Interpersonal Connection: Examining Synchrony in Emotions and Physiology in Friends During Interactions

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INTERPERSONAL CONNECTION: EXAMINING SYNCHRONY IN EMOTIONS AND PHYSIOLOGY IN FRIENDS DURING INTERACTIONS

By

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A Thesis submitted to the Faculty of the Graduate School, Marquette University, in Partial Fulfillment of the Requirements for the Degree of Master of Psychology

Milwaukee Wisconsin

May 2022
Interpersonal synchrony is the alignment of emotions, behaviors, and physiology and is associated with prosocial behaviors and subjective connectedness. Few studies have examined synchrony in friend dyads. The present study compared emotional and physiological synchrony during emotional and neutral interactions, explored how social role may influence empathy, and tested if friendship characteristics predicted synchrony. Participants were 56 friend dyads recruited from a predominantly White, Midwestern university. The study included two sessions. In the first session, participants completed prequestionnaires and each participant identified three emotionally salient situations that they had not shared with their friend. The second session was an interaction session where they each discussed their daily routine (neutral interaction) and one of the emotional situations that they identified in the previous session (emotional interaction). A total of four stories were shared during the interaction session. Electrodermal activity was collected throughout the conversations and participants reported their state affect following each conversation.

Synccalc, an algorithm used to quantify synchrony, was used in the current study to obtain synchrony coefficients and determine the degree of influence within the dyad (Peressini & Guastello, 2016). Contrary to hypotheses, we did not find emotional and physiological synchrony in the neutral or emotional interaction. Still, participants reported similar positive and negative affect and subjective arousal states during the conversations. Further, listeners reported feeling more state empathy during the emotional conversations. Limitations including linear modeling, the experimental paradigm, and timing parameters for emotion and physiological states are discussed.
ACKNOWLEDGMENTS

Joia L. Wesley

I am deeply indebted to my research advisor, Dr. Nakia Gordon, for her guidance, insight, and support throughout my research journey. I am also thankful to my committee members for their expertise, feedback, and valuable suggestions. Additionally, I express deep gratitude to my grandparents, family, friends, and community for their love and support throughout my academic journey. Lastly, I would like to thank God, Marquette University, and the Graduate School.
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Interpersonal Connection: Examining Synchrony in Emotions and Physiology in Friends During Interactions

Empathy, mutuality, and emotional support are all characteristics that promote interpersonal connection. This connectedness is linked to optimal psychological and physical well-being (Blieszner 2014; Fiori et al., 2020; Yu & Chang, 2021) – its absence is linked to psychiatric disorders, morbidity, and mortality (Ryff & Singer, 2000). Indeed, the importance of positive interpersonal connection can be underscored by a growing awareness that well-being should include love, intimacy, happiness, and positive relationships with others (Ryff & Singer, 2000). As such, it is critical to understand the processes involved in the facilitation of interpersonal connectedness. For instance, interpersonal synchrony – the dynamic interplay and coordination between individuals that can take on behavioral, physiological, or emotional forms – and empathy are both related to connectedness (Marci et al., 2007; Palumbo et al., 2017; Rennung & Göritz, 2016). These processes have largely been explored in therapeutic, parent-child, and romantic relationships. However, research is limited in the context of friends. The current study aims to fill that gap by examining the role empathy and friendship quality play in interpersonal connectedness, defined by emotional and physiological synchrony.

Friendships are important throughout the lifespan and are associated with subjective wellbeing. In early childhood, friendships are important for developing interpersonal and prosocial skills (Blieszner, 2014). In adolescence, friendships shift to more of an emphasis on emotional support and interpersonal validation (Blieszner, 2014). Friendships are also important in adulthood as they promote intimacy and emotional closeness and are foundational to romantic relationships. For instance, a longitudinal study found that romantic relationships with an emphasis on elements of friendship –
companionship, emotional support, and security—compared to an emphasis on personal and sexual needs—is predictive of long-lasting relationship satisfaction (VanderDrift et al., 2012). In addition to supporting romantic relationships, friendships remain important for older adults. As adults age, they rely on friendships for instrumental and emotional support (Blieszner, 2014). These friendships in later life are also associated with positive subjective wellbeing and feelings of connectedness (Blieszner, 2019; Fiori et al., 2019).

Similar to other relationships, elements of a positive friendship are mutuality, trust, companionship, and emotional closeness (Blieszner, 2014). These elements work together to facilitate emotional processes between friends such as providing emotional support and empathy. For example, individuals are more likely to share an emotional experience with someone they have a close relationship with (Rimé et al., 2020). This is associated with various outcomes. For example, individuals share emotional experiences to strengthen interpersonal bonds and elicit empathy, understanding, and support from the listener (Delelis & Christophe, 2016). In other words, friends solicit emotional support from each other as a way to fortify existing connections. These connections may be further strengthened by interpersonal synchrony. Rimé and colleagues (2020) propose a process model of emotion sharing in dyads that leads to synchrony. Within this process the sender elicits an emotional response in the receiver, the sender and the receiver converge in affect, and socio-affective processes such as empathy, emotional closeness, and social cohesion facilitate synchrony. In this way, emotions are embedded in interpersonal relationships.

**Emotional Synchrony**
Emotions – an embodied experience including physiological, behavioral, and subjective components – are largely social (Butler, 2011). In the interpersonal context, emotions are one of the primary ways to communicate and connect. They provide information about one’s internal state and one’s relationship with their social context. Emotions are also self-organizing, motivating and prepare individuals for action. Though emotions reflect an individual’s inner experience, they are largely interpersonal and are influenced by our relationships with others. Thus, emotions give rise to other interpersonal processes such as emotional synchrony (Butler, 2015; Main et al., 2017).

For example, one of the ways individuals communicate their internal state is through emotional expressions. An emotional display of sadness communicates that the sender is suffering a form of loss and thus motivates the receiver to console the sender. When the receiver experiences and subjectively feels the sender’s emotional states, the dyad is exhibiting emotional synchrony. Emotional synchrony – the degree to which individuals’ emotional states are aligned – is associated with coordination, prosocial behaviors, subjective connectedness, and empathy (Butler, 2015; Anderson et al., 2003). Emotional synchrony functions to promote efficient information processing, facilitate emotion regulation, and strengthen interpersonal connection (Wood et al., 2021). One process facilitating emotional synchrony is the social transmission of emotions.

