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ORIGINAL PAPER

Friends in Sync? Examining the Relationship Between the Degree of Nonverbal Synchrony, Friendship Satisfaction and Support

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Abstract
Nonverbal synchrony (NVS), the degree of spontaneous coordination of movements among dyads, has been associated with important social outcomes among romantic and stranger dyads, including the degree of social affiliation. Recently, automated methods, such as Motion Energy Analysis (MEA), have been used to objectively measure NVS. In this study, we examined MEA-quantified NVS among 143 friend dyads and its association with friendship satisfaction, closeness, and support. Friend dyads engaged in two conversations about a problem one friend was experiencing and took turns generating problems. Half the dyads were randomized to a co-rumination condition, where they were given instructions that prompted co-rumination, or a natural condition, where they were prompted to speak about the problem as they naturally would. Friendship satisfaction was measured at baseline while friendship support was measured at baseline and following each conversation using self-report scales. NVS was significantly present above chance during the task, but for each conversation, levels of NVS were not (a) *predicted by* the degree of friendship satisfaction or support, or (b) *predictive of* the degree of post-conversation friendship support. Furthermore, exploratory analyses revealed that for individuals who rated their dyad partner as a friend versus a close friend, greater synchrony trended toward predicting lower friendship support during the second conversation. Overall, this study demonstrates that an automated assessment of movement was able to detect NVS among friend dyads during a problem-focused discussion, but raises questions about the role that NVS plays among friends in this context.

Keywords Nonverbal behavior · Nonverbal synchrony · Close relationships · Interpersonal · Motion energy analysis

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Introduction

As social animals, the extent of our social connection carries significant consequences for our mental and physical health and well-being. For instance, social connection is associated with greater happiness (Mogilner, 2010), less physiological dysregulation, better physical health, and longevity (Yang et al., 2016). Additionally, social connection lays the foundation for more enduring and meaningful social relationships from lifelong friendships to strong romantic partnerships, which are also associated with positive outcomes. Specifically, friendships alleviate loneliness (Chen & Feeley, 2014) and give significant purpose to our lives across the lifespan (Bruggencate et al., 2018). Given the importance of social relationships to love, happiness, and well-being, understanding the factors that contribute to successful social interactions is crucial for our understanding of how social connections are created and maintained.

Nonverbal Synchrony and Close Relationships

One factor that has been associated with social connection is nonverbal behavior (e.g., gestures, gross body movements, facial expressions, etc.), as common understanding and empathy are largely expressed through coordinated nonverbal action (Burgoon et al., 1995). During social interactions, individuals' nonverbal behaviors are often dynamic and reflect a form of coordinated movements over time. For instance, research has shown that interacting strangers spontaneously walk in step with each other (van Ulzen et al., 2008), sway their bodies at the same rate when communicating during a puzzle-solving task (Shockley et al., 2003), and bicycle at similar speeds when discussing emotional events (Sharon-David et al., 2019). Furthermore, the degree of spontaneous coordination and imitation of movements—known as nonverbal synchrony (NVS) (Condon & Ogston, 1966)—has been associated with higher degrees of social affiliation (Hove & Risen, 2009), feelings of connectedness (Noy et al., 2015), cooperation (Reddish et al., 2013), and relationship satisfaction among stranger dyads.

While this research has demonstrated that NVS is closely linked with social connection among strangers, it is largely an open question whether the relationship enhancing effects of NVS exist in close relationships, particular among friendships. Given that NVS has been found to create a sense of togetherness that satisfies both interactants' need for intimacy and emotional closeness (Vacharkulksemsuk & Fredrickson, 2012), it may be that the positive relationship-enhancing effects of NVS are even more pronounced in an intimate partner context. There is reason to believe this might be the case.

Within romantic relationships, research has found that happily married couples have shown more coordinated body language, such as one partner displaying a more open body stance followed by their partner displaying a similar open stance shortly after, during problem-solving discussions compared to dissatisfied couples (Julien et al., 2000). Additionally, greater NVS has been related to increased feelings of emotional closeness and intimacy, and a greater sexual desire for the partner among romantic couples (Sharon-David et al., 2019). Together, this work provides strong support for the integral role that NVS plays in the development and maintenance of important positive social relationships.

