, several limitations in the existing literature make it difficult to draw clear conclusions about the role of INS across relationship contexts. First, many studies do not adequately control for differences in time spent together across relationship types. As noted Chen et al., (2024) one limitation of their study was recruiting friends who may not spend as much time together as the couples. Spending more time together weekly could lead couples to have more similar cognitive styles and emotional experiences. A second limitation is the use of non-equivalent measures across relationship types. For example, Chen et al. (2024) used different relationship quality questionnaires for the couple and friend dyads, which prevents direct comparison of relationship quality across groups. Additionally, many studies rely on brief and highly controlled emotional stimuli. An important limitation of this study of Chen et al. (2024) was the use of short film scenes designed to elicit specific emotions. The movies used to elicit sadness were ~2 minutes long, which is a limited timeframe and makes it difficult to ensure that the targeted emotion was elicited. In another study by L. Li et al. (2022) researchers used marital and non-marital movies to assess neural synchrony across romantic couples. After further investigation, we discovered that only marital movies included dialogue, and none of the non-marital movies depicted conversational scenes. This structural difference in stimuli may have contributed to differences in neural synchrony across brain regions. As a result, it is difficult to determine whether the reported synchrony reflected the content or broader differences in dialogue and narrative structure. This distinction is important because researchers in this study also linked synchrony during these stimuli to marital satisfaction, meaning that stimulus structure may complicate interpretations of how relationship quality relates to neural synchrony.

1.7 Current Research

To address these limitations, the current study seeks to examine how relationship satisfaction and social proximity shape neural synchrony during naturalistic emotional processing. Building on prior work that has primarily compared heterosexual romantic couples with friends, this study aims to address several key limitations identified in previous research. First, differences in social proximity between couples and comparison groups (e.g., friends) may confound interpretations of synchrony, as increased shared experience may drive neural similarity. To address this, the present study includes roommate dyads, allowing social proximity and shared daily interaction to be more closely matched to that of romantic couples. A second limitation concerns the use of different relationship quality measures for couples and friends, which prevents direct comparisons across relationship types. Accordingly, the current study employs a relationship satisfaction measure that can be applied consistently across both romantic couples and roommates. Finally, prior studies have relied on brief emotional film clips, which may limit the reliability of emotional engagement. To improve ecological validity, this study uses longer emotionally evocative audiovisual stimuli (5–7 minutes) across positive, negative and neutral emotional conditions. These stimuli have been previously validated and shown to reliably elicit the targeted emotions (Klamer et al., 2025).

In this experiment, participants underwent EEG recording while viewing emotionally charged stimuli of positive, negative, and neutral valence. This design allows us to examine whether neural synchrony differs as a function of relationship satisfaction and relationship type, and to determine whether heightened synchrony is specific to romantic bonds or also emerges from close, non-romantic cohabitation. Consistent with previous work (Chen et al., 2024; L. Li et al., 2022), shared narrative stimuli are used to elicit synchronized neural activity, making movies an ideal naturalistic context for examining emotional processing across different relationship dynamics.

In this study, we sought to examine how neural synchrony varies as a function of relationship type (romantic couples versus roommates) and relationship satisfaction across different emotional contexts. First, we hypothesized that if romantic relationships are associated with unique patterns of INS compared to non-couples (e.g., Chen et al., 2024; Li et al., 2022) couples would exhibit higher overall INS compared to roommates, consistent with prior findings. However, if social proximity and shared experience more strongly drive INS, this would support the hypothesis that no significant group differences would emerge, because roommate dyads in the present study were approximately matched on shared daily interaction and social proximity. Second, we hypothesized that neural synchrony would be greater during high-arousal stimuli compared to low-arousal (neutral) stimuli, regardless of valence, consistent with evidence that arousal (rather than valence) drives interpersonal neural synchronization (Long et al., 2022). Third, we hypothesized that if relationship type modulates INS, relationship satisfaction within romantic couples would further modulate neural synchrony across emotional contexts, such that higher satisfaction would be associated with greater synchrony during positive stimuli, especially in the gamma band, whereas lower satisfaction would be associated with increased synchrony during negative stimuli, consistent with a compensatory mechanism (Fachner et al., 2019; Kinreich et al., 2017; Chen et al., 2024). Conversely, if shared experience more strongly drives INS, satisfaction-based differences in synchrony would not differ significantly between couples and roommates. Finally, we hypothesized that if relationship type drives INS, these effects would be reflected in specific neural signatures, including heightened alpha-band synchronization in the frontal regions among romantic couples, particularly during negative emotional stimuli, and increased beta-band synchronization in the right temporal region among roommates during negative stimuli (Chen et al., 2024); however, if shared experience is the primary driver, these group-specific neural signatures would not be expected to emerge.

Overall, this thesis seeks to provide valuable insight into how relationship type, relationship satisfaction, and emotional valence are associated with neural synchrony during shared naturalistic experiences. By examining these factors together, the present study aims to clarify how close social bonds shape neural alignment during emotional processing and to contribute to a more nuanced understanding of the neural mechanisms underlying emotional coordination in romantic and close non-romantic relationships.

CHAPTER 2: METHODS

2.1 Introduction

Building on the theoretical framework outlined in Chapter 1, the present thesis directly addresses a critical limitation of the study done by Chen et al. (2024): the inability to disentangle romantic bonding from shared social proximity. Overlapping cognitive styles and emotional experiences in couples can stem from how much more time they spend together compared to friends. To address this limitation, the present study compares romantic couples with roommate dyads, who share daily proximity and cohabitation but not a romantic bond. This design allows us to look at whether increased inter-brain neural synchrony is a result of romantic attachment or a reflection of close, non-romantic cohabitation. Another limitation of the previous study by Chen et al. (2024) was using short movie clips, which we have accounted for by using longer naturalistic audiovisual stimuli of positive, negative and neutral valence.

The primary aim of this chapter is to test whether romantic couples exhibit greater inter-brain neural synchrony than roommate dyads during shared emotional experiences. We further examined whether neural synchrony varies across emotional valence and frequency bands, with particular attention to prefrontal alpha-band synchronization. Based on prior findings, we hypothesized that (1) if romantic attachment uniquely drives INS, romantic couples would demonstrate greater overall inter-brain synchrony compared to roommates during naturalistic film viewing; however, if shared daily proximity is the primary driver, no significant group difference would be expected given that roommate dyads were approximately matched on social proximity; (2) neural synchrony would be greater during high-arousal stimuli compared to low-arousal neutral stimuli, regardless of valence, consistent with evidence that arousal rather than valence drives interpersonal neural synchronization; (3) if relationship type modulates INS, relationship satisfaction within romantic couples would differentially relate to neural synchrony, such that higher satisfaction would be associated with increased synchrony during positive stimuli (particularly in the gamma band), whereas lower satisfaction would be associated with increased synchrony during negative stimuli (particularly in the alpha band), consistent with a compensatory mechanism; conversely, if shared proximity drives INS, satisfaction-based differences would not differ significantly between couples and roommates; and (4) if relationship type drives INS, these effects would be reflected in frequency- and region-specific neural signatures, including heightened prefrontal alpha-band synchronization among romantic couples and greater right temporal beta-band synchronization among roommate dyads during negative emotional stimuli; however, if shared proximity is the primary driver, these group-specific neural signatures would not be expected to emerge.

To test these hypotheses, individuals from each dyad were recorded separately while viewing identical emotionally evocative film stimuli. INS was quantified using PLI, computed across corresponding frequency bands and regions of interest between dyad members. This approach aligns with prior work on intersubject neural similarity demonstrating that shared neural responses during naturalistic stimulus viewing reflect shared interpretation, emotional alignment, and social proximity (Hasson et al., 2004; Nummenmaa et al., 2012; Parkinson et al., 2018).

2.2 Participants

We collected data from 78 participants (22 pairs of romantic couples and 17 pairs of roommates) while they watched three emotionally charged movie clips and underwent EEG recording. Three dyads (two romantic couples and one roommate pair) were excluded from analyses due to technical recording issues and excessive EEG artifacts that rendered the data unusable. The final sample size was 72 participants (49 females/23 males, mean age = 22.37, standard deviation = 3.74), 20 pairs of romantic couples (21 females/19 males, mean age = 23.77, standard deviation = 4.28) and 16 pairs of roommates (29 females/3 males, mean age = 20.62, standard deviation = 1.84). Demographic characteristics of the sample are presented in Table 2.1. This sample size was chosen based on an a priori power analysis that was conducted using G*Power 3.1.9.6 for an independent samples t-test comparing dyad type (romantic couples vs. roommates). Assuming a medium-to-large effect size (Cohen's d = 0.70), $\alpha = .05$ (two-tailed), and power = .80, the required total sample size was estimated at 68 participants (34 dyads). The selected effect size was also informed by prior work on emotion elicitation (Lungu et al., 2015) and neural synchrony in romantic couples (Chen et al., 2024) and is consistent with prior hyperscanning and emotion elicitation studies, which typically include between 16 and 24 dyads (Djalovski et al., 2021; Duan et al., 2022; Long et al., 2022; Pan et al., 2017). Participants were primarily recruited through campus flyers, departmental email lists, and undergraduate classes, as well as the Lethbridge community via posters. Participants receiving extra course credit for compensation received up to 2% for their full participation. Participants receiving monetary compensation would receive $15 per session. This study was approved by the University of Alberta Research Ethics Board (Protocol No. Pro00146663).

The inclusion criteria for the study were as follows: (1) Participants must be between the ages of 18-40 years; (2) If participating as romantic couples, must have been together for more than 3 months; (3) If participating as roommates, must have lived together for more than 3 months; (4) Have normal to corrected-to-normal vision; (5) Have no neurological or vision conditions that would prevent them from doing the tasks of the study; (6) Do not have a history of strabismus/amblyopia (crossed/lazy eyes), and/or poor 3D (depth) perception; (7) Do not have lower-than-normal acuity, visual impairments or neurological disorders; (8) Do not have any implanted metals in head and/or pulse makers.