Emotion transmission is the transference of emotions from one person to another (Butler, 2015). This occurs through mimicry and emotional contagion. Mimicry is matching or aligning nonverbal behaviors such as facial expression, posture, and bodily movements (Fischer & Hess, 2017). This process is automatic and unconscious and occurs between three to five seconds following the sender’s expression (Prochazkova &
Kret, 2017). Mimicry is associated with empathy, similarity, likeability, affiliation and increased prosociality (Chartrand & Lakin, 2013; Butler, 2015). Mimicry is also observed in emotional contagion – the transfer of emotional states between individuals (Hatfield et al., 1993). Not surprisingly, emotional contagion occurs more between individuals in close relationships compared to acquaintances (KiMura et al., 2008). This is likely a result of the amount of time individuals spend with each other, the ability to recognize the emotional state of a close loved one compared to a stranger, or the motivation to readily “catch” the emotions of a close loved one compared to a stranger. So, while conceptually related, these processes are different from synchrony in that synchrony prioritizes alignment in temporal and oscillating dynamics between two or more individuals. The temporal and oscillating dynamics represent the timing and relationship that can take in-phase, concurrently, or anti-phase, with a short time lag. In contrast, mimicry and emotion contagion typically occur within seconds, with a short time lag between interactants, and is not continuous across time (Fujiwara & Daibo, 2018).

Emotional synchrony occurs when individuals exhibit similar affective experiences across time (Arimoto & Okanoya, 2014). This can occur when individuals are attuned to the same external stimuli, even if they are not interacting (Butler 2015; Golland et al., 2015). This may be due to similar appraisal responses (Butler, 2015). It could also be the mere copresence, being in the same space, of another individual and the automaticity of synchrony. To test the mere copresence of synchrony, Bruder and colleagues (2012) examined emotional synchrony in friend and stranger dyads while watching the same film in two conditions (dyads who interacted and dyads who did not interact). Three separate films were used to induce amusement, sadness, and fear. They
found evidence of emotional synchrony between friends and strangers in the condition where dyads could interact. However, when dyads could not interact, researchers still found evidence of emotional synchrony in the friend condition only.

The study mentioned above suggests two important assumptions about synchrony. The first assumption is that social interaction may enhance synchrony between individuals that exceeds mere copresence synchrony. This may be due to underlying interpersonal processes such as mimicry and emotional contagion. The second assumption is that relationship characteristics are germane to interpersonal synchrony. Specifically acquainted individuals, compared to strangers, experience a unique type of emotional synchrony that is not limited to social interaction. This may be attributed to qualities of their relationship such as familiarity or emotional closeness. Thus, it is likely that synchrony occurs automatically and unconsciously, and depends on relationship characteristics and social contexts.

A common paradigm used to examine how social context affects synchrony is an experimental design where individuals have to engage in different tasks and researchers examine differences in synchrony across those tasks. For example, there is a plethora of literature examining synchrony across stress inducing interactions compared to neutral or positive interactions (Arimoto & Okanoya, 2014; Coutinho et al., 2019; Cook, 2020; Guastello et al., 2006; Levenson & Gottman, 1983). These foundational studies examining synchrony across different tasks are important because they capture the variation in synchrony patterns during interactions (e.g., in-phase and anti-phase synchronization).
Arimoto and Okanoya (2014) examined synchronization across a cooperative and competitive task. Competitive tasks are a type of conflictual interactions and can be characterized as highly aroused and negatively valanced. In this study, participants engaged in two types of video-recorded interaction tasks. They found evidence for emotional synchrony during both tasks; however, emotional synchrony was stronger during the cooperative task compared to the competitive task for male dyads. This finding is consistent with literature which suggests that emotional synchrony may be associated with affiliation and prosocial processes. One implication for greater synchrony in the cooperative interaction task compared to the competitive one is that cooperative tasks yield prosocial behaviors and attitudes, such as affiliation, between individuals. Additionally, cooperative tasks involve the pursuit of a common goal.

Cook (2020) examined affective and physiological synchrony in adolescent friends during a conflict interaction task. Friends exhibited emotional and physiological synchrony. Yet, friendship characteristics did not account for emotional synchrony alone. This finding is consistent with the literature on synchrony in romantic couples which suggests that individuals synchronize during conflictual interactions. However, it is inconsistent with other studies that suggest interpersonal synchrony is associated with relationship quality. It is important to note that Cook (2020) operationalized friendship quality using the Interactional Dimensions Coding Systems Revised scale which included characteristics such as support, communication, positive interactions, and conflict management. It is possible that since the researchers did not account for length of friendship, time spent together, intimacy, or emotional closeness – factors that influence the strength of synchrony – they did not observe that relationship.
Another indicator of friendship quality is friendship maintenance across time. Anderson & colleagues (2003) examined emotional synchrony in romantic couples and roommates across two time points, six months apart. Participants engaged in three conversations describing their daily routines (neutral), recent accomplishments (positive), and current worries (negative). They reported affect following each conversation. These researchers found evidence of emotional synchrony during interactions in romantic partners and roommates. Further, they found that emotional synchrony at time one was predictive of relationship satisfaction, closeness, and longevity at time two (Anderson et al., 2003). Additionally, they found that dyads became more emotionally similar (emotionally synchronized) by the second time point. This is consistent with the literature that suggests emotional synchrony increases as partners spend more time together (Sels et al., 2019). These findings demonstrate the beneficial functions of emotional synchrony for interpersonal relationships. They also suggest that emotional synchrony may be important for perceived closeness, relationship satisfaction, and friendship longevity.

Social connection is also a key factor in synchrony. Researchers experimentally manipulated social connectedness to examine emotional synchrony and physiological arousal between strangers (Cwir et al., 2011). Social connectedness was manipulated by having participants believe that they had unique similarities with the confederate. In the no connection condition, the participants and confederate did not have similarities. These researchers found that in the social connection condition, participants experienced greater emotional and physiological synchrony compared to in the no social connection group. This finding suggests that perceived (but not actual) connection facilitates physiological and emotional synchrony. Given that friends choose one another and likely have shared
qualities, one would expect synchrony to be strong and perhaps enhanced for friends who report strong friendship satisfaction.