Despite the significant amount of work examining the association between NVS and various aspects of social ability and relationship quality across romantic and stranger dyads,

there have been few studies that have examined the role of NVS among friends. Fujiwara and colleagues (2020) examined the role of NVS in unstructured dyadic interactions between same-sex strangers and friends. The authors hypothesized two alternate potential roles of NVS among dyadic interactions. First, as greater NVS has been found among better acquainted individuals compared to less acquainted individuals (e.g., Latif et al., 2014), one possibility was that friend dyads, compared to stranger dyads, would demonstrate greater NVS. In contrast, given evidence that NVS can work as a form of social glue in creating new social bonds (Vacharkulksemsuk & Fredrickson, 2012), the other possibility was that stranger dyads would demonstrate greater NVS than friend dyads. In support of the first possibility, they found greater NVS for friends compared to strangers. In support of the second possibility, NVS predicted the motivation to develop/deepen a friendly relationship among the stranger dyads. These findings suggest that while NVS may be present among friend dyads, it may also index important interpersonal processes present in early close, platonic relationship formation.

As friendships represent a significant source of happiness and well-being for many (Lucas & Dyrenforth, 2006), continuing to develop our understanding of the factors that contribute to strong friendships will better inform our understanding of how these important relationships are built and maintained. Specifically, as work has demonstrated that NVS is positively related to greater relationship satisfaction, increased feelings of emotional closeness and support among romantic and stranger dyads, there is a growing need to better understand if NVS is related to these positive relationship aspects among friends, and, if so, what factors might moderate the association between NVS and these relationship qualities.

Methods for Examining NVS

In previous research, nonverbal behavior and synchrony have been assessed with several methods, most of which involve subjective, observational coding. One such method is the Ethological Coding System for Interviews (Troisi & Moles, 1999), which involves hand coding the gestures and movements of an individual (e.g., looking at the interviewer, nodding) as they are being interviewed by a clinician. Though these rating methods are frequently used and have demonstrated strong reliability and validity, they are time-consuming both in terms of training and in implementation, are subject to clinical judgment, and cannot capture certain kinematic aspects of movement, such as the amplitude, that may contain important information about social communication.

In recent years, computationally intensive methods have been developed for quantifying movement and NVS that are free from rater bias, easy to implement, and highly sensitive to dynamic changes in movement. To utilize automated techniques to quantify the degree of NVS, a dyadic interaction is oftentimes videorecorded (e.g., Ramseyer & Tschacher, 2011), though there exist techniques that employ a motion capture system with sensors on the body to track movement (e.g., Romero et al., 2017). For studies that use video-based tracking, the videorecording is then read by a software program that utilizes frame-differencing algorithms to capture changes in individual movement over successive video frames within each dyad partner.

One popular computerized program is Motion Energy Analysis (MEA), which calculates changes in gray scale pixel density over successive video frames to measure the amount of body movement within an individual (e.g., Ramseyer & Tschacher, 2011). The program

includes a graphic user interface that allows users to specify regions-of-interest (ROIs) for where movement should be measured.

From outputted time-series data, researchers may then utilize various methods for quantifying the degree of NVS between two interacting dyad members. One such method is through the use of Pearson product-moment correlations, which assesses the strength of the association between two continuous time-series data of dyad members' movements at a lag of 0 (see Novotny & Bente, 2022 for a review). While this measure is straightforward to interpret, it is limited to capturing simultaneous movement, and fails to capture the time-varying, dynamic aspects of NVS between individuals, which may ultimately prove to be a better indicator of interpersonal closeness and related processes.

Rolling window cross-lagged correlations have become a popular time-series analysis method as they provide correlations between two time series data across varying time lags (e.g., Ramseyer & Tschacher, 2011) to quantify the degree of NVS between two individuals over time. By measuring the correlation between two movement data streams within time-lagged windows, this method allows for the measurement of both simultaneous movement and sequential movement within a short time frame and at different specified lag times to be captured under the definition of NVS. This has advantages in allowing for the capture of changes in movement patterns over time. However, similar to the Pearson correlation, this method is sensitive to noise in the video (e.g., fluctuations in lighting, extraneous movement in the frame, etc.) and requires specific conditions for the video to be of sufficient quality to examine movement.

The development of MEA and the analysis methods described here (see Novotny & Bente, 2022 for other means of analyzing movement data) have yielded exciting insights into nonverbal behavior and synchrony across both clinical and nonclinical contexts. In nonclinical settings, MEA has primarily been used to examine NVS in unacquainted dyads. For example, Tschacher and colleagues (2014) investigated the association between NVS and unacquainted interactants' affect across cooperative, competitive, and enjoyable interactions, and how NVS influences and is influenced by affect. The authors found that positive affect was associated with greater NVS and that negative affect was associated negatively with the degree of NVS. Furthermore, the authors found that greater NVS acted as a predictor rather than an outcome of greater positive and lower negative affect. Overall, these findings suggest that NVS is present across multiple settings and is related to important contextual variables.