Table 2.1

Demographic Characteristics of the Sample (N = 72)

Variable	***n***	**%**
Age		
M (SD)	22.44 (3.79)	
Range	18–36	
Sex at birth		
Female	50	69.4
Male	22	30.6
Gender identity		
Woman	46	63.9
Man	21	29.2
Gender diverse [a]	5	6.9
Sexual orientation		
Heterosexual	54	75.0
Sexual minority [b]	17	23.6
Prefer not to answer	1	1.4
Ethnicity		
White	54	75.0
South Asian	8	11.1
East/Southeast Asian	4	5.6
Latin American/Hispanic	3	4.2
Black	2	2.8
West Asian	2	2.8
Other/Multiple	1	1.4
Highest level of education		
High school diploma or equivalency	49	68.1
Other post-secondary certificate/diploma	9	12.5
Bachelor’s degree	8	11.1
Master’s degree	1	1.4
Doctoral or professional degree	1	1.4
Identifies as person with disability		
No	58	80.6

Yes	14	19.4

Note. a Gender diverse includes non-binary, genderqueer, agender, and transgender identities. b Sexual minority includes bisexual, lesbian, gay, queer, pansexual, and asexual identities. Percentages may not sum to 100 due to rounding.

2.3 Procedure

Upon arrival, written informed consent was obtained, and participants completed an EEG safety questionnaire. Prior to electrode placement, participants were instructed to remove all earrings, smartwatches and mobile phones. These items were kept in a separate room for the duration of the experiment. Participants were seated in a well-lit, soundproof room approximately 60 cm from a computer monitor. Head circumference was measured to determine the appropriate net size for EEG recording. The vertex (Cz) was identified using standard anatomical landmarks. Specifically, the midpoint between the nasion (brow bridge) and the inion was marked, followed by the midpoint between the left and right preauricular points. The intersection of these two midpoints was marked as the vertex using a soluble red marker. A 128-channel HydroCel Geodesic Sensor Net was fitted following the standard vertex (Cz) localization procedure. The net was soaked in electrolyte solution for five minutes prior to placement and gently patted dry to remove excess solution. The net was carefully expanded and positioned by lowering it directly onto the participants' heads, aligning the Cz electrode with the marked vertex. The researcher ensured the net was symmetrically positioned and made consistent, firm contact with the scalp across all electrodes. Electrode impedances were adjusted to remain below 100 kΩ to achieve the best EEG recording quality.

Participants were instructed to remain as still as possible and to avoid speaking during EEG recording. A member of the research team remained in the room to monitor the equipment and note any technical issues. Another researcher was monitoring the data quality from the control room during the experiment. EEG was recorded while participants watched three short audiovisual movies in differing emotional valance (negative, positive and neutral). Stimuli were presented using PsychoPy Builder (Version 2021.2.1) and run via PsychoPy Runner on a Windows 11 computer. Audio was delivered through Altec Lansing ACS5 stereo speaker at a comfortable listening volume. Each trial was initiated by a participant's keypress, which simultaneously triggered stimulus onset and sent a synchronization marker to the EEG acquisition system, marking the beginning of the recording epoch for that stimulus. EEG recording continued throughout both film viewing and subsequent completion of the Modified Differential Emotions Scale (Fredrickson, 2001). A second trigger was sent at stimulus offset, and these onset and offset markers were later used to segment the continuous EEG recording, isolating epochs corresponding exclusively to film viewing periods for analysis.

To control for potential order effects, film presentation was counterbalanced across participants. Prior to and after each film, participants were asked verbally whether they were comfortable continuing the session. Following the viewing of each film, the participants completed the Modified Differential Emotions Scale to assess their emotional responses (Fredrickson, 2001). The 16-item measure captures a range of positive, negative and neutral emotional states, as well as subjective arousal. After watching all film stimuli, participants were escorted to a separate room to complete additional questionnaires, including the Burn's Relationship Satisfaction Scale (RSAT; Burns et al., 1994; Heyman et al., 1993) (while thinking about the individual with whom they participated in the study) and the Demographic questionnaire. Upon completion, the participants were debriefed and compensated either with course credit or monetary reimbursement.

2.4 Stimuli

Three short films of differing emotion and arousal were chosen. The first film, named *Wicken* (Hashmic House Films, 2019), is a short horror clip. This movie was selected to elicit negative valence emotion and high arousal. The second movie, *One Minute Time Machine* (Avery, 2023), a short comedy, was used because of its positive valence emotion and high arousal. The third film, *How to Create an Effective Training Video* (iSpring, 2020), a short instructional video, served as a neutral and low-arousal stimulus (Klamer et al., 2025). All films were edited prior to presentation using iMovie (v.10.4.3, 2024) to remove opening and closing credits. Additionally, one scene containing a jump scare was removed from the negative movie to reduce the likelihood of movements during the EEG recording.

2.5 Behavioural Measures

Relationship satisfaction was assessed using Burns' Relationship Satisfaction Scale (RSAT; Burns et al., 1994; Heyman et al., 1993). RSAT is a self-report scale that asks individuals to rate their satisfaction in their closest relationship in the following seven relationship areas: communication and openness, resolving conflicts, degree of affection and caring, intimacy and closeness, satisfaction with your role in the relationship, satisfaction with the other person's role in the relationship, and overall satisfaction with your relationship (Heyman et al., 1993). The response options range from Very Dissatisfied (0) to Very Satisfied (6). The RSAT has good internal consistency (coefficient alpha = .94) and is strongly correlated with other measures of relationship satisfaction such as the Locke-Wallace MAT ($r = .80$), the Dyadic Adjustment Scale ($r = .89$) and Norton's (1983) Quality of Marriage Index ($r = .91$; Burns et al., 1994; Heyman et al., 1993). An important reason for choosing this questionnaire by the researcher was that even though RSAT was originally designed to evaluate satisfaction in a romantic relationship or the most intimate relationship, it can still be used to evaluate a relationship with a friend, family member or a colleague (Burns, 2000). Based on the RSAT scoring key, scores of 31 and higher indicate greater satisfaction in the relationship, and scores of 30 and lower indicate lower satisfaction. Individual total scores were first computed for each participant, and the dyad's relationship satisfaction score was then derived by averaging the two partners' total scores. Participants also completed a comprehensive demographic questionnaire that assessed age, handedness, sex at birth, gender, sexual identity, spoken languages, ethnicity, highest level of education completed, and whether they identify themselves as a person with disability.

2.6 EEG Acquisition

EEG data were acquired using a Magstim EGI 128 Channel Geodesic Sensor Net imaging system (GES 400; Magstim EGI, Eugene, OR, USA). Electrodes were arranged according to the HydroCel Geodesic Sensor Net layout based on the international 10–10 system. The HydroCel net consists of evenly distributed electrodes across the scalp, allowing for relatively higher spatial sampling of electrical activity and improved characterization of large-scale neural dynamics. Continuous EEG signals were recorded at a sampling rate of 1000 Hz and digitized using Net Station Acquisition software (Version 5.5.0). Data were referenced online to the Cz electrode, and all electrode impedances were kept below 100 kΩ in accordance with the manufacturer's guidelines for high-quality data. Electrode impedances were monitored and maintained between film presentations to ensure stable signal acquisition. Vertical and horizontal electrooculogram (EOG) activity was recorded using dedicated periocular electrodes to monitor eye blinks and movements. EEG data were recorded continuously throughout stimulus presentation. All experiments were built in PsychoPy Builder (Version 2021.2.1) and run in

PsychoPy Runner on a Windows 11 computer (Version 25H2). The speakers used were the Altec Lansing ACS5, a two-piece set. Event markers were sent from the PsychoPy experimental script to the EEG acquisition system to precisely synchronize stimulus events with the recorded brain signals. These markers included the onset and offset of each film stimulus and were used to ensure accurate temporal alignment between neural activity and stimulus presentation during subsequent analyses.

2.7 Data Preprocessing

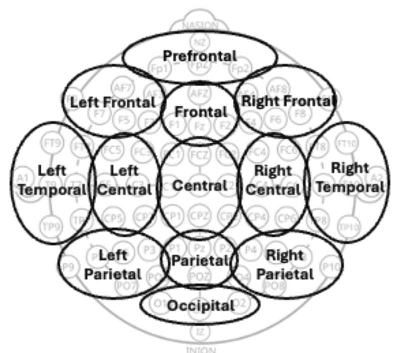
After data collection for each participant, researchers reviewed the raw data using Net Station Review and noted any channels exhibiting excessive noise, drift, unusual activity or artifact contamination. EEG data were preprocessed using EEGLAB (Version 2025.0.0; Delorme & Makeig, 2004), a free toolbox based on MATLAB (Version 2024b). Continuous EEG signal were band-pass filtered between 0.1 to 50 Hz using a Finite Impulse Response (FIR) filter to remove slow drifts and high-frequency noise, in accordance to previous literature (Chen et al., 2024). Bad channels identified during initial inspection were interpolated using spherical spline interpolation based on the surrounding electrodes (Chen et al., 2024). Subsequently, the data were re-referenced to the mean of all channels to reduce reference bias and improve signal comparability across channels. Independent component analysis (ICA) was conducted to remove components associated with non-neural artifacts, such as eye movement and muscle activity (Cohen, 2015). Components were identified through visual inspection of spatial topographies and time courses, and artifactual components were removed from the data. After ICA correction, continuous EEG data were segmented to only include the duration of the movie stimulus. Segmentation was performed using event triggers marking the onset and offset of each movie, ensuring that only task-relevant data were retained for subsequent analysis.

2.8 Phase Lag Index Computation

After preprocessing, EEG data for each participant were extracted into 13 ROIs based on previous studies (Adebimpe et al., 2015; Bian et al., 2014; Chen et al., 2024; Kim et al., 2019). We made adjustments to the number of electrodes in each region due to differences in net sizes (see Table 2.2)

Table 2.2

The 13 ROIs and their corresponding electrode channels.