Despite the emerging evidence of a positive association between emotional synchrony and relationship satisfaction, other research suggests that emotional synchrony, specifically during negative interactions, may be detrimental to romantic partners because of negative affect reciprocity (Levenson & Gottman, 1983). For example, Levenson and Gottman (1983) explored physiological synchrony and interpersonal emotion dynamics in married couples during a conflictual interaction. They found that married couples exhibited negative affect reciprocity and physiological linkage during the negative interaction which was associated with poor marital satisfaction. In this case, negative affect reciprocity may represent one partner influencing the other’s affective state. These studies highlight mixed findings on the association between emotional synchrony and relationship satisfaction and underscore the importance of considering context, valence, arousal, and type of social interaction.

Emotional synchrony and empathy are both processes involved in interpersonal connectedness and therefore may be associated. For example, emotional synchrony is important for validating emotional experiences within friendships and may facilitate empathy. Specifically, a way emotional synchrony may be related to empathy is by increasing one’s subjective awareness of their partners’ emotional state, and consequently facilitating an empathic response.

**Empathy**

Like emotions, empathy is also multidimensional, including affective, behavioral, cognitive, and physiological components. Zaki and Ochsner (2012) proposed a model of
empathy that includes three components: affective, cognitive, and prosocial concern. These processes work in tandem to produce empathy (Kerem et al, 2001). Cognitive empathy is understanding the experience of another through perspective-taking or inferring another’s’ mental state (Zaki & Ochsner, 2012). Affective empathy involves sharing or subjectively experiencing the emotional state of another. Emotional contagion is a subcomponent of affective empathy. Prosocial concern is the behavioral facet of empathy, motivating individuals to help another based on the cognitive and affective components. These processes are distinct highlighting different underlying processes; however, they are interwoven. Providing an effective empathic response depends on a balance between these processes (Main et al., 2017). Thus, it is important to account for the different components of empathy when exploring its relationship to interpersonal connection.

Empathy is an interpersonal process that involves a target and empathizer. A target is the individual who is soliciting empathy, and an empathizer is the individual who is providing empathy (Main et al., 2017). The subjective experience of a target and empathizer are different. Providing an empathic response involves perspective taking abilities and identifying with the emotions of others (Kerem et al., 2001). However, receiving empathy requires more explicit processes such as perspective taking from the empathizer (Kerem et al., 2001). Given the dynamic, complex process of empathy, there are many ways in which providing an empathic response may be ineffective.

Processes such as emotional synchrony may enhance or hinder empathy (Zaki, 2020). When the empathizer subjectively feels the emotions of another, it may increase prosocial behaviors. On the other hand, subjectively feeling the emotions of an individual
in distress may result in the empathizer experiencing a dysregulated state and impede their ability to demonstrate prosocial concern. Interpersonal processes such as emotion regulation may be an important factor in empathy. Research suggests that a strong predictor of an effective empathic response is when the empathizer is curious. For the empathizer, empathy requires curiosity and an interest to distill the meaning behind the targets’ emotions (Main et al., 2017). When empathy is executed appropriately, it is adaptive and beneficial for friendships.

Much has been made of the importance of empathy in interpersonal connections. Empathy allows one to accurately perceive, understand, and appropriately respond to another’s emotions (Zaki, 2014). However, empathy is more than communicating and predicting the intentions and behaviors of others, empathy produces authentic connection (Morelli et al., 2015; Zaki, 2014). Empathy has been explored broadly in different types of interpersonal contexts. For example, research suggests that therapist’s perceived empathy is a strong predictor of positive therapeutic outcomes (Elliot et al., 2018). Other studies examining empathy in romantic relationships suggest that empathy is associated with relationship satisfaction. Similar findings have been suggested in friendships. Research suggests that empathy is associated with friendship quality and closeness. This association is mediated by intimacy and interpersonal competence (Chow et al., 2013). In other words, the closer friends report feeling, the more empathy is effective in their friendship functioning. This is consistent with evidence that suggests that individuals engage in empathy more with close others compared to strangers (Depow et al., 2020). Furthermore, individuals regulate their empathic responses based on social closeness. Kardos and colleagues (2017) found that individuals more readily expend empathic
resources for individuals within their close social network compared to distant networks. As such, it is likely that friends who report being closer may experience more empathy within their relationship.

Emotion sharing, representing the affective component of empathy, offers a unique addition to empathy and involves processes such as emotional synchrony (Kerem et al., 2001). However, while affective empathy may involve affect matching, it is not required. What is important, however, is for the target to verbally or nonverbally express their affective state and for the empathizer to identify with the feelings of the target (Kerem et al., 2001). Thus, affective empathy can be parallel, merely mirroring the emotions of another, or reactive, appropriately responding to another’s emotions. Bizzego and colleagues (2020) proposed using physiological synchrony as an index of affective empathy, given the complex nature of empathy. Hence, physiological synchrony may be a way to measure affective empathy, and more specifically how friends within a dyad are connecting physiologically and emotionally.

**Physiological Synchrony**

Physiological synchrony is a type of interpersonal synchrony that represents the interdependent rhythmic and temporal coupling between two or more people (Mayo & Gordon, 2020; Palumbo et al., 2017). Physiological synchrony patterns can be in-phase or anti-phase. In the context of dyads, in-phase physiological synchrony is the change in patterns of physiological states in the same direction (Reed et al., 2013). By contrast, anti-phase physiological synchrony is change in patterns of physiological states in opposite directions. For example, anti-phase physiological synchrony can occur during an interaction when an individual experiences an emotion accompanied by physiological
activation and the other person experiences no emotion reflected by no activation or deactivation of physiological patterns. These patterns may reflect different things. For example, anti-phase physiological synchrony may reflect turn taking during social interactions (Reed et al., 2013; Chen et al., 2021). Anti-phase physiological synchrony may also reflect emotional synchrony of negative affect during negative interactions (Chen et al., 2021). In this case, interacting partners are taking turns inducing negative emotional responses and thus influencing each other’s physiological patterns. It is important to account for different patterns of responding while measuring physiological synchrony.