Current Research

In this study, our aim was to evaluate the role that NVS plays among friend dyads as they engage in problem-focused conversation tasks and evaluate NVS as both a cause and consequence of important relationship variables (e.g., friendship closeness and satisfaction). Towards that goal, we used data originally collected as part of a larger study focused on the intrapersonal costs and interpersonal benefits of co-rumination (Tudder et al., 2022). Co-rumination represents an interpersonal emotion regulation strategy wherein interactants extensively and exhaustively discuss stressors (Rose, 2002). Researchers hypothesize that, through co-rumination, individuals gain the support of others with the goal of receiving insight into difficulties and reducing negative affect (Dam et al., 2014). While individuals who co-ruminate tend to experience certain interpersonal benefits, such as increased trust

and emotional intimacy with their partner (Rose, 2002), they also often experience personal costs, such as depressed mood (White & Shih, 2012).

To our knowledge, there are no studies to date that have examined the effects of co-rumination on the degree of NVS. Thus, we did not have specific hypotheses regarding the association between co-rumination and the degree of NVS. However, this dataset provided a rich opportunity to examine NVS in a problem-focused discussion among friendship dyads and as such, we focus our primary analyses on examining the association between NVS and friendship satisfaction and support. In the interest of exploring the effects of co-rumination and other conversation-specific variables on NVS and its association with friendship satisfaction, closeness, and support, we conducted additional exploratory analyses that examined these variables as moderators and covariates in this association.

To measure body movement, we used MEA given its increasing usage and simplistic user interface. With the motion energy output, we utilized windowed cross-lagged correlations to quantify the degree of NVS between dyad partners to allow for the measurement of both simultaneous and time-lagged movement coordination within a given interaction.

The primary aims and hypotheses of the present study are four-fold. First, as NVS has been significantly present among unacquainted dyads (Tschacher et al., 2014) and friend dyads (Fujiwara et al., 2020) as they engage in social interaction tasks, we expect that NVS will be significantly present among friend dyads as they engage in a problem-focused conversation task (Hypothesis 1). Second, as previous work has demonstrated that the overall quality of friendships significantly affects other relationship attributes, including happiness (Demir & Özdemir, 2010), we expect that greater friendship satisfaction will be predictive of greater synchrony during both conversations in the task (Hypothesis 2). Third, as a recent meta-analysis found a positive small to medium effect of NVS on increased perceived social bonding (Mogan et al., 2017), we expect that common aspects of social bonding, such as greater ratings of closeness to the partner and feeling socially supported by the partner, will also be predictive of greater NVS during both conversations (Hypothesis 3).

Fourth, as NVS has been examined as both a predictor and as an outcome of various attributes of strong relationships, we were interested in examining if NVS would represent both a predictor and an outcome in the same study or would be better represented as one compared to the other. Specifically, given previous work that has found NVS to be predictive of variables related to social bonding (Mogan et al., 2017), we expect that greater NVS during the conversations will also be predictive of higher ratings for feelings of closeness to the partner and social support measured immediately after each conversation (Hypothesis 4).

Finally, in addition to the main analyses, we examined the influence of three relationship and conversation-specific variables on the association between the degree of NVS and corresponding friendship satisfaction and feelings of closeness and support to the friend. Specifically, we examined relationship and conversation-specific variables as moderators in this association and controlled for these variables in subsequent models examined the direct association between the degree of NVS and friendship variables.