ROI name	Channels Name	Montage
Prefrontal	E22, E9, E14, E21, E15	
Left Frontal	E33, E24, E26, E23, E27, E32	
Frontal	E11, E19, E4, E16	
Right Frontal	E124, E122, E3, E2, E123, E1	
Left Central	E28, E36, E47, E29, E41, E42	
Central	E13, E112, E129, E37, E87, E6, E30, E105, E55	
Right Central	E117, E104, E98, E111, E103, E93	
Left Temporal	E58, E34, E46, E44	
Right Temporal	E108, E116, E102, E114	
Left Parietal	E58, E52, E51, E67, E65, E64	
Right Parietal	E92, E96, E97, E77, E90, E95	
Parietal	E62, E72, E60, E85	
Occipital	E75, E70, E83	

Four common frequency bands were extracted for analysis: *theta (4~7 Hz), alpha (8~12 Hz), beta (13~30 Hz), and gamma (31-49 Hz;* Chen et al., 2024). To quantify INS, we used PLI, a phase-based connectivity measure that captures the consistency of non-zero phase differences between two signals (Stam et al., 2007). PLI was used to measure synchrony across different frequency bands in two brain regions and is robust against volume conduction and other artifacts. PLI is defined as:

$$PLI = |E[sgn(\mathrm{Im}(X_{ij}))]|$$

Where X_{ij} represents the cross-spectrum between signals i and j, *Im* denotes the imaginary part, and *sgn* is the sign function. The imaginary component captures phase differences that deviate from zero-lag, while the sign function reduces these values to their directional component (i.e., whether one signal consistently leads or lags the other). The expectation operator E computes the average of these signed values across time or epochs.

As a result, PLI reflects the degree to which one signal consistently leads or lags the other. Values close to 1 indicate a stable phase relationship, whereas values near 0 indicate no consistent phase lead-lag structure. By ignoring zero phase-lag differences, PLI minimizes the influence of volume conduction and common-source artifacts, making it a robust measure.
INS was computed using an in-house Python pipeline implemented with the MNE library. Continuous EEG recordings from each participant were segmented into 2-second epochs. Epoch counts were matched across dyad members using MNE's epoch equalization procedure to ensure temporal alignment. Since bad channels were interpolated during preprocessing, all electrodes were preserved across participants. To ensure valid electrode-to-electrode comparisons between dyad members, a common-channel selection step was implemented during PLI computation. This step served as a safeguard by confirming that only overlapping channel labels were included in the analysis, although no channels were expected to be missing.

PLI was computed using MNE's 'spectral_connectivity_epochs' function with the multitaper method, which provides a stable estimate of frequency-specific connectivity. PLI was calculated for each epoch and then averaged across all epochs to obtain a single connectivity estimate per dyad for each frequency band. Connectivity was initially computed across all possible cross-brain channel pairs between participants. Specifically, each channel in participant A was paired with every channel in participant B, allowing for a comprehensive estimation of inter-brain phase synchronization across the scalp. PLI values were computed within predefined frequency bands, with frequency averaging applied within each band. To examine region-specific effects, electrodes were grouped into predefined ROIs. For ROI-level analyses, PLI values were calculated using homologous electrode pairs only, such that each channel in participant A was paired with the corresponding channel in participant B (e.g., E11-E11). Mean PLI values were then computed across these matched electrode pairs within each ROI. In addition to ROI-level estimates, a global PLI measure was calculated by averaging across all cross-brain channel pairs.

2.9 Statistical Analysis

To quantify emotional similarity between dyads, a Modified Differential Emotions Scale (Mod Diff) score was computed. For each film, absolute differences between dyad members' responses were calculated for all 16 emotion items. These absolute differences were then summed to generate a total emotional divergence score for each dyad per film. Higher Mod Diff scores show larger differences in emotional responses, whereas lower scores show more similar emotional responses within dyad members.

Statistical analysis was conducted using SPSS (Version 30). To compare differences in PLI between romantic couples and roommate dyads, a series of independent samples *t*-tests were conducted separately for each frequency band (theta, alpha, beta, and gamma), frontal ROIs, and each emotional condition (positive, negative, and neutral), resulting in a total of 16 comparisons per condition. To control for multiple comparisons across ROIs and frequency bands, false discovery rate (FDR) correction was applied using the Benjamini-Hochberg procedure, with the number of tests defined based on the total number of ROI-frequency comparisons within each condition. To examine whether emotional responses differed between groups, a further series of independent samples t-tests were conducted comparing romantic couples and roommate dyads on behavioural synchrony scores (Mod Diff) separately for each film condition (negative, positive, and neutral). To ensure comparability between groups, an additional independent-samples t-test was conducted to comparing romantic couples and roommate dyads on relationship duration.

Pearson correlation analyses were conducted to examine associations between relationship satisfaction and neural synchrony (PLI), between relationship satisfaction and behavioural synchrony (Mod Diff), between behavioural synchrony (Mod Diff) and neural synchrony (PLI), and between neural synchrony (PLI) and duration of the relationship. Each of these analyses were performed separately within each group (romantic couples and roommates), and across frequency bands, ROIs, and emotional conditions. For all statistically significant *t*-tests and correlations, Bayesian analyses were conducted to quantify the strength of evidence for both the null and the alternative hypotheses. Bayesian independent-samples *t*-tests and Bayesian Pearson correlations were performed using SPSS (Version 30). Bayes factors (BF_{01}) were reported, providing an estimate of the likelihood of the data under the null hypotheses to the alternative hypotheses. Values of BF_{01} greater than 1 indicate evidence in favour of the null hypothesis, whereas values less than 1 indicate evidence in favour of the alternative hypothesis. Following Jeffreys' (1998) classification, BF_{01} values between 1 and 3 were interpreted as anecdotal evidence for the null hypothesis, values between 3 and 10 as moderate evidence, and values greater than 10 as strong evidence for the null hypothesis. Conversely, BF_{01} values between 0.33 and 1 were interpreted as anecdotal evidence for the alternative hypothesis, values between 0.10 and 0.33 as moderate evidence, and values below 0.10 as strong evidence for the alternative hypothesis. This approach allowed for a more nuanced interpretation of results beyond traditional p-values.

CHAPTER 3: RESULTS

3.1 Group Differences in Neural Synchrony

We used SPSS (version 30; IBM Corp., 2024) to run independent-samples *t*-tests comparing participants in the couples and roommate groups to examine whether PLI scores differed between the two groups across three stimuli and different frequency bands. Consistent with our hypotheses, couples exhibited significantly higher PLI values than roommates during the negative valence movie. Specifically, in the frontal ROI within the *alpha* frequency band, couples ($M = 0.053$, $SD = 0.012$) showed significantly higher PLI than roommates ($M = 0.047$, $SD = 0.009$), $t(34) = 1.77$, $p = 0.043$, *Cohen's d* = 0.59 (one-tailed independent *t*-test). A Bayesian *t*-test yielded $BF_{01} = 1.097$, suggesting that the data were largely inconclusive and provided minimal evidence in favour of the null hypothesis.

Similar group differences were observed in the *theta* and *beta* frequency bands. In the frontal ROI, *theta*-band PLI was significantly higher in couples ($M = 0.062$, $SD = 0.023$) compared to roommates ($M = 0.051$, $SD = 0.010$), and this difference approached significance, $t(34) = 1.75$, $p = 0.088$, *Cohen's d* = 0.589 (two-tailed independent *t*-test). A Bayesian *t*-test yielded $BF_{01} = 1.121$, indicating weak to no evidence for the null hypothesis. In the left frontal ROI, *theta* was significantly higher in couples ($M = 0.063$, $SD = 0.013$) compared to roommates ($M = 0.054$, $SD = 0.010$), $t(34) = 2.262$, $p = 0.030$ (two-tailed), *Cohen's d* = 0.759. A Bayesian *t*-test yielded $BF_{01} = 0.5$, suggesting weak support for the alternative hypothesis. Similarly, *beta*-band PLI in the frontal ROI was significantly higher in couples ($M = 0.058$, $SD = 0.006$) compared to roommates ($M = 0.053$, $SD = 0.006$), $t(34) = 2.203$, $p = 0.034$ (two-tailed), *Cohen's d* = 0.739. A Bayesian *t*-test yielded $BF_{01} = 0.554$, indicating limited support for the alternative hypothesis. None of these significant results survived FDR correction.

A similar pattern was also observed during the positive valence movie across the *theta* frequency band. In the frontal ROI, couples indicated a significantly stronger PLI ($M = 0.076$, $SD = 0.025$) compared to roommates ($M = 0.063$, $SD = 0.012$), and this difference approached significance, $t(34) = 1.998$, $p = 0.055$ (Equal variances not assumed, two-tailed independent *t*-test), *Cohen's d* = 0.627. A Bayesian *t*-test yielded $BF_{01} = 0.949$, indicating that the evidence was largely inconclusive. Similar results were observed in the left frontal ROI. Couples showed significantly higher *theta*-band PLI ($M = 0.080$, $SD = 0.035$) compared to roommates ($M = 0.059$, $SD = 0.013$), $t(34) = 2.473$, $p = 0.021$ (Equal variances not assumed, two-tailed), *Cohen's d* = 0.760. A Bayesian *t*-test yielded $BF_{01} = 0.497$, indicating anecdotal evidence favoring the alternative hypothesis. As with the negative valence condition, these effects did not survive FDR correction. Even though these results did not survive FDR correction, the observed pattern is consistent with prior findings by Chen et al. (2024), who demonstrated greater INS in couples compared to non-romantic dyads, particularly in the frontal regions. No significant differences were observed across *theta, alpha, beta* and *gamma* in the neutral valence movie. The overall pattern of group differences across frequency bands, regions of interest, and emotional conditions is summarized in Figure 3.1.