Physiological synchrony can be measured concurrently, measuring partners physiology at the same time, or with a time lag, accounting for subsequent patterns. Research suggests that physiological linkage with a time lag accounts for psychological processes such as empathy (Messina et al., 2013). This can be explained by the interpersonal process of turn-taking. Importantly this suggests that there is an individual driving or influencing the other individual’s emotional and physiological state, in the context of a dyad (Palumbo et al., 2017). Similar to in empathy, there is an empathizer and a target. Time lags can account for psychosocial processes that occur during physiological synchrony.

The sympathetic and parasympathetic nervous system, within the autonomic nervous system, is commonly used to explore physiological synchrony and by proxy empathy (Palumbo et al., 2017). Mayo and Gordon (2020) expanded physiological synchrony to include interbrain synchrony and hormonal synchrony. Autonomic nervous system synchrony can be assessed using measures including heart rate (HR), heart rate
variability (HRV), respiratory sinus arrhythmia (RSA), blood pressure, and electrodermal activity (EDA) (Palumbo et al., 2017). These measures reflect both the parasympathetic nervous system (PNS) and sympathetic nervous system (SNS).

Physiological synchrony of the PNS and SNS may reflect different things (Palumbo et al., 2017; Danyluck & Page-Gould, 2019, Mayo et al., 2021). Danyluck and Page-Gould (2019) examined PNS and SNS synchrony across social tasks to predict affiliation and friendship interest. They used RSA as an index of PNS and cardiac sympathetic index (CSI) to measure SNS. They found that RSA synchrony predicted affiliation and friendship interest among strangers. However, SNS synchrony did not show a clear pattern of association. Despite this finding, other researchers consider autonomic nervous system synchrony broadly as an index of shared emotional experiences (Mayo & Gordon, 2020). Thus, physiological synchrony may be an indicator of psychosocial processes such as empathy and perceived connectedness within different interpersonal relationships.

Physiological synchrony has been explored in several relationship forms. Physiological linkage in the context of therapists and clients is associated with empathy, perceived empathy, and likeability. Marci and Orr (2006) examined physiological synchrony and empathy in two conditions. One condition was the therapist performing in an emotionally neutral manner, which is consistent with typical therapist-client interactions. The other condition was the therapist performing in an emotionally distant manner which was characterized as not appropriately responding to the client’s verbal and nonverbal cues and averting eye contact. This produced two groups, clients in the emotional distant group or neutral group. They found that clients in the emotional distant
condition exhibited low physiological synchrony and low therapist’s perceived empathy ratings. In a follow up study, Marci and colleagues (2007) collected skin conductance activity from therapists and clients during therapy sessions. The clients completed self-reports of therapist’s perceived empathy and acute affect. They found that greater physiological synchrony was associated with higher perceived empathy. Furthermore, they found that therapists exhibited more solidarity and positive regard towards their patients during high moments of physiological synchrony. In this case, physiological synchrony facilitated positive therapeutic alliance between a client and therapist. Thus, empathy, understanding, and emotional closeness are associated with physiological synchrony.

Physiological synchrony has also been explored in romantic partners. Research is mixed on the relationship between physiological linkage, shared affect, and relationship satisfaction. A common experimental paradigm used to explore physiological synchrony is an interaction task and simultaneous measures of physiological indices (Chen et al., 2021). Coutinho and colleagues (2019) conducted an experiment where romantic partners engaged in positive and negative conversations. They found evidence for synchrony in both interactions, however synchrony was higher during the negative interaction. This finding is consistent with research that suggests evidence of more physiological synchrony during negative compared to neutral or positive interactions. Another study using the same experimental design, found similar findings. Levenson and Gottman (1983) found that physiological synchrony during high-conflict interactions was associated with negative affect reciprocity and explained 60% of the variance in marital
satisfaction. Specifically, physiological synchrony was associated with poor relationship satisfaction.

Yet other research suggests that physiological synchrony is associated with positive interpersonal outcomes such as relationship satisfaction, cooperation, and shared positive affect (Chen et al., 2021; Hu et al., 2022). Helm and colleagues (2014) examined respiratory sinus arrhythmia (RSA) synchrony and coregulation in romantic partners during positive, negative, and neutral conversations. They found that relationship satisfaction moderated RSA synchrony between romantic couples across interactions. Specifically, couples in a high-quality relationship exhibited stronger RSA synchrony. Additionally, physiological synchrony is associated with cooperation. Behrens and colleagues (2020) examined physiological linkage in dyads during two prisoner’s dilemma games. In one game, participants were allowed to interact. In the other game, interaction was blocked by an opaque partition. Throughout the experiment, HR and EDA were collected – skin conductance level (SCL) was derived from EDA. The results suggest that physiological synchrony and cooperation is higher when individuals face each other. This finding underscores the nonverbal cues, specific to social contexts, that are important in facilitating physiological synchrony. Further, this finding expands the mixed findings on the consequences of physiological synchrony.

Another factor affecting physiological synchrony is emotional context. Physiological synchrony may reflect shared emotional experiences (Chen et al., 2021). For example, Chen and colleagues conducted a longitudinal study to test three competing hypotheses: physiological synchrony is greater during shared negative emotions, physiological synchrony is greater during shared positive emotions, and there is no
difference in the degree of physiological synchrony between shared positive and negative emotions. They took a momentary approach, examining couples’ physiological synchrony over short epochs (15 seconds) during a 15-minute conflictual interaction. They obtained self-report affect, using a rating dial, and behavioral indices of emotion using an emotion coding system. Their findings suggest that couples exhibit physiological synchrony during shared positive emotional interactions and that this was associated with greater relationship satisfaction. They conducted a 5-to-6-year follow-up study and found the same findings. These robust findings provide strong evidence that interpersonal synchrony for positive affect is related to positive relational functioning.

Although the relationship between physiological synchrony and adaptive and maladaptive psychosocial processes remains unclear, factors that may influence this relationship are arousal, valence, physical proximity, and social context.