We first examined whether task condition acted as a moderator and/or covariate in the association between the degree of NVS and corresponding friendship satisfaction and feelings of closeness and support given that previous work has found that when self-disclosure is ruminative in nature, it can have both interpersonal benefits, such as greater trust, and intrapersonal costs (Tudder et al., 2022). Second, we examined relationship seriousness (i.e., dyad partners identified as friends, close friends, or best friends) as a moderator given

existing findings of a positive association between the degree of synchrony and the degree of affiliation (Hove & Risen, 2009). We controlled for relationship seriousness in models examining the direct relationship between the degree of synchrony and the degree of affiliation given that relationship seriousness might correlate highly with friendship closeness or support. Third, we explored whether post-conversation ratings of the discussion leading to a better sense of understanding of the problem moderated the association between NVS and the friendship variables and controlled for these ratings in models examining the direct association between NVS and friendship variables. This was based on previous work that found that greater synchrony was associated with increased efficacy on a collaborative problem-solving exercise (Miles et al., 2017). Thus, we sought to examine whether ratings of the discussion being fruitful might reflect a stronger positive association between NVS and friendship satisfaction, closeness, and support. Finally, we included ratings of problem understanding as a covariate in models examining the direct association between the degree of NVS and friendship variables to control for the possibility that greater ratings of problem understanding may correlate with friends' ratings of how close and supported they feel by their friend.

Methods

Participants

This study involved secondary data analysis of an original study conducted at Ohio University with a large dataset. In the original study (Tudder et al., 2022), friend dyads were recruited for a study at Ohio University through flyers posted around campus and through emails sent to students. Dyads were eligible to participate if both participants were 18–30, did not have a cardiac pacemaker, considered themselves to be close or best friends, and were not in a romantic relationship with each other. Those who were eligible to participate were compensated with either course credit or $16. Of note, the above criteria was specific to the original study for which a subset of the data was analyzed for the purposes of this paper.

From the available data, 25 dyads were excluded due to compromised video data quality, 3 dyads were excluded due to at least one partner having missing data across multiple self-report variables, and 1 dyad was excluded due to one partner labeling their partner as an acquaintance rather than as a friend. Thus, the final number of dyads with at least partial data was 143 (same assigned sex-at-birth dyads = 121, different sex-at-birth dyads = 22, same self-reported race = 111, different self-reported race = 32), consisting of 286 individuals (230 female sex-at-birth, 56 male sex-at-birth, M_{age} = 18.87, SD = 1.37, 79.7% White, 9.4% Black/African American, 0.3% American Indian or Alaska Native, 4.2% Asian or Asian American, 1.0% Native Hawaiian or other Pacific Islander, 4.5% mixed race, 0.7% other, 96.9% not of Hispanic, Latinx or Spanish origin). Out of the total sample, 108 individuals (37.8%) identified their relationship with their dyad partner as best friends, 129 (45.1%) as close friends, and 49 (17.1%) as friends and the average friendship length was 27.9 months, SD = 40.91. Of note, 14 individuals were missing relationship length data, and 6 individuals were missing relationship seriousness data. To conserve our sample size for the analyses, we opted to copy the relationship length and seriousness data from the partner for these indi-

viduals. See Table 1 for the main demographics for the full sample. See the Supplemental Materials for additional demographic information at the individual and dyad-level.

Of note, as others in the field have found that the degree of NVS differs among female-female dyads compared to male-male dyads (Fujiwara et al., 2019), and between racially concordant and racially discordant dyads (Hamel et al., 2022), we conducted exploratory analyses examining whether the degree of NVS differs according to dyad sex-at-birth composition (female-female, male-female, male-female) or between racially concordant and racially discordant dyads. We found that there were no differences in the degree of NVS according to dyad sex-at-birth composition or according to dyad-race concordance. Results of these exploratory analyses can be found in the Supplemental Materials.

Sample Size Determination

Sample size for the original study was determined based on an a priori power analysis performed to address the hypotheses of the original study (see Tudder et al., 2022). Specifically, Tudder and colleagues (2022) conducted a series of Monte Carlo simulations with equality

Table 1 Demographic data for the final sample. $N=286$ individuals (143 dyads). Demographic information does not include those from dyads who were excluded

Variable	Full sample	
	M	*SD*
Age	18.87	1.37
Friendship length (months)	27.90	40.91
NVS Conversation 1 ($N_{dyads} = 135$)	0.16	0.02
NVS Conversation 2 ($N_{dyads} = 116$)	0.17	0.02
	N	*%*
Self-reported sex at birth		
Male	56	19.6
Female	230	80.4
Dyad sex composition		
Both female	104	72.7
Both male	17	11.9
Male and female	22	15.4
Race		
White	228	79.7
Black, African American	27	9.4
Asian	12	4.2
Native Hawaiian/Pacific Islander	3	1.0
American Indian or Alaska Native	1	0.3
Mixed	13	4.5
Other	2	0.7
Dyad race composition		
Same Race	111	77.6
Different Race	32	22.4
Hispanic origin		
No, Hispanic	277	96.9
Yes, Hispanic	9	3.0
Relationship Seriousness		
Friends	49	17.1
Close friends	129	45.1
Best friends	108	37.8

constraints for the paths modeling effect of each dyad using past dyadic datasets with similar physiological measures as theirs to approximate the effects. Their power analysis revealed that 120 dyads were needed to achieve sufficient power (>0.80) to detect small-to-medium interaction effects.