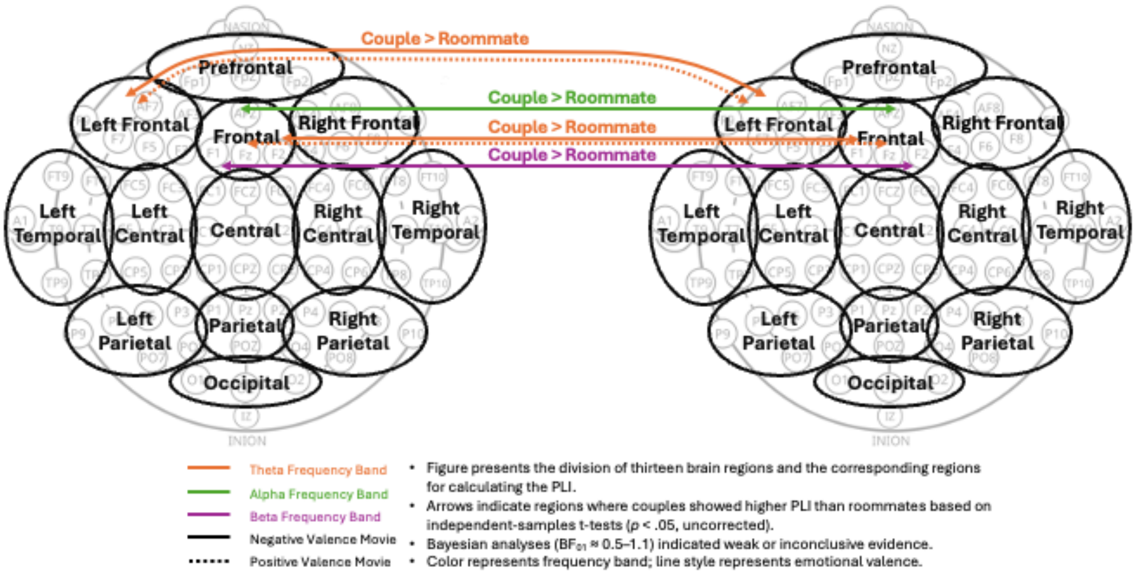


Figure 3.1: Summary of group differences in PLI between couples and roommates across frequency bands, ROIs, and emotional conditions. Colored lines indicate frequency bands (theta, alpha, beta), and line styles represent emotional valence (solid = negative; dashed = positive). Arrows indicate regions where couples showed higher PLI than roommates based on independent-samples t-tests (uncorrected $p < 0.05$ or approaching significance). Bayesian analyses indicated weak or inconclusive evidence. No significant group differences were observed in the neutral condition.

3.2 Group Differences in Emotional Similarity (Mod Diff)

Independent-samples t-tests were conducted to examine whether emotional responding, as measured by Mod Diff scores, an absolute difference score reflecting the divergence in emotional ratings between dyad members, differed between romantic couples and roommate dyads across film conditions. For interpretive purposes throughout this thesis, Mod Diff is discussed in terms of emotional similarity, where lower scores indicate greater similarity between dyad members' emotional responses. Analyses were performed separately for negative, positive, and neutral films. Results indicated that Mod Diff scores were comparable across all film conditions between groups. In the negative valence film, Couples (*M* = 19.35*, SD* = 5.70) and Roommates (*M* = 22.56*, SD* = 10.11) showed similar levels of emotional similarity. In the positive valence film, Couples (*M* = 20.45*, SD* = 7.37) and Roommates (*M* = 20.31*, SD* = 7.00) also exhibited comparable Mod Diff scores. A similar pattern was observed in the neutral valence film with Couples (*M* = 11.65*, SD* = 6.53) and Roommates (*M* = 15.68*, SD* = *8.37*). No significant group differences were observed in Mod Diff scores for the negative ($p > 0.05$), positive ($p > 0.05$), or neutral valence film ($p > 0.05$). These findings indicate that emotional similarity between dyad members did not differ significantly between romantic couples and roommate dyads across any of the film conditions (see Figure 3.2).

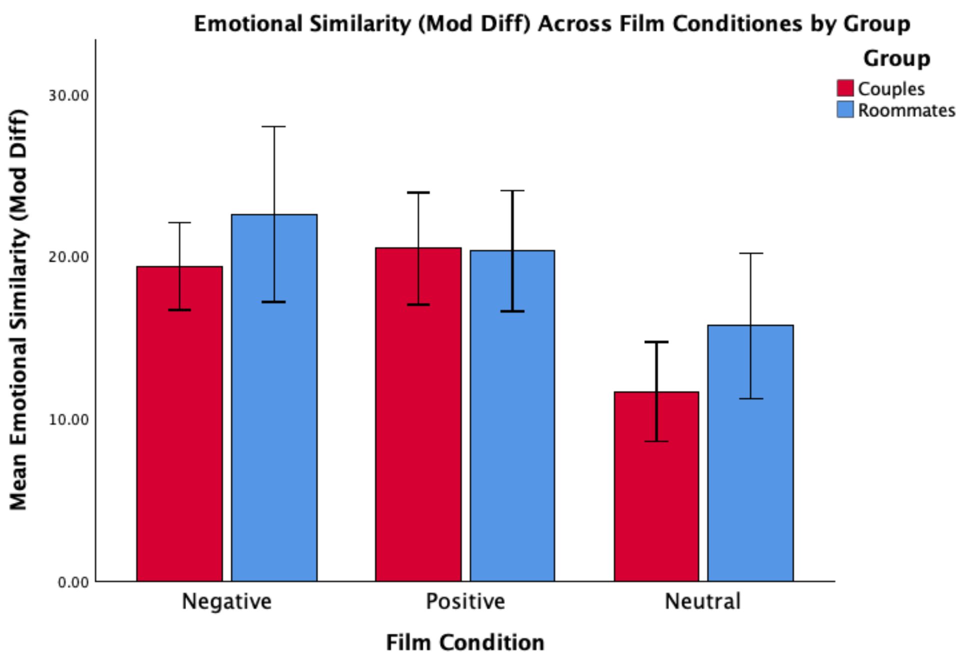


Figure 3.2: Mean emotional similarity (Mod Diff scores) across negative, positive, and neutral film conditions for couples and roommate dyads. Error bars represent standard error of the mean. No significant group differences were observed across conditions.

3.3 Relationship Satisfaction and Neural Synchrony

Pearson correlation analysis revealed several significant associations between relationship satisfaction and neural synchrony across frequency bands; however, none survived FDR correction for multiple comparisons. In the *theta* band, during the positive valence movie, a significant positive correlation was observed among roommates ($r(14) = 0.587$, $p = 0.017$, $R^2 = 0.344$) in the right parietal ROI. Bayesian correlation analysis yielded $BF_{01} = 0.587$, indicating anecdotal evidence favouring the alternative hypothesis.

In the *alpha* band, relationship satisfaction was primarily negatively correlated with PLI, such that higher satisfaction was associated with lower PLI across several ROIs and movie conditions. During the negative movie, significant negative correlations were observed across the central ROI in both couples ($r(18) = -0.45$, $p = 0.046$, $R^2 = 0.203$) and roommates ($r(14) = -0.51$, $p = 0.044$, $R^2 = 0.260$). Bayesian correlation analysis yielded $BF_{01} = 0.814$ for couples and $BF_{01} = 0.696$ for roommates, indicating weak evidence in favour of the alternative hypothesis. Similarly, during the positive movie, significant effects were observed only among roommates in the left frontal ROI ($r(14) = -0.498$, $p = 0.05$, $R^2 = 0.248$, $BF_{01} = 0.775$) and the left temporal ROI ($r(14) = -0.565$, $p = 0.023$, $R^2 = 0.319$, $BF_{01} = 0.398$). Bayesian correlations also provided limited support for the alternative hypothesis. Mixed patterns were observed during the neutral movie. In couples, a significant negative correlation between relationship satisfaction and PLI was found in the right central ROI ($r\ (18) = -0.573$, $p = 0.008$, $R^2 = 0.328$, $BF_{01} = 0.185$), with Bayesian analysis providing moderate evidence in favour of the alternative hypothesis. In contrast, among roommates, a significant positive correlation was observed in the central ROI ($r\ (14) = 0.52$, $p = 0.039$, $R^2 = 0.270$, $BF_{01} = 0.634$), whereas a significant negative correlation was found in the right temporal ROI ($r(14) = -0.526$, $p = 0.037$, $R^2 = 0.276$, $BF_{01} = 0.600$). Bayesian Analysis provided weak evidence in support of the alternative hypothesis.

In *beta* band, correlations between relationship satisfaction and neural synchrony varied by movie condition and group. During the positive valence movie, significant positive correlations were observed in the roommates, with higher relationship satisfaction associated with increased PLI in both the central ($r(14) = 0.545$, $p = 0.029$, $R^2 = 0.297$, $BF_{01} = 0.494$) and right central ROIs ($r(14) = 0.606$, $p = 0.013$, $R^2 = 0.367$, $BF_{01} = 0.244$), with Bayesian analyses providing anecdotal and moderate evidence for alternative hypothesis, respectively. In the neutral valence movie, a divergent pattern emerged across groups. In couples, relationship satisfaction was negatively correlated with PLI in the right temporal ROI ($r(18) = -0.458$, $p = 0.042$, $R^2 = 0.210$, $BF_{01} = 0.752$), whereas in roommates, a positive correlation was observed in the same region ($r(14) = 0.588$, $p = 0.017$, $R^2 = 0.345$, $BF_{01} = 0.307$). Bayesian analysis provided weak support for both groups in favour of the alternative hypothesis.

In the *gamma* band, significant effects were observed exclusively during the negative valence movie for couples, where relationship satisfaction was negatively correlated with PLI. Specifically, these correlations were found in the left parietal ($r(18) = -0.511$, $p = 0.021$, $R^2 = 0.261$, $BF_{01} = 0.421$, indicating anecdotal evidence for the alternative hypothesis) and prefrontal ROIs ($r(18) = -0.544$, $p = 0.011$, $R^2 = 0.307$, $BF_{01} = 0.242$, indicating moderate evidence for the alternative hypothesis).

Overall, a distinct pattern emerged across the relationship satisfaction and PLI correlation analyses. In couples, negative correlations between relationship satisfaction and PLI were observed in multiple ROIs during negative and neutral valence movies. A similar pattern was also shown in prior findings by Chen et al. (2024) and supports the interpretation that increased neural synchrony may act as a compensatory mechanism for couples with low satisfaction. In contrast, among roommates, *beta* and *theta* frequency bands showed significantly positive correlations with PLI scores during positive and neutral stimuli. Additionally, *gamma*-band activity showed significant negative correlations only in couples during the negative valence movie, whereas *alpha*-band synchrony was predominantly negatively associated with PLI and relationship satisfaction across stimuli in both groups.