Notably, the above studies found evidence of physiological synchrony in dyads with an established interpersonal relationship. Other work has found evidence of synchrony between strangers. Bizzego & colleagues (2020) explored physiological synchrony across multiple relationship types and emotionally induced states. Emotions were induced using short movie clips eliciting different emotional states – embarrassment, calmness, fear, pride, sadness, and romance. These researchers validated these clips to confirm that they differed in valence and arousal. Heart rate (HR) and heart rate variability (HRV) were collected from both individuals within the dyad. Dyads included friends, romantic partners, and strangers. Interestingly, they found that physiological synchrony was higher in strangers compared to romantic partners and friends across the emotional states. To confirm this finding, Bizzego and colleagues
(2021) replicated this study examining EDA synchrony and found similar findings. These researchers concluded that synchrony may function to facilitate a bond between individuals. Thus, strangers, due to novelty, have a higher propensity for synchrony compared to romantic partners and friends who have an existing relationship. In the study discussed above, characteristics such as empathy and relationship quality – which have both been demonstrated to be related to physiological synchrony in the context of therapist-client, romantic, and to some degree friendships – were not examined.

Still, limited studies have examined the relationship between empathy, physiological synchrony, and relationship satisfaction in friendships. Among the limited studies, Cook (2020) examined the relationship between cortisol and salivary alpha amylase (sAA) synchrony and friendship quality and affect amongst friends during a stressful interaction task. She found evidence for emotional and physiological synchrony. Interestingly, lower friendship quality was associated with stronger physiological synchrony. This finding may be due to how this researcher measured physiological synchrony. Typically, physiological synchrony is measured using an autonomic nervous system index such as EDA and HR; however, in this study, the researchers examined hormonal synchrony as measured by cortisol and sAA. As such, the interpretation of physiological synchrony changes. Another explanation for these findings is that friendship characteristics such as intimacy, attachment, and amount of time spent together were not considered. Thus, it is possible that there is a positive relationship between physiological synchrony and friendship quality. The current study aims to explore this relationship.

**Current Study**
Interpersonal synchrony represents a way individuals connect emotionally and physiologically. These connections are important for our wellbeing. Several studies have examined interpersonal synchrony in different relationships and social contexts. In the therapeutic context, synchrony is associated with empathic accuracy and therapist’s perceived empathy. These are associated with better therapeutic outcomes (Marci & Orr, 2006; Marci et al., 2007). Similarly, synchrony in the context of romantic relationships is associated with positive relationship outcomes (relationship quality, satisfaction, and longevity), depending on social context and the emotional valence. Few studies have examined this in friendships despite friends being ubiquitous and an important interpersonal relationship across the lifespan. As such, the current study had the following aims: (1) examine differences in physiological synchrony between neutral and emotional interactions, (2) explore differences in state empathy between the speaker and listener during emotional interactions, and (3) test if friendship characteristics predict emotional and physiological synchrony.

The current study used an emotionally provocative interaction task to examine emotional and physiological synchrony between friends. Friends shared one emotional story and one neutral story. Thus, four stories were shared in the dyad. Continuous measures of EDA were collected and following each conversation participants provided self-reported emotions. Questionnaires were administered before and after the interaction task to measure empathy and friendship characteristics.
Method

Participants

For the present study a total of 122 participants (61 dyads) were recruited from the Marquette University Psychology Subject Pool. Dyads were required to be same-gender friends who reported being in a friendship for at least four months. Participants were also required to be 18 years of age or older. Two mixed gender dyads were run in error, and therefore were excluded from all analyses. Two dyads did not complete the second part of the study, so they were excluded from all analyses. One participant fainted during the interaction session, and therefore we excluded this dyad from our analyses.

The present study included 112 participants (56 dyads) ages ranged from 18 to 22 ($M = 19.10$, $SD = 1.095$). Participants were majority female (67.9%). The racial distribution of the sample was as follows: 51.8% Caucasian/White, 17.0% Hispanic/Latino, 9.8% Asian, 8.9 % Biracial, 6.3% African American/Black, 3.6% Middle Eastern, 2.7% American Indian/Alaska Native. The majority of participants self-identified as heterosexual (83%). All participants denied being in a romantic relationship with whom they participated. Friendship length ranged from 4 to 186 months ($M = 25.18$ $SD = 30.650$). Participants were asked to describe how they met, and the descriptions were coded as follows: 49.1% met in college, 21.1% met in high school, 14% were roommates, 8.8% were teammates, 7% met in childhood. All study methods and procedures were approved by the Institutional Review Board of Marquette University, Milwaukee, WI.

Measures
**Acute Affect.** Affect was measured along a continuous automated visual analog scale (VAS) anchored by 0 (*not at all*) to 10 (*extremely*). The 12 affect descriptors included: Disgusted, Sad, Cheerful, Pity, Neutral, Happy, Guilty, Emotionally Connected, Aroused, Angry, Sympathetic, Empathetic, and Compassionate. A Qualtrics form was presented on IPADS with emotions and the VAS. All emotions were presented on one page with each emotion anchored to the left and bolded. A definition accompanied each emotion. Participants were instructed to move the cursor, anchored to the middle of the scale, in the direction of *not at all* to *extremely* using their finger. There were five separate Qualtrics pages with the same emotions for baseline and each conversation type.

**State Empathy.** The State Empathy Composite Score was created for this study to measure acute empathy. Empathic (“*understanding and sharing in the emotional experiences of another*”), Emotionally Connected (“*feeling an emotional alignment and/or bond with your friend*”), and Sympathetic (“*compassion for the sorrows and troubles of another*”) are emotions and prosocial descriptors that were included in this measure. Similar to the acute affect measure, state empathy was measured along a continuous automated visual analog scale anchored by 0 (*not at all*) to 10 (*extremely*). Participants were instructed to move the cursor to indicate their acute empathy. Average scores across these emotions were computed. Higher scores indicated greater state empathy.