Following data analysis, for models examining the degree of NVS as an outcome, we conducted a sensitivity power analysis to determine the size of the effect we would be able to detect given our dyad-level sample sizes that ranged from 111 to 130 dyads depending on the analysis. Results indicated that we would be able to detect a medium effect of Cohen's $d = 0.496–0.536$ (alpha = 0.05) with 80% power.

Procedures

Participants were brought to private testing rooms when they arrived for the study and were asked to complete a problem-generation questionnaire (see *Measures* section below). Next, they received instructions for the problem-focused conversation where one partner (the *discloser*) was randomly assigned to discuss one of the problems they identified. Their partner (the *responder*) was asked to respond to their friend. Participants rated the severity for each problem, and the researcher selected the discloser's problem with the greatest severity rating for discussion. At the beginning of the visit, participants also completed questionnaires about their friendship (e.g., how serious the friendship was), how satisfied they were with their friendship, and how supported and close they felt to their friend.

Dyads were then randomized to one of two conditions. In the *co-rumination* condition (N_{dyads} = 78), dyads were given instructions that prompted co-rumination; specifically, to stay on topic, go over the problem multiple times, speculate about the causes and consequences of the problem, and uncover and dig into negative emotions. In the *natural* condition (N_{dyads} = 65), dyads were told to discuss the problem as they naturally would. Across both conditions, dyads were given physical cards to remind them of their instructions. Following this, they were instructed to "gather their thoughts" for three minutes in private testing rooms. Next, a foldable sound-insulated wall separating the two private participant rooms was collapsed and dyads were video-recorded as they engaged in the first problem-focused 8-minute conversation centered around the discloser's selected problem. After the conversation, the wall was replaced and participants answered a series of questionnaires regarding how close and supported they felt to their friend now, and how much the conversation led to better understanding of the problem (see *Measures* section below). After dyads completed the first conversation, the discloser and responder switched roles and repeated the above steps for a second conversation. Finally, at the conclusion of the visit, participants completed a demographic questionnaire. The protocol, and informed consent procedures, and secondary data analysis were approved by the University Institutional Review Board at Ohio University. The secondary data analysis procedures were also approved by the University of Rochester Research Subjects Review Board. Given that the original study was designed to test hypotheses regarding co-rumination, participants completed additional tasks and questionnaires not relevant to the current investigation and will not be discussed in this manuscript. Furthermore, as part of the original study goals, physiological equipment, such as blood pressure cuffs, were attached to participants as they completed the conversations. For more information about the original study, please see Tudder, Wilkinson, Gresham and Peters (2022). For a graphic depiction of the study design, see Fig. 1.

Motion Energy Analysis (MEA) and NVS

The problem-focused conversations were video-recorded at a frame rate of 25 frames per second using two fixed cameras, one facing each dyad partner, that were later joined together using a split screen. Prior to processing a video with MEA, we visually inspected the videos to ensure that there were no quality concerns, such as light fluctuations, changes in zoom, and drastically different distances from the camera between dyad partners, all of which have been described as necessary data exclusions for MEA (Ramseyer, 2020b). We removed 25 dyad videos due to video quality issues as discussed in the Participants section. We trimmed eligible videos to only include the conversations for videos that ran long or accidentally included other tasks in the study. There was a total of 135 shared dyad recordings for the first conversation and 116 shared dyad recordings for the second conversation, following data exclusions. Across both conversations, 143 dyads had eligible recordings for at least one conversation. Prior to processing the videos through MEA, we split the shared dyad split screen video in half due to them having an extra-wide filming frame that was incompatible with the MEA program. Thus, we ran videos of single interactants individually through MEA to generate an objective quantification of movement.

MEA is based on a frame-differencing algorithm and calculating NVS requires multiple processing steps. Motion energy was defined as differences in gray-scale pixels between consecutive video frames with differences representing body movement of participants as the background remained static. Within the MEA program, we defined a single region-of-interest (ROI) that covered the entire head and upper body of the participant (Fig. 2) and drew the ROI for each participant. After specifying the ROI, the MEA program processes the video and exports a single csv file that contains time series of the raw pixel changes within the specified ROI for each participant. Data processing of the raw motion energy values was then processed using the rMEA package in RStudio (*RMEA*, for an example of use see Kleinbub & Ramseyer, 2021).