3.4 Emotional Similarity (Mod Diff) and Neural Synchrony

Pearson correlation analyses were conducted to examine correlations between Mod Diff scores and PLI across frequency bands, ROIs and film conditions. Overall, correlations between Mod Diff scores and PLI were limited, with only one surviving FDR correction for multiple comparisons. Specifically, in the *beta* band during the negative valence movie, a significant negative correlation was observed in the right central ROI for roommates ($r(14) = -0.676$, adjusted $p = 0.048$, $R^2 = 0.457$, $BF_{01} = 0.088$), indicating strong evidence for the alternative hypothesis (see Figure 3.3). This negative correlation suggests that a lower difference in Mod Diff scores between roommates (i.e., higher emotional synchrony) was associated with greater neural synchrony (as measured by PLI).

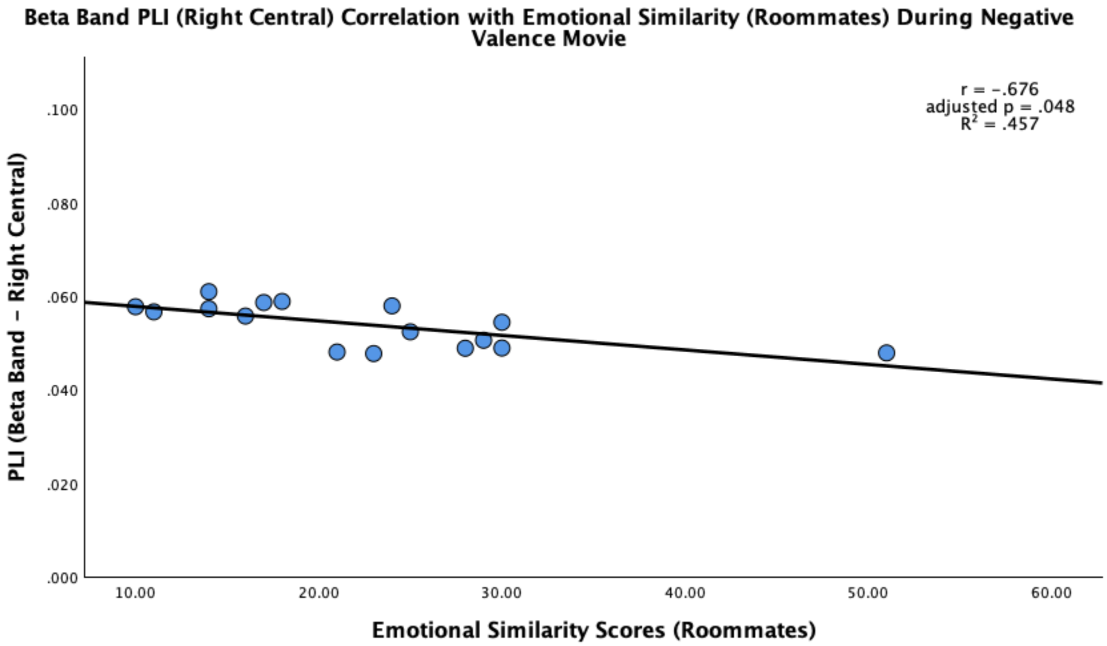


Figure 3.3: Scatterplot illustrating the negative correlation between emotional similarity (Mod Diff scores) and beta-band neural synchrony (PLI) in the right central ROI among roommate dyads during the negative valence movie. Each point represents a dyad. Higher Mod Diff scores reflect lower emotional similarity.

Several additional correlations reached significance at the uncorrected level. These effects were observed across multiple frequency bands and ROIs, however they were inconsistent in direction, and none survived FDR correction. A full summary of correlations between Mod Diff scores and PLI across all frequency bands, ROIs, and film conditions is presented in Table 3.1. Two additional correlations approached significance after FDR correction. These included a negative correlation in the beta band during the negative valence movie in the left temporal ROI in the Roommates group (adjusted $p = 0.060$), and a positive correlation in the theta band during the positive valence movie in the left temporal ROI in Roommates group (adjusted $p = 0.072$).

Table 3.1

Correlations Between PLI and Mod Diff Scores Across Frequency Bands, ROIs, and Groups

Frequency	Movie	ROI	Group	r	*p*	R^2	BF_{01}	BF_{01} Interpretation
Theta	Negative	Parietal	Couples	-0.486	0.030	0.236	0.562	Anecdotal evidence for H_1
Theta	Positive	Left Temporal	Roommates	-0.657	0.006	0.431	0.120	Moderate evidence for H_1
Theta	Neutral	Left Parietal	Couples	-0.455	0.044	0.207	0.782	Anecdotal evidence for H_1
Alpha	Negative	Right Parietal	Roommates	-0.616	0.011	0.380	0.214	Moderate evidence for H_1
Alpha	Neutral	Left Frontal	Roommates	-0.526	0.036	0.277	0.599	Anecdotal evidence for H_1
Beta	Negative	Left Temporal	Roommates	-0.619	0.01	0.384	0.205	Moderate evidence for H_1
Beta	Positive	Right Temporal	Couples	0.565	0.009	0.319	0.208	Moderate evidence for H_1
Gamma	Negative	Parietal	Couples	0.519	0.019	0.269	0.385	Anecdotal evidence for H_1
Gamma	Positive	Right Frontal	Roommates	-0.562	0.023	0.316	0.411	Anecdotal evidence for H_1
Gamma	Positive	Prefrontal	Roommates	-0.520	0.039	0.270	0.634	Anecdotal evidence for H_1
Gamma	Neutral	Occipital	Couples	-0.481	0.032	0.231	0.595	Anecdotal evidence for H_1

3.5 Relationship Duration and Neural Synchrony

Prior to examining correlations between relationship duration and neural synchrony, an independent-samples t-test was conducted to assess whether Couples and Roommates differed in relationship duration. Relationship duration did not significantly differ between Couples (M = 36.57, SD = 34.09) and Roommates (M = 19.62, SD = 13.42), $t(34) = 1.872$, $p = 0.052$, however this effect approached significance. Correlation analyses between relationship duration and PLI revealed two significant correlations that survived FDR correction, both within the *theta* band. In the Roommates group, a significant positive correlation was observed during the positive valence movie in the right central ROI ($r(14) = 0.703$, adjusted $p = 0.024$, $R^2 = 0.494$, $BF_{01} = 0.055$), indicating strong evidence for the alternative hypothesis (see Figure 3.4). Similarly, in the Couples group, a significant positive correlation was observed during the negative valence movie in the right temporal ROI ($r(18) = 0.611$, adjusted $p = 0.048$, $R^2 = 0.373$, $BF_{01} = 0.102$), reflecting moderate evidence for the alternative hypothesis (see Figure 3.5). These findings indicate that longer relationship duration is positively correlated with higher neural synchrony measured by PLI. Several additional correlations reached significance at the uncorrected level. These uncorrected findings were inconsistent in direction and distribution across frequency bands, ROIs, and groups (see Table 3.2). These findings suggest that relational factors may influence neural synchrony. While other research such as Chen et al. (2024) has focused on relationship quality, the present results provide preliminary evidence that relationship duration may also relate to neural synchrony.

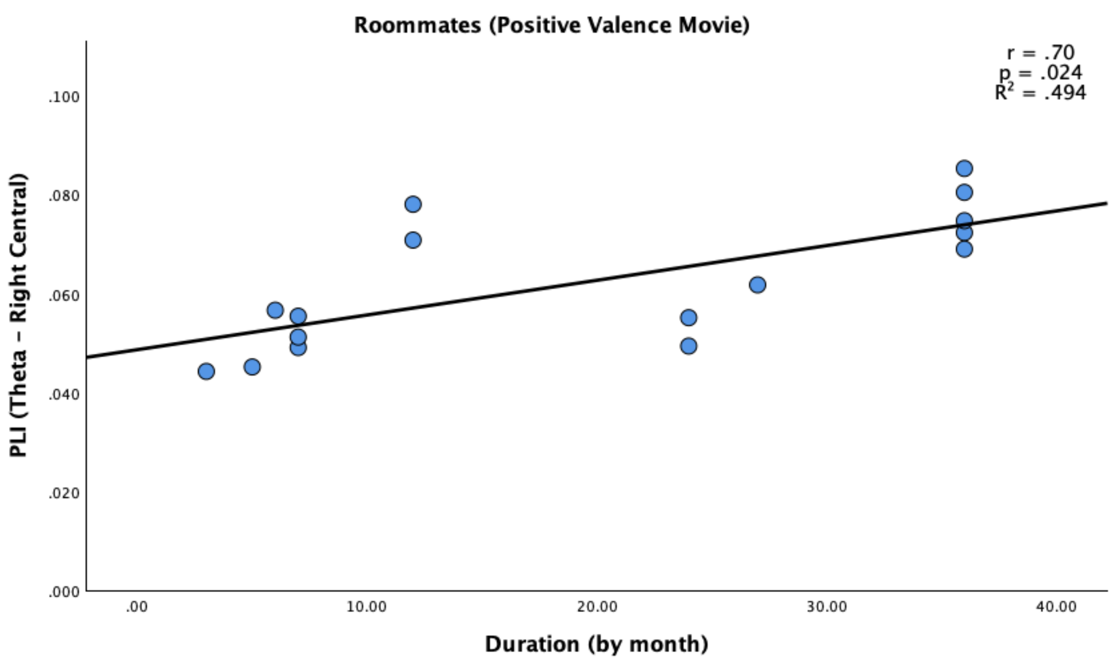


Figure 3.4: Positive correlation between relationship duration (months) and theta-band PLI in the right central region for Roommate dyads during the positive valence movie. Each point represents a dyad. The fitted regression line indicates that longer duration was associated with higher neural synchrony. This effect remained significant after FDR correction ($r(14) = 0.703$,

adjusted p = 0.024, $R^2 = 0.494$) with Bayesian analysis indicating strong evidence for the alternative hypothesis ($BF_{01} = 0.055$).