**Trait Empathy.** Trait cognitive and affective empathy were measured using The Interpersonal Reactivity Index (IRI; Davis, 1980). The IRI is a 28-item questionnaire that asks about the degree to which different experiences of affective and cognitive empathy
applies to an individual. Participants indicated if an experience applies to them on a 5-point Likert scale ranging from 0 (Does not describe me well) to 4 (Describes me very well). This questionnaire comprises of four subscales: Perspective Taking (PT), Fantasy (F), Empathic Concern (EC), and Personal Distress (PD). PT measures the tendency to adopt another’s perspective. F measures the tendency to adopt a fictional character’s perspective. EC measures the tendency to experience sympathy and concern for others. PD measures the tendency to experience anxiety or distress in interpersonal situations. Scores were calculated individually for each subscale since research supports a four-factor structure of IRI (Chrysikou & Thompson, 2016). Scores were calculated by computing the overall mean for each subscale. Higher scores indicated greater empathy corresponding to each subscale. Research has shown that the internal consistency for the measure is good. Women tend to score higher on the IRI (Chrysikou & Thompson, 2016; Davis, 1980). Thus, internal reliability coefficients are computed for each subscale by sex: Fantasy subscale men (Cronbach’s α = .78) women (Cronbach’s α = .75), Perspective-taking subscale men (Cronbach’s α = .75) women (Cronbach’s α = .78), Empathetic Concern subscale men (Cronbach’s α = .72) women (Cronbach’s α = .70), Personal Distress subscale men (Cronbach’s α = .78) women (Cronbach’s α = .78). For the current study, the measure had excellent reliability (Cronbach’s α = .874)

**Friendship Quality.** The McGill Friendship Questionnaires -Friend’s Functions (MFQ-FF; Mendelson & Aboud, 1997) assessed friendship quality. The MFQ-FF is a 30-item questionnaire that uses a Likert-scale to measure the frequency that their participation partner (friend) fulfills friendship functions ranging from 0 (never) to 8 (always). There are six friendship functions that represent subscales (Stimulating
Companionship, Help, Intimacy, Reliable Alliance, Self-Validation, and Emotional Security). Higher scores indicate greater fulfillment in the friendship. For the current study, items were averaged to obtain a mean score that measured overall friendship quality (Cronbach’s $\alpha = 0.95$).

Questions were also included in the demographics form to assess friendship characteristics. Participants were asked to report the length of friendship. Additionally, dyads were asked to describe how they met each other in a few sentences.

**Conversation topic prompts.** During the first session, participants independently completed pre-questionnaires. Each participant provided three short responses to the following prompt: “When you come in for the second session, you will be asked to share, in detail for 5 minutes, one negative emotional moment in your life with your friend. To help you prepare for your conversation please answer the following. Please briefly identify three negative emotional experiences. Ideally, these will be events that you did NOT share in detail with the friend you are participating with. Explain a bit of those events in detail here. Just give a couple sentences about the event. You will only be discussing one of these three events.”

**Equipment**

**Electrodermal Activity.** The BIOPAC MP150 system is a data acquisition device for collecting physiological measures (BIOPAC System Inc., Santa Barbara, California, USA). Electrodermal activity (EDA) was collected using the GSR100C amplifier, which applies a constant voltage of 0.5 volt between two Ag-AgCl EL507 electrodes (BIOPAC Systems Inc.), and isotonic gel (gel 101). Electrodes were placed on participants’ nondominant hands on the volar surface of the distal phalanges of the index
and middle finger. Physiological recording was continuously collected throughout the experiment. AcqKnowledge was used for data preprocessing.

**Procedure**

The study included two sessions. The first session – the prequestionnaire session – was an informed consent process where the purpose, length of study, description of study, and risk and benefits were explained. Dyads underwent consent separately to mitigate risks of coercion. Once participants gave their written consent, they completed questionnaires which included personal demographics, friendship demographics (length of friendship, how they became acquainted, etc.), MFQ-FF, Toronto Empathy Questionnaire (not included in analyses), and descriptions of three emotionally provoking experiences that have not been shared with their participation partner.

Participants were instructed to rank order the three emotionally provocative experiences based on emotional salience ("How would you rank your experiences based on how emotional you felt in those moments - with ranking #1 being the most emotional you felt?"). Additionally, for each emotional experience identified, participants were asked to report the emotional intensity from 1 (not emotional) to 5 (extremely emotional). Following the completion of the questionnaires, dyads signed up for the interaction session. Participants completed the prequestionnaire session at least 24 hours before coming in for the interaction session.

Prior to the interaction session, research assistants selected the most emotionally salient conversation topic that participants identified during session one to discuss during session two. Upon arrival for the second session, participants were reminded of the purpose of the study and their rights as participants. To begin, all participants were
connected to the physiological recording instrument, BIOPAC Systems, Inc GSR100C to measure electrodermal activity (EDA) which was continuously measured throughout the experiment. Two electrodes were used in combination with an isotonic gel (GEL101) and connected to both participants’ non-dominant index and middle finger on the distal phalanges. Once both participants were set up, the research assistant ensured that the electrodermal activity recording appeared normal and began a five-minute baseline measure of electrodermal activity. During this time participants were instructed to refrain from interacting and stare at each other’s collar bone. Next, participants were given IPADS with the VAS Qualtrics Form to complete baseline emotion ratings comprised of 10 different emotions: Disgusted, Sad, Cheerful, Pity, Neutral, Happy, Guilty, Emotionally Connected, Aroused, Angry, Sympathetic, and Empathetic.

Following the baseline measures of electrodermal activity and affect, research assistants introduced the interaction task to the participants. Participants completed an interaction task comprised of four five-minute conversations: two neutral and two emotional stories. The conversation order was as follows: participant A’s neutral story, participant A’s emotional story, participant B’s neutral story, participant B’s emotional story. Research assistants instructed participant A to discuss an average day and encouraged them to go into detail about what they would normally do on an average day. This represented the neutral story. Following participant A's neutral story, both participants rated their emotions using the VAS. Research assistants reminded participant A which emotionally salient conversation topic to discuss as identified during session one. Next, participant A began their emotional story. Following participant A's emotional story, both participants rated their emotions using the VAS. Next, the same procedure
was repeated for participant B. During the interactions, research assistants instructed participants to respond to their friend like they normally would and refrain from interrupting and taking over the conversation. Following the completion of these tasks, research assistants detached the electrodes from the participants, and participants completed a post-questionnaire. At the end of the study, participants were debriefed and provided with mental health resources.
Results

Data Preprocessing

Preliminary data reduction included determining a lag length and down-sampling rate using five randomly selected dyads. EDA was originally sampled at 200 observations per second. It was down sampled at 1, 2, and 3 observations per second. Lagged autocorrelations and cross correlations were computed at 1, 2, 3, 4, 5, and 6 seconds. Lag length and down sampling rate were determined by selecting the combination of autocorrelations and lag lengths with the greatest mean. The current study used a down-sampling rate of 3 observations per second and analyzed using a lag length of 1 second. Additionally, since EDA was continuously collected throughout all the tasks (including the acute affect ratings), the data was reduced to only include physiological responding during the conversations.