We used standard preprocessing steps (e.g., Ramseyer & Tschacher, 2014; Tschacher et al., 2014). First, we smoothed the time-series with a moving average filter of 0.5 s, which reduced fluctuations due to signal-distortion present across the videos. To account for differ-

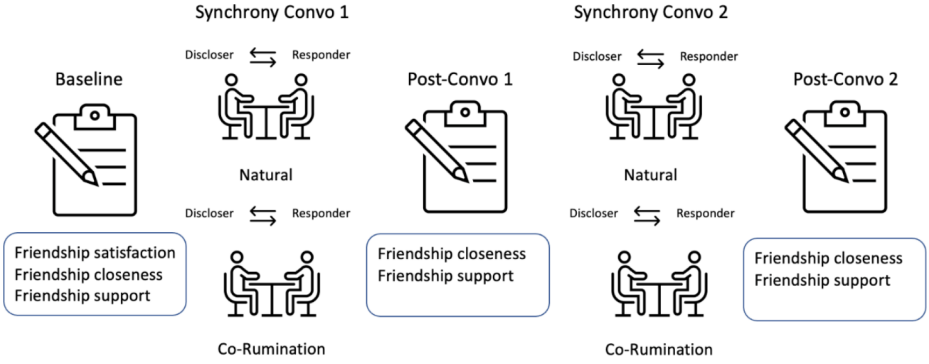

Fig. 1 Graphic depicts the general study layout. Self-report questionnaires were completed at baseline and immediately following each conversation. Dyads were randomized to participate in either the co-rumination condition or the natural condition. Each dyad completed two conversations and for each conversation, each partner played the role of either the discloser or the responder. For the second conversation, dyad partners completed the role they had not completed in the prior conversation

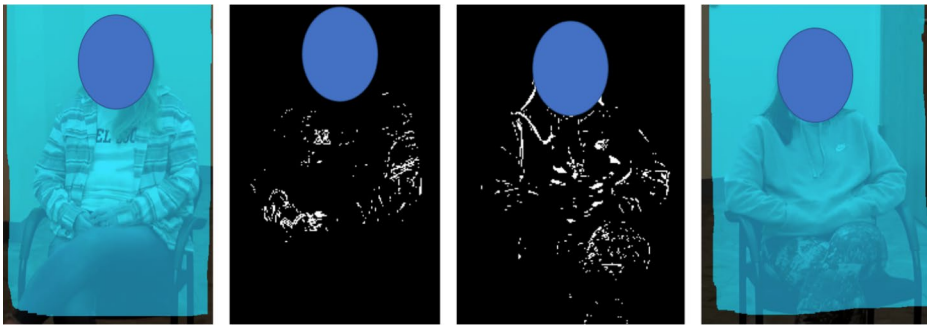

Fig. 2 Motion energy analysis regions of interest drawn. Colored images are stills taken from a videorecording of graduate students demonstrating the setup for the social interaction with the regions of interest covering the head and upper body represented by blue boxes. Black and white images are of corresponding motion energy. Motion energy was calculated only within the single predefined region of interest (blue box) for each individual

ent sized ROIs, we *z*-transformed the data and a threshold for minimal movement was specified. Here, we used the default threshold provided by the author of MEA thereby excluding extreme values higher than 10 times the standard deviation. Data that were filtered and corrected according to these steps were then analyzed for NVS.

We formally quantified NVS within dyads according to instructions outlined by the creator of the MEA program (Ramseyer, 2020b). Specifically, in each 8-minute conversation, motion energies for both partners were cross-correlated in consecutive windowed segments of 30 s duration. The window size of 30 s was chosen to account for the shorter turn-taking latencies in a problem-focused discussion, in line with previous work (Tschacher et al., 2014). Cross-correlations for positive and negative time-lags up to 5 s in steps of 0.1 s were then computed by stepwise shifting one time-series in relation to the other (Ramseyer & Tschacher, 2011). Cross-correlations were then transformed using the Fisher *r*-to-*Z* transformation, and their absolute values were aggregated over the entire 8-minute interval for the conversation, yielding a shared global value of NVS for the conversation of each dyad (Ramseyer & Tschacher, 2011). The use of absolute values allowed for both positive and negative cross-correlations to contribute positively to the synchrony measure, which has been shown to be more representative of movement coordination (Tschacher et al., 2014). These values were then used in all subsequent analyses as the NVS variable. See Fig. 3 for example MEA graphs for dyads with high and low synchrony.