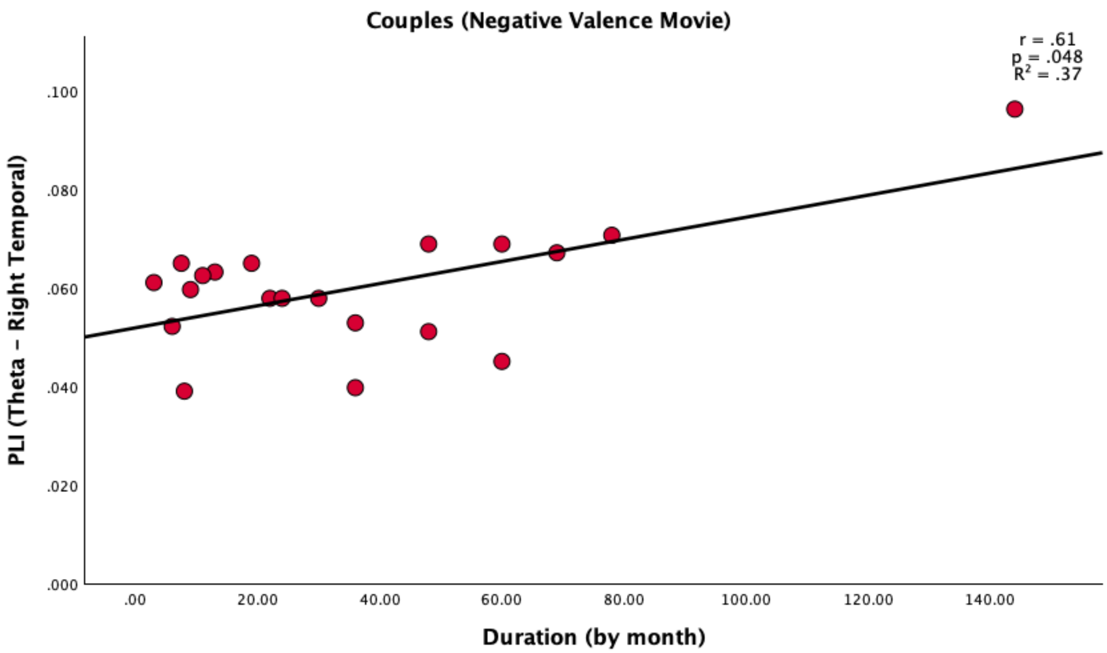


Figure 3.5: Positive correlation between relationship duration (months) and theta-band PLI in the right temporal region for romantic couples during the negative valence movie. Each point represents a dyad. The fitted regression line indicates that longer relationship duration was associated with increased neural synchrony. This effect remained significant after FDR correction (r(18) = 0.611, adjusted p = 0.048, $R^2 = 0.373$), with Bayesian analysis indicating moderate evidence for the alternative hypothesis ($BF_{01} = 0.102$).

Table 3.2

Correlations Between PLI and Relationship Duration Across Frequency Bands, ROIs, and Groups

Frequency	Movie	ROI	Group	r	*p*	R^2	BF_{01}	BF_{01} Interpretation
Theta	Negative	Left Frontal	Couples	-0.492	0.028	0.242	0.527	Anecdotal evidence for H_1
Theta	Negative	Right Frontal	Couples	0.552	0.012	0.305	0.249	Moderate evidence for H_1

Theta	Positive	Right Central	Couples	-0.499	0.025	0.249	0.485	Anecdotal evidence for H_1
Alpha	Neutral	Occipital	Couples	0.550	0.012	0.302	0.257	Moderate evidence for H_1
Beta	Negative	Frontal	Couples	0.481	0.032	0.232	0.593	Anecdotal evidence for H_1
Beta	Neutral	Prefrontal	Couples	0.455	0.044	0.207	0.782	Anecdotal evidence for H_1
Gamma	Negative	Right Parietal	Couples	0.450	0.046	0.203	0.815	Anecdotal evidence for H_1
Gamma	Positive	Left Temporal	Couples	-0.508	0.022	0.258	0.437	Anecdotal evidence for H_1

CHAPTER 4: GENERAL DISCUSSION

The present thesis sought to examine how social proximity, relationship type, relationship satisfaction, and emotional context shape INS during naturalistic stimuli. Building on a growing body of literature suggesting that neural synchrony reflects shared emotional processing, attention, and successful interpersonal communication (Azhari et al., 2025), this work specifically examined whether romantic relationships are associated with distinct patterns of neural synchrony compared to other close dyads, or whether these differences are a reflection of broader factors such as social proximity and shared experience. As outlined in the introduction (section 1.4), prior studies have consistently reported increased INS among individuals who are socially close (i.e., romantic partners, friends, parent-child dyads), particularly during engaging tasks such as emotionally-charged movie viewing or social interactions (Chen et al., 2024; Djalovski et al., 2021; Long et al., 2022; Parkinson et al., 2018). However, many of these studies have not adequately controlled for differences in social proximity, leaving open the possibility that previously observed group differences may be driven by shared experience rather than relationship type.

To address these limitations, the present study employed a naturalistic EEG paradigm in which romantic couples and roommate dyads viewed emotionally evocative stimuli of positive, negative and neutral valence. This study was designed to address methodological gaps identified in previous work, including the use of non-comparable relationship quality measures, reliance on short emotional stimuli, and failure to account for social proximity. By recruiting roommate dyads who share daily environments and interactions, and by applying a consistent measure of relationship satisfaction across both groups, this study aimed to more precisely isolate the role of relationship type from social proximity. Neural synchrony was identified using a phase-based

EEG connectivity measure, the PLI, which is robust to artifacts and volume conduction (Chen et al., 2024; Stam et al., 2007).

Based on previous findings, several hypotheses were proposed (Section 1.7). First, it was expected that romantic couples would exhibit higher neural synchrony than roommates, reflecting stronger shared neural processing during shared emotional experiences (Chen et al., 2024). However, given that the present study controlled for social proximity by recruiting cohabiting roommate dyads, an alternative outcome was also considered: if social proximity and shared experiences are the primary drivers of INS rather than relationship type, no significant differences in neural synchrony would be expected between groups, given that roommate dyads were approximately matched on social proximity. Second, neural synchrony was expected to vary as a function of emotional arousal, with high-arousal stimuli eliciting greater synchrony than low-arousal (neutral) stimuli across both groups (Long et al., 2022). Third, relationship satisfaction was predicted to modulate neural synchrony within romantic couples, such as higher relationship satisfaction would be associated with higher neural synchrony during positive stimuli, whereas lower satisfaction would be associated with increased neural synchrony during negative stimuli, consistent with a compensatory mechanism illustrated by previous work (Chen et al., 2024; Fachner et al., 2019; Kinreich et al., 2017). Finally, these effects were expected to manifest in frequency and region-specific patterns, including frontal alpha synchrony in couples and right temporal beta synchrony in roommates during negative stimuli, as suggested by previous work (Chen et al., 2024). Our key findings are highlighted below.

4.1 Neural Synchrony Across Relationship Types

The primary aim of this study was to examine whether neural synchrony differs across romantic couples and roommate dyads. Based on prior literature, it was expected that romantic couples would exhibit higher levels of INS compared to roommate pairs, reflecting greater neural alignment during shared emotional processing (Chen et al., 2024). However, because the present study controlled for social proximity by including roommate dyads, an alternative outcome was also considered: if neural synchrony is primarily driven by shared experience rather than relationship type, then no significant differences would be expected between groups. Previous work has consistently reported increased neural synchrony in romantic couples, particularly in frontal regions and within the alpha band during the negative valence movie, suggesting that synchrony may serve as a neural marker of relationship-specific emotional coordination (Chen et al., 2024).

The findings of this study offered limited and inconsistent support for the hypothesis that romantic attachment uniquely drives INS. Results from independent-samples *t*-tests comparing couples and roommates revealed higher PLI values in couples within the frontal ROI in the alpha and beta frequency bands during the negative valence condition, suggesting a potential relationship-type effect in these regions. Additionally, results from independent-samples t-tests showed higher theta-band synchrony in couples compared to roommates within both frontal and left frontal ROIs during the negative valence condition, indicating a consistent pattern of increased frontal synchrony in couples during emotionally arousing stimuli. In the positive valence condition, results from independent-samples t-tests comparing couples and roommates revealed higher theta-band synchrony in couples within frontal and left frontal ROIs, suggesting that this pattern extends across emotionally arousing stimuli. However, many of these effects either approached significance or were significant only under one-tailed testing, and none survived correction for multiple comparisons. Bayesian analyses further indicated that these effects were largely inconclusive, providing only anecdotal support for group differences.

Therefore, the current results suggest while some weak and recurring evidence of increased neural synchrony in couples is present, particularly within frontal regions during emotionally arousing stimuli, the overall pattern of non-significant and inconclusive findings more strongly supports the hypothesis that shared social proximity and cohabitation, rather than romantic attachment, drives interpersonal neural synchrony. In contrast, the predicted greater beta-band synchronization in the right temporal region among roommate dyads was not observed across any condition, failing to support this aspect of the frequency- and region-specific hypothesis.

This lack of strong group differences may be explained by a key methodological aspect of the present study: the control of social proximity. Previous studies have reported greater INS in romantic couples compared to other dyads, such as friends. For example, Long et al. (2022) examined romantic couples and friends during emotionally valenced discussions and found that couples showed stronger INS during conflict-related interactions, particularly in sensorimotor regions. Similarly, prior work has demonstrated increased neural synchrony in couples during naturalistic social tasks, such as mutual gaze, emotional communication, and movie-watching tasks (e.g., Chen et al., 2024; Kinreich et al., 2017). However, a critical limitation of these studies is that they did not explicitly control for differences in social proximity. Although some studies matched groups on acquaintance length, they did not account for the extent of shared daily experiences or the intensity of interaction in participants' everyday lives. Because romantic couples typically engage in more frequent and sustained interactions than friend dyads, increased neural synchrony in these studies may reflect greater shared experience rather than relationship type per se. By recruiting roommate dyads who share living environments and engage in frequent daily interactions, the current study minimized this confound, allowing for a more direct comparison between relationship types. In this context, the absence of a significant difference suggests that previously reported effects of increased synchrony in romantic couples may have been confounded by differences in social proximity, and that when this variable is adequately controlled, the assumed neural signature of romantic attachment may not be as distinct as prior research has implied. The present results raise the possibility that shared daily experiences and cohabitation, rather than romantic bonding alone, may be a more parsimonious explanation for the elevated INS consistently observed in couple dyads across the hyperscanning literature.