To calculate the synchrony coefficients, the R script (procplayer2.r) computed ordinary least squares regression models for each participant’s EDA. This produced matrices, autocorrelations, and transfer coefficients for each participant. SyncCalc used the matrices which comprised of the transfer coefficients to identify the empaths and drivers. Similarly, ordinary least squares regressions were computed for each participant to obtain emotional synchrony coefficients with a lag of 0. Emotions comprised of Disgusted, Sad, Cheerful, Pity, Neutral, Happy, Guilty, Aroused, and Angry.

Preliminary Analyses

We performed a manipulation check of our data to determine whether participants were experiencing a range of emotions and whether they were more emotional during the emotional conversations relative to the neutral ones. Figure 1 illustrates mean (95% CI)
emotion ratings for speakers and listeners across the 4 conversations. Eight 2 (person: speaker, listener) x 4 (conversation valence: neutral 1, emotional 1, neutral 2, and emotional 2) repeated measures ANOVAs were conducted to statistically evaluate any differences in emotion ratings. Table 1 summarizes the main effects of person, conversation valence, and the interaction effects. There were significant main effects of conversation valence for the following emotions: cheerful, happy, sad, disgust, and neutral. Specifically, participants reported greater positive affect during the neutral conversations compared to the emotionally provocative conversation and greater negative affect during the emotionally provocative conversation. There were interaction effects (conversation valence x person) for the following emotions: angry, pity, and guilty. Listeners reported feeling more pity during the emotional conversation. Speakers reported feeling more anger and guilt during the emotional conversations. There were no main effects of person for any of the conversations or emotions.

Primary Analyses

The first aim evaluated whether synchrony differs in emotionally salient and neutral interactions. To evaluate whether emotional synchrony coefficients differed between emotional and neutral conversations, a one-way repeated-measures ANOVA was calculated comparing emotional synchrony coefficients at each conversation time: neutral conversation 1 (N1) \( (M = 00, sd = 00) \), emotional conversation 1 (E1) \( (M = 00, sd = 00) \), neutral conversation 2 (N2) \( (M = 00, sd = 00) \), and emotional conversation 2 (E2) \( (M = 00, sd = 00) \). No significant effect was found \( (F (3, 156) = .011, p > .05) \). To evaluate whether EDA synchrony differed between emotional and neutral conversations, a one-way repeated-measures ANOVA was calculated comparing the EDA synchrony...
coefficients at each conversation time: N1 ($M = 00, sd = 00$), E1 ($M = 00, sd = 00$), N2 ($M = 00, sd = 00$), and E2 ($M = 00, sd = 00$). No significant effect was found ($F(3, 108) = .030, p > .05$).

The second aim intended to explore differences in empathy between drivers and empaths. There was no way to differentiate empaths and drivers given the nonsignificant transfer coefficients and synchrony coefficients near zero. Such that, for a given dyad the empath and driver were always the same individual. Thus, the Chi-squared test comparing the proportion of empaths and drivers to speakers and listeners (Aim 2a), and the t-test comparing differences in state empathy between the driver and the empath (Aim 2b) could not be completed.

The third aim examined the relationship between friendship characteristics and synchrony. Friends reported having high friendship quality ($M = 208.45, sd = 24.27$) and an averaged friendship length of 25 months. The majority of friends met in high school (49.1 %) and college (21.1%). Given the near zero synchrony coefficients, the linear regression to predict emotional (Aim 3a) and physiological (Aim 3b) synchrony from friendship quality and length could not be completed.
Discussion

The purpose of the current study was to explore how friends connect during emotionally provocative interactions by examining physiological and emotional synchrony. We also explored the relationship of synchrony, empathy, and friendship quality. We hypothesized that friends would exhibit more emotional and physiological synchrony during emotionally provocative conversations relative to neutral conversations, listeners within the dyad would exhibit more state empathy and their physiological states would be influenced by the speaker within the dyad, and friendship characteristics such as friendship quality and length of friendship would be a predictor of emotional and physiological synchrony. Overall, the results did not support any of our hypotheses.

Friends did not exhibit emotional and physiological synchrony in either emotional or neutral conversations. There are several possible explanations for these findings. Research suggests mixed findings on EDA synchrony (Palumbo et al., 2017). First, despite evidence of synchrony in romantic partner, therapist-client, and parent-child dyads, there is also evidence of no observable synchrony. For example, Reed and colleagues (2013) did not find EDA synchrony in romantic partners during positive and negative conversations. Specifically, the magnitude of EDA synchrony was zero. They concluded that the timing parameters used to measure EDA was limited and did not account for social and emotional situations.

Another possible explanation for these findings is the statistical analysis used. The current study used a linear regression modeling to detect synchrony; however, nonlinear models may be more appropriate for EDA. Guastello, Pincus, and Gunderson (2006)
compared EDA synchrony using linear models and nonlinear models and found that nonlinear models detect more EDA synchrony compared to linear models. Thus, nonlinear modeling may be more appropriate for detecting physiological synchrony for the current study.

The experimental paradigm is another possible explanation for the findings. Specifically, the nature of the conversation task. Each person within the dyad shared an emotional and neutral story. At the beginning of each conversation, the listeners were instructed to listen to their friend share their story with limited interruptions. Thus, not reflecting the true back and forth interaction between friends. It is possible this type of interaction task does not account for the feedback of a natural conversation and the real time reactions to each person within a dyad, thus not capturing how individuals are responding to each other's physiological and emotional states.

Another possible explanation for the null findings is participants responding to the social context, but not each other. Autocorrelation effects were found for each member of the dyad at a lag of 1 second, meaning that participants’ electrodermal responding was predicted by their responding one second prior. This mutual increase in arousal suggests that participants are responding to being in the same social context – having a conversation – but they are not reacting to each other during the conversation. Again, this may be due to the nature of the conversation.