Measures

Problem-Generation Questionnaire

The problem-generation questionnaire prompted participants to write about two extradyadic problems that they were currently experiencing. Participants then responded to 7 items that assessed the severity of these problems on a scale of 1 (*not at all)* to 7 (*very much*). Example items included “How upsetting is this problem?” and “How hard would it be to solve this problem?”. Responses were summed and the problem with the highest severity score was chosen for the discussion.

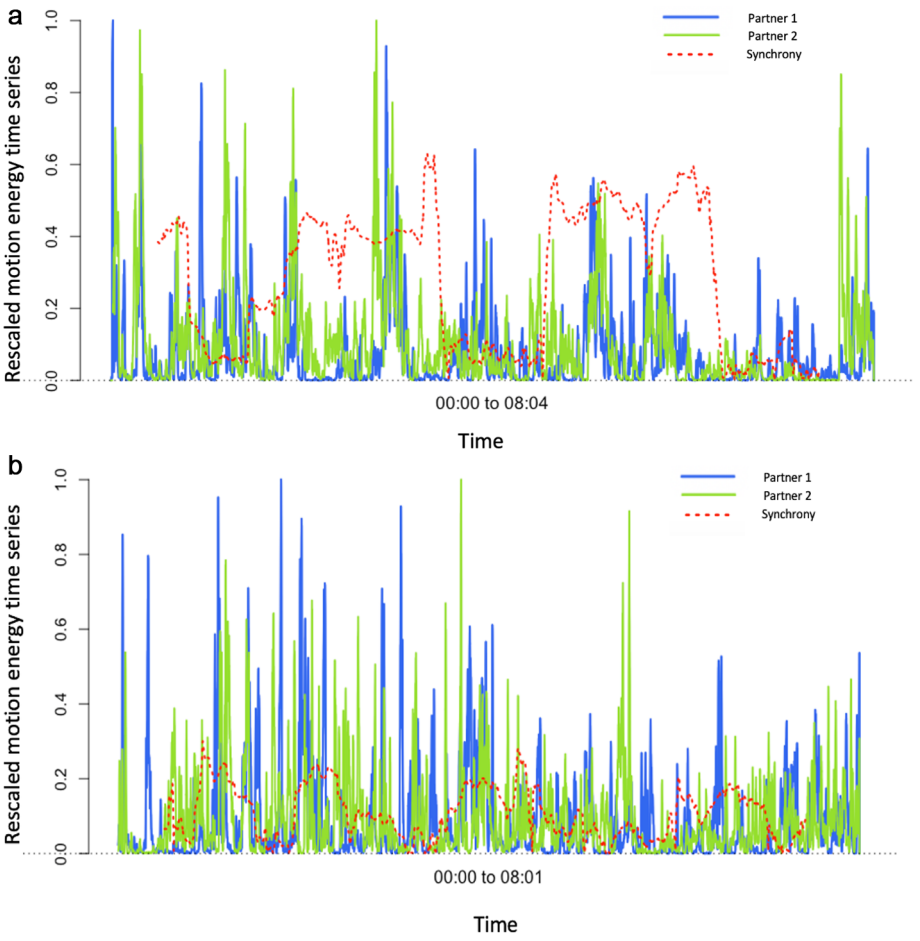

Fig. 3 Example motion energy graphs over time representing dyadic movement for each partner (blue, green) and calculated synchrony values at a lag of 0s for two dyads during the interaction (red dotted). Figure 3*a* represents the motion energy over time for the dyad with a high synchrony value, $M=0.24$. Figure 3*b* represents the motion energy over time for the dyad with a low synchrony value, $M=0.09$

Friendship Satisfaction

Prior to the problem-focused conversation, all participants completed a version of the *Couples Satisfaction Index-16* (CSI-16, Funk & Rogge, 2007) that was adapted to assess participants' satisfaction with their friendship with their dyad partner at baseline. The CSI-16 includes 16 items that are rated on 6-point (0=*never/not at all true/not at all*, 5=*all the time/completely true/completely*) and 7-point Likert scales (1=*extremely unhappy*, 7=*perfect*). Sample items include "we have a warm and comfortable friendship" and "how well does your friend meet your needs". Higher scores indicate higher levels of relationship satisfaction. To score the CSI-16, all items were summed with relevant items reverse-scored. Omega was 0.95, demonstrating high reliability.