This interpretation aligns with broader findings in the INS literature, which emphasize the importance of shared experiences in shaping neural alignment. As demonstrated by Parkinson et al. (2018), individuals who are more closely connected within real-world social networks exhibit more similar neural responses during naturalistic movie viewing. In their study, participants first reported their real-world friendships within a cohort, and a subset then underwent fMRI while watching a series of naturalistic video clips. Neural similarity, measured using inter-subject correlations across brain regions, was found to decrease as social distance increased, even after controlling for demographic similarities. These findings suggest that individuals who are socially closer tend to perceive and interpret the world in more similar ways. Similarly, studies of parent-child dyads have shown that neural synchrony is sensitive to the quality and nature of social interaction (Nguyen et al., 2021). Using a fNIRS hyperscanning paradigm during naturalistic mother-infant interactions, Nguyen et al. (2021) found that neural synchrony increased with greater physical proximity and mutual engagement, with higher synchrony observed during face-to-face interactions compared to joint watching conditions. Importantly, affectionate touch was positively associated with neural synchrony, whereas more intrusive or stimulating touch was linked to reduced synchrony, suggesting that the quality and type of interaction play a critical role in shaping neural alignment between individuals. These findings suggest that neural synchrony may develop from repeated shared experiences and aligned interpretations of stimuli, rather than being limited to specific relationship types.

Taken together, these findings suggest that while romantic couples may show a tendency toward increased frontal neural synchrony during emotional processing, this effect was not consistent. Instead, the results support a more nuanced interpretation in which neural synchrony reflects shared experiences, familiarity, and social proximity, rather than being uniquely driven by relationship type. In this view, romantic relationships may still exhibit elevated synchrony under certain conditions, but these differences appear to diminish when comparison groups are matched on key social factors such as cohabitation and daily interaction. This study highlights the importance of accounting for social proximity in dyadic research.

4.2 Neural Synchrony as A Function of Emotional Arousal

The present study also examined whether neural synchrony varied as a function of emotional arousal during naturalistic movie viewing. It was hypothesized that neural synchrony would be greater during high-arousal stimuli compared to low-arousal (neutral) stimuli, regardless of valence, consistent with prior evidence suggesting that arousal, rather than valence, is a key driver of interpersonal neural synchronization (Long et al., 2022). The findings from the current study support this hypothesis. Results from independent-samples *t*-tests comparing couples and roommates revealed higher PLI values in emotionally arousing conditions (negative and positive movies), particularly within frontal ROIs across alpha, theta and beta frequency bands, suggesting increased neural synchrony during high-arousal stimuli. Specifically, group differences (couples > roommates) were observed in the negative valence condition across alpha, theta, and beta bands in frontal regions, and similar patterns were observed in the positive valence condition within the theta band in both frontal and left frontal ROIs. In contrast, results from independent-samples t-tests did not reveal any significant differences between groups in the neutral condition across frequency bands, indicating an absence of neural synchrony effects during low-arousal stimuli.

This pattern may suggest that neural synchrony is more strongly driven by the level of emotional engagement or arousal associated with a stimulus, rather than by its valence. The presence of neural synchrony effects across both positive and negative conditions, combined with the absence of such effects in the neutral condition, is broadly consistent with the interpretation that emotional arousal, rather than emotional valence, underlies these patterns of neural alignment. However, given that none of these effects survived correction for multiple comparisons, these observations should be interpreted with caution. These findings are consistent with previous research demonstrating that emotionally arousing stimuli enhance neural synchrony across individuals. As reported by Long et al. (2022), increased INS during emotionally engaging conditions suggests that heightened arousal facilitates shared attention and coordinated processing of external stimuli. Together, these findings highlight the importance of emotional arousal as a key factor driving neural synchrony during naturalistic experiences. Rather than reflecting agreement in emotional valence, neural synchrony appears to emerge from shared engagement with emotionally salient stimuli, suggesting the idea that arousal plays a central role in aligning neural activity across individuals.

4.3 Relationship Satisfaction and Neural Synchrony

The present study also looked at whether relationship satisfaction modulates neural synchrony during naturalistic emotional processing. To test this, Pearson correlation analyses were conducted between relationship satisfaction scores and PLI across frequency bands, ROIs, and emotional conditions. Results from these correlation analyses revealed several associations between relationship satisfaction and neural synchrony across conditions; however, none of these correlations survived correction for multiple comparisons, indicating that the observed effects were not robust. At the uncorrected level, correlations were observed in both positive and negative directions across frequency bands and regions, indicating an inconsistent pattern of association. These findings do not provide strong statistical evidence for a consistent relationship between relationship satisfaction and neural synchrony across conditions.

This pattern contrasts with prior findings reported by Chen et al. (2024), who observed that relationship satisfaction was associated with neural synchrony in romantic couples. Specifically, they reported a significant negative correlation between relationship quality and prefrontal alpha-band neural synchrony in romantic couples, such that lower relationship quality was associated with higher levels of neural synchrony. Further analyses indicated that low-quality couples exhibited greater neural synchrony than both high-quality couples and friends, which the authors interpreted as a compensatory mechanism reflecting increased effort to maintain emotional alignment. In the present study, however, this pattern was not consistently observed across frequency bands, ROIs, or emotional conditions.

One possible explanation for this discrepancy lies in methodological differences between studies. In previous research, including Chen et al. (2024), different measures of relationship quality were used across dyad types, limiting direct comparability between groups. In contrast, the present study employed a consistent measure of relationship satisfaction across both romantic couples and roommate dyads, allowing for a more controlled comparison. This may suggest that using consistent measures between groups is an important consideration when examining associations between relationship quality and neural synchrony.

Another important consideration is that the association between relationship satisfaction and neural synchrony may be context-dependent or reflect compensatory processes. Chen et al. (2024) reported that lower relationship quality was associated with increased neural synchrony in negative valence movies (i.e., sadness), interpreting this correlation as a compensatory mechanism. However, the present findings did not consistently replicate this negative association between relationship satisfaction and neural synchrony, indicating that such effects may be context-dependent or sensitive to differences in experimental design. Additionally, the lack of strong associations between relationship satisfaction and neural synchrony may reflect the influence of other, more proximal factors driving neural alignment. For example, Long et al. (2022) demonstrated that inter-brain synchrony increased during emotionally engaging conditions, suggesting that heightened arousal facilitates shared attention and coordinated processing. Similarly, Parkinson et al. (2018) showed that individuals who are more closely connected within real-world social networks exhibit more similar neural responses during naturalistic movie viewing, indicating that shared experience contributes to neural alignment. In addition, Nguyen et al. (2021) found that neural synchrony increases with greater physical proximity and mutual engagement during caregiver-infant interactions, highlighting the importance of interaction quality in shaping neural synchrony. Within this framework, relationship satisfaction may contribute indirectly to neural alignment, but its effects may be overshadowed by more immediate factors such as stimulus engagement. Taken together, these findings suggest that relationship satisfaction does not show a consistent or robust association with neural synchrony during shared emotional experiences. Rather than having a direct and consistent influence, its role may be complex, context-dependent, and mediated by other interpersonal and situational factors.

4.4 Emotional Similarity and Neural Synchrony

Another aim of the study was to examine whether behavioural emotional similarity between dyad members was associated with neural synchrony. Emotional similarity was measured using the Modified Differential Emotions Scale (Mod Diff) score (Fredrickson, 2001), calculated as the absolute difference between dyad members' emotional ratings for each film, with lower values indicating greater similarity in emotional responses. Based on prior work, it was expected that greater emotional similarity would be associated with greater neural synchrony, reflecting shared emotional experience and coordinated processing between individuals (Chen et al., 2024).

To examine group differences in emotional similarity, independent-samples *t*-tests were conducted comparing Mod Diff scores between couples and roommate dyads across each movie condition. Results from these independent-samples *t*-tests did not reveal any significant differences between groups across negative, positive, or neutral conditions, suggesting that both groups exhibited comparable levels of emotional alignment during the task. Further, to examine whether emotional similarity was associated with neural synchrony, Pearson correlation analyses were conducted between Mod Diff scores and PLI across frequency bands, ROIs, and emotional conditions. Results from this analysis revealed a significant negative association between emotional similarity and neural synchrony in the beta band within the right central ROI during the negative valence condition in the roommates group, which survived correction for multiple comparisons. The Bayesian analysis also indicated strong evidence for the alternative hypothesis. This finding indicates that greater emotional similarity (i.e., lower Mod Diff scores) was associated with higher neural synchrony. In addition to this significant finding, several correlations reached significance at the uncorrected level across frequency bands and regions;

however, these effects were inconsistent in direction, and none survived correction for multiple comparisons, indicating that they were not robust.

These findings partially align with prior work linking emotional alignment to neural synchrony. For example, Chen et al. (2024) reported a positive correlation between behavioural (emotional) and neural synchronization in couples, such that greater alignment in emotional responses was associated with higher INS. The present results extend this literature by demonstrating that emotional similarity can predict neural synchrony even in non-romantic dyads, particularly when social proximity is controlled. Importantly, the direction of the observed effect (higher emotional similarity associated with higher PLI) supports the interpretation that neural synchrony reflects shared emotional processing. This is consistent with the idea that aligned emotional responses facilitate coordinated neural activity during naturalistic experiences. Taken together, these findings suggest that emotional similarity can contribute to neural synchrony, but that this relationship is not uniform across conditions or groups. Rather than serving as a consistent predictor of neural synchrony, emotional similarity appears to interact with contextual factors such as emotional arousal (Long et al., 2022) and shared experiences (Parkinson et al., 2018), further supporting the broader conclusion that neural synchrony emerges from dynamic interpersonal and situational processes.

4.5 Relationship Duration and Neural Synchrony

Relationship duration was examined to determine whether relationship length contributes to patterns of neural synchrony during naturalistic emotional processing. This analysis aimed to determine whether the amount of time individuals have known each other relates to how similarly their brains respond during shared experiences. To assess this, Pearson correlation analyses were conducted between relationship duration (in months) and PLI across frequency bands, ROIs, and emotional conditions, following an initial independent-samples t-test confirming that relationship duration did not significantly differ between couples and roommate dyads.