Though the results did not provide evidence for synchrony, the results do suggest evidence for other interpersonal processes. For example, preliminary results suggest positive affect decreased and negative affect increased during both emotional conversations. Additionally, state empathy increased during emotional conversations.
This suggests that participants attended to the social and emotional contexts during the conversation; however, it is unclear if they perceived empathy which is a predictor of physiological synchrony.

The null findings may reflect the lack of empathy – or lack of perceived empathy. Marci & Orr (2006) did not find evidence for EDA synchrony in therapist-client dyads when the therapist exhibited behaviors of emotional distance (e.g., lack of eye contact) and lacked emotional attunement (e.g., not providing validation or reflecting). Further in a follow up study, Marci and colleagues (2007) found that client-perceived therapist empathy was positively associated with EDA synchrony.

There are several possible reasons for why friends may not have perceived empathy. First, given the conversation task, friends did not provide verbal validation, affirmations, or other types of emotional support which are essential for empathy. Additionally, participants were limited in enacting nonverbal behaviors of empathy (e.g., leaning in or offering a hug) due to the equipment and plexiglass separating the interacting dyads (COVID precaution). As such, we cannot be sure that participants perceived empathy from their friends during the conversations. However, perceptions of empathy may be an important indicator of synchrony.

Providing and receiving empathy are different subjective experiences. Our measure of empathy only accounts for providing empathy and does not account for friend-perceived empathy. It is possible that although listeners were reporting providing an empathic response during the speakers’ emotional stories, the speakers did not perceive their responses as empathy. Given the relationship between perceived empathy
and synchrony, it is possible that during the conversations, friends were not experiencing empathy from their friends and thus not experiencing EDA and emotional synchrony.

Another possible explanation for the null findings may be due to the data analysis. First, it is challenging to optimize the timing of a physiological system (skin conductance) and psychological construct (affect, empathy, friendship quality) since these operate at different time scales (Marzoratti & Evans, 2022; Palumbo et al., 2017). Further, determining a lag (time differences between individuals’ responses) that coordinates with a physiological system and psychological construct, is challenging. These decisions are often made during data preprocessing. The current study used a time lag of 1 second which may not reflect the natural timing of a conversation. Other studies used longer lags such as 10 seconds (Coutinho et al., 2019), 20 seconds (Reed et al., 2013), and lag (Chen et al., 2021). Other researchers use a data driven approach and compare synchrony across different lags (Guastello & Mirabito, 2018).

The current study used an emotionally provocative conversation task to examine emotional and physiological synchrony between friends. The findings do not support evidence for synchrony. However, our approach may have limited the interpretation of the data. First, using a linear model may not account for the nonlinear dynamics of EDA between friends during conversations. Second, the conversation task may have limited the emergence of spontaneous interpersonal processes that are important for facilitating synchrony and empathy. Third, we used a data driven approach for determining lag length and down-sampling rates; however, even with a data driven approach the parameters were selected. It may be more accurate to extend the lag length to 20 seconds.
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APPENDIX A

Table 1.

Repeated Measures ANOVAs Comparing Affect Across Conversation Valence & Person

<table>
<thead>
<tr>
<th>Variable</th>
<th>df\textsuperscript{num}</th>
<th>df\textsuperscript{denom}</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheerful</td>
<td>3</td>
<td>144</td>
<td>1724.788</td>
<td>687.153</td>
<td>176.639**</td>
</tr>
<tr>
<td>Happy</td>
<td>3</td>
<td>144</td>
<td>1765.269</td>
<td>810.937</td>
<td>182.672**</td>
</tr>
<tr>
<td>Sad</td>
<td>3</td>
<td>144</td>
<td>2033.290</td>
<td>992.497</td>
<td>155.078**</td>
</tr>
<tr>
<td>Disgust</td>
<td>3</td>
<td>144</td>
<td>209.507</td>
<td>108.124</td>
<td>13.841**</td>
</tr>
<tr>
<td>Neutral</td>
<td>3</td>
<td>141</td>
<td>916.765</td>
<td>398.797</td>
<td>66.739**</td>
</tr>
<tr>
<td>Pity</td>
<td>3</td>
<td>144</td>
<td>1065.937</td>
<td>410.637</td>
<td>.197**</td>
</tr>
<tr>
<td>Person</td>
<td>1</td>
<td>48</td>
<td>1.946</td>
<td>1.946</td>
<td>.789</td>
</tr>
<tr>
<td>Conversation x Person</td>
<td>3</td>
<td>144</td>
<td>497.649</td>
<td>194.353</td>
<td>40.843**</td>
</tr>
<tr>
<td>Guilty</td>
<td>3</td>
<td>144</td>
<td>474.139</td>
<td>221.014</td>
<td>33.574**</td>
</tr>
<tr>
<td>Person</td>
<td>1</td>
<td>48</td>
<td>.055</td>
<td>.055</td>
<td>.009</td>
</tr>
<tr>
<td>Conversation x Person</td>
<td>3</td>
<td>144</td>
<td>173.723</td>
<td>57.908</td>
<td>15.199**</td>
</tr>
<tr>
<td>Angry</td>
<td>3</td>
<td>144</td>
<td>471.673</td>
<td>208.415</td>
<td>35.907**</td>
</tr>
<tr>
<td>Person</td>
<td>1</td>
<td>48</td>
<td>2.624</td>
<td>2.624</td>
<td>.346</td>
</tr>
<tr>
<td>Conversation x Person</td>
<td>3</td>
<td>144</td>
<td>106.221</td>
<td>44.515</td>
<td>11.019**</td>
</tr>
</tbody>
</table>

Note. df\textsuperscript{num} indicates degrees of freedom numerator. df\textsuperscript{denom} indicates degrees of freedom denominator. All main effects of emotions are presented. Main effects of person are presented if the interactions are significant. Greenhouse-Geisser multiplier for degrees of freedom, SS, MS, F value, and p value in this table incorporate this correction.

** p < .05, *** p < .001
Figure 1.

*Averaged Emotions of Speaker and Listener During Each Conversation*

*Note:* \* \( p < .05 \)