The findings from these correlation analyses revealed two significant positive correlations between relationship duration and PLI that survived correction for multiple comparisons, in both romantic couples and roommate dyads, particularly within the theta frequency band. Specifically, in romantic couples, a significant positive correlation was observed in the theta band within the right temporal ROI during the negative valence condition, indicating that longer relationship duration was associated with increased neural synchrony. Similarly, in roommates, a significant positive correlation was observed in the theta band within the right central ROI during the positive valence condition, such that longer duration was correlated with increased neural synchrony. Both of these effects survived FDR correction and were supported by Bayesian analyses, indicating moderate to strong evidence for the alternative hypothesis. In addition to these significant findings, several correlations reached significance at the uncorrected level across frequency bands and regions; however, these effects were inconsistent in direction and did not survive correction for multiple comparisons, indicating that they were not robust.

These results suggest that relationship duration may be linked to the degree of neural alignment between individuals during shared experiences. One possible interpretation is that individuals who have known each other for longer periods may develop more similar ways of perceiving, interpreting, or attending to environmental stimuli, as closeness in social networks has been associated with greater similarity in neural responses during naturalistic tasks (Parkinson et al., 2018), and shared attention provides a mechanism through which individuals coordinate their focus and exchange information about the environment (Stephenson et al., 2021)

Over time, this may lead to more aligned patterns of attention, perception, and emotional processing, which, in turn, manifest as increased neural synchrony during shared experiences.. Extending this interpretation, individuals who spend more time together may also gradually develop more similar underlying psychological tendencies. Supporting this idea, research has shown that personality traits, particularly those related to character, can converge over time in long-term close relationships, for example, with spouses becoming more similar as the duration of their partnership increases (Yang et al., 2015). This suggests that repeated social interaction and shared experiences may shape underlying psychological dispositions. Such convergence may, in turn, influence how individuals attend to and interpret external stimuli. Consistent with this, Matz et al. (2022) demonstrated that neural synchrony during naturalistic viewing is driven by shared interpretations of stimuli rather than shared attention, such that individuals who interpret the same stimulus in similar ways exhibit more aligned neural responses.

Similarly, Parkinson et al. (2018) showed that individuals who are closer in real-world social networks exhibit more similar neural responses when viewing the same stimuli, with neural similarity decreasing as social distance increases, suggesting that distance in a real-world social network is associated with convergence in how the world is perceived at the neural level. Extending this, Nguyen et al. (2021) found that higher-quality interactions, characterized by greater behavioural reciprocity during cooperative tasks, were associated with stronger inter-brain synchrony in prefrontal regions, indicating that moment-to-moment interaction dynamics play a key role in shaping neural alignment. More broadly, recent systematic evidence suggests that inter-brain synchrony reflects shared attention, emotional attunement, and coordinated behaviour, and varies dynamically as a function of relationship type, interaction context, and emotional state (Azhari et al., 2025). Finally, theoretical accounts of social cognition emphasize that shared understanding emerges through ongoing interpersonal interaction (Schilbach & Redcay, 2025). Together, these findings suggest that neural synchrony may reflect the cumulative effects of shared experiences and interpersonal alignment over time, rather than being solely driven by relationship type.

The findings from the present study provide meaningful support for the role of relationship duration in shaping neural synchrony. Specifically, the observed positive associations between duration and PLI suggest that individuals who have known each other for longer periods tend to exhibit greater neural alignment during shared experiences. This pattern is consistent with the broader framework of social proximity, which proposes that increased familiarity and interaction over time contribute to more aligned patterns of processing. At the same time, relationship duration likely reflects a range of underlying factors, including accumulated shared experiences, personality similarities, and interaction dynamics, which may collectively contribute to neural synchrony. As such, duration can be understood as an index of these overlapping influences, highlighting the complexity of factors that shape neural alignment in naturalistic contexts. Notably, the strongest and most consistent effects emerged in relation to relationship duration, with longer relationships associated with greater neural synchrony in both couples and roommate dyads. This finding suggests that neural synchrony may be more closely linked to the accumulation of shared experiences over time rather than to characteristics such as relationship type or self-reported relationship quality.

4.6 Limitations and Future Directions

While the present study provides important insights into neural synchrony within social contexts, several limitations should be considered when interpreting the findings. One limitation of the current study is the relatively modest sample size. Although the number of recruited dyads was comparable to previous EEG studies in this field, the present sample was likely better suited to detecting medium-to-large effects. As such, more subtle group differences may not have been reliably captured, particularly in cases where effects approached significance but did not survive FDR correction. Having larger samples in future studies would allow for more robust testing of group-level differences and increase confidence in detecting smaller but potentially meaningful effects in neural synchrony.

Another important limitation is the sex distribution across groups. The romantic couples and roommate dyads were not matched in sex composition, which introduces a potential confound. Specifically, the romantic couples consisted exclusively of heterosexual male-female dyads, whereas the roommate group was composed almost entirely of female-female dyads. Sex differences have been shown to influence emotional processing (Kret & De Gelder, 2012), and it is therefore possible that some of the observed trends in neural synchrony were partially influenced by this imbalance. Future research should aim to recruit more balanced and diverse dyad pairings, including same-sex couples and opposite-sex roommate dyads, to better isolate the confounding effects of sex from relationship dynamics. Further, the current study did not include same-sex romantic couples, which limits the generalizability of the findings, and including them would provide a more comprehensive understanding of how neural synchrony changes across different forms of social bonds.

An additional limitation concerns the distribution of relationship satisfaction within the sample. Although relationship satisfaction was examined as a key variable, the range of satisfaction scores may have been limited, particularly because fewer participants represented lower levels of satisfaction. This is important given that prior research (e.g., Chen et al., 2024) has reported varying levels of relationship quality, particularly when comparing high and low satisfaction dyads. The limited representation of lower satisfaction relationships in the current sample may therefore have reduced the ability to fully evaluate how relationship quality modulates neural synchrony. Future studies should address this by intentionally recruiting a broader range of relationship satisfaction, particularly including more individuals with lower satisfaction, to better evaluate how relationship quality modulates neural synchrony.

Another methodological consideration is that the present study did not employ a hyperscanning design. Neural synchrony was instead assessed across individuals, allowing for examination of shared patterns of neural activity without capturing real-time inter-brain dynamics. While this approach provides a meaningful estimate of how similarly individuals process information, it reflects neural similarity rather than direct, time-locked coupling between brains. In contrast, hyperscanning approaches enable the use of online measures that capture the temporal alignment of neural activity as it unfolds across individuals. This distinction has been emphasized in recent theoretical work, which highlights that perceiving the world alongside another person is not simply the sum of two individual processing in parallel, the presence of another can alter how each person interprets their shared environment (Deroy et al., 2024). Relatedly, researchers have argued that real-time engagement between individuals may shape neural processes in ways that are not fully captured when brains are studied independently (Schilbach & Redcay, 2025). Thus, while the current design captures an important aspect of neural synchrony, it may underestimate the extent to which neural alignment emerges dynamically across individuals. Future work incorporating hyperscanning methods will be important for directly assessing these real-time interpersonal dynamics.

A further limitation concerns the lack of detailed information regarding the amount of time and types of activities shared between dyad members. While relationship duration was assessed, this measure did not capture variations in day-to-day interaction patterns. For example, it is unclear whether all romantic couples were cohabiting or how long they had been living together, and similarly, the extent and nature of shared activities among roommate dyads were not directly measured. Given that neural synchrony is thought to be shaped by ongoing interaction, shared environments, and engagement in joint activities, the absence of these measures limits the ability to precisely characterize the mechanisms underlying the observed effects. Future research should incorporate more detailed assessments of cohabitation status and time spent together to better disentangle the specific aspects of social proximity that contribute to neural synchrony.

4.7 Conclusion

In conclusion, this thesis examined how relationship type, satisfaction, emotional arousal, and emotional similarity contribute to neural synchrony during naturalistic emotional processing. Using EEG and PLI analysis, the present study examined inter-brain synchrony in romantic couples and roommate dyads while approximating comparable levels of social proximity by including roommate dyads, who were expected to have relatively high levels of familiarity due to shared living arrangements. The findings provide limited support for the idea that romantic relationships are uniquely associated with increased neural synchrony. Although weak evidence suggested greater synchrony in romantic couples within frontal regions during negative and positive emotionally arousing stimuli, these effects were not robust and did not survive correction for multiple comparisons. Similarly, relationship satisfaction was not significantly associated with neural synchrony, and emotional similarity did not differ across groups, contrasting with some prior findings in the literature.

Instead, the results point to a more general mechanism underlying neural synchrony, in which shared experience and exposure to similar environments play a key role in shaping neural alignment across individuals. This interpretation is supported by the observed associations between relationship duration and neural synchrony, suggesting that longer relationship duration may be linked to more similar patterns of neural processing during shared experience. More importantly, by including roommate dyads and attempting to account for social proximity, the present study addresses a critical limitation in prior dyadic research. Social proximity may provide a potential explanation for the limited group differences between couples and roommates. This interpretation is supported by the present findings, which showed no robust group differences in neural synchrony, but significant positive associations between relationship duration and neural synchrony in both groups. Together, these results suggest that the extent of shared experience, rather than relationship category alone, may be an important factor in shaping neural alignment. Rather than indicating that romantic relationships are uniquely associated with increased neural synchrony, the current findings point to a broader mechanism in which neural synchrony emerges from shared experiences and ongoing interpersonal engagement. This has important implications for the field of social and cognitive neuroscience. Much of the existing literature has interpreted heightened inter-brain synchrony as evidence of relationship-specific processes; however, the present findings suggest that such effects may instead reflect differences in familiarity, interaction history, and shared environments that are not always explicitly measured or controlled.

By directly testing these competing explanations within the same experimental framework, this thesis provides evidence that challenges relationship-type-based interpretations of neural synchrony and advances a more nuanced account centred on social proximity. This highlights the importance of future dyadic research to move beyond categorical comparisons and instead incorporate more precise, quantitative measures of shared experience. Ultimately, this work suggests that the neural signatures of closeness may be less about who someone is to us in a formal sense and more about the history of shared experience we have accumulated with them. Relationships that involve frequent interaction, cohabitation, and sustained mutual engagement may foster neural alignment regardless of whether they are romantic in nature. This has broader implications for how we understand human connection intimacy, as reflected in the brain, may be built incrementally through shared exposure to the world rather than conferred by relationship category alone. As such, the boundaries between relationship types may be less neurally distinct than previously assumed, and the mechanisms that bring two people into alignment may be more universal than the labels we use to describe them.

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