Measures of Closeness and Perceived Support from the Partner

All participants filled out two self-report measures, the *Closeness to the Partner* measure and the *Social Support* measure, created to examine closeness to the partner and perceived social support from the partner both at baseline and immediately after each conversation. The scale items were developed to assess forms of support (e.g., emotional, esteem, practical, autonomy) that promote relationship well-being (see Hammond & Overall, 2015; Jayamaha & Overall, 2019; Overall et al., 2010).

The *Closeness to the Partner* measure consisted of seven items that were rated on a scale from 1 to 7 (1 = *strongly disagree*, 7 = *strongly agree*). Sample items include "to what extent do you agree or disagree that you feel care for/loved by your friend?" "…close/intimate with your friend" and "…understood/validated by your friend?". To score the instrument, individual subscales for closeness to the partner, perceived support, responsiveness to the partner, and an overall composite score for closeness were created where an average was taken from relevant items that fit within each subscale. Thus, higher scores on each subscale corresponded with greater closeness to the partner, perceived support, and/or responsiveness to the partner respectively.

The *Social Support* measure consisted of twenty-three items that were rated on a scale from 1 to 7 (1 = *strongly disagree*, 7 = *strongly agree*). Sample items include "my friend is understanding and caring", "my friend is there for me if I need them" and "my friend offers me help or advice". To score the instrument, individual subscales for autonomy support, competence support, practical support, emotional support, and invisible emotional support were created where an average was taken from relevant items that fit within each subscale. Thus, higher scores on each subscale corresponded with greater autonomy support, competence support, practical support, emotional support, and invisible emotional support respectively.

In the present study, we conducted a principal components analysis (PCA) using SPSS Version 27.0 to identify underlying principal components and to reduce the dimensionality of the *Closeness to the Partner* and *Social Support* measures for use in subsequent analyses, thereby avoiding collinearity of predictors. Additionally, the smaller number of components reduced the problem of alpha inflation, since the complete set of self-report data concerning these two measures included 9 subscales of the available instruments (4 subscales from the *Closeness to the Partner* measure and 5 subscales from the *Social Support* measure) that were measured both before and after each conversation. The PCA scree plots suggested that a single component model fit best for the measures taken before and after each conversation. We then computed weighted standardized principal component regression scores for the single component at baseline and after each conversation. Thus, the principal component scores for closeness to partner and social support items–hereafter, "friendship support"—is used for all subsequent analyses. For more information about the three components, please see the supplemental materials.

Exploratory Moderating Variables

In addition to examining the main variables of interest, we were also interested in examining whether the below variables moderated the association between NVS and friendship satisfaction and support.

Task condition. A binary variable that indicated whether the conversation task each dyad was randomized to was the Natural Condition (-1) or the Co-Rumination Condition (1).

Relationship seriousness. A categorical variable indicating the self-reported friendship seriousness of the friends (1 = acquaintances, 2 = friends, 3 = close friends, 4 = best friends). Of note, one dyad partner identified their partner as an acquaintance. Given that this study was aimed at studying friends, the dyad was removed from all analyses.

Problem understanding. Two items assessed the extent to which the conversation led to better understanding of the problem. One item measured whether "our conversation led to greater understanding of the causes and consequences of the problem". The other item measured whether "our conversation led to greater understanding of the negative emotions related to the problem". Both items were measured on a scale from 1 to 7 (1 = *strongly disagree*) to 7 (7 = *strongly agree*) and averaged to create a composite score.

Data Analytic Plan

Question 1: Is Synchrony Significantly Greater than Pseudosynchrony During the Conversations?

First, we evaluated whether the MEA-derived synchrony values explained more synchrony than that which may occur by chance (i.e., pseudosynchrony). To do so, we created pseudointeractions using a function in RMEA that creates automated surrogate algorithms (RMEA, n.d.). Specifically, this function implements a shuffling process where all possible combinations between two interactants' motion energy values in the original data are computed. The function then removes the original pairings and finally extracts a specified number of MEA datasets without replacement. Thus, we extracted MEA 'pseudo' data for 257 videos to match the number of videos we processed via MEA. This procedure kept the same structure of the real data intact while permuting the original data to create artificial time-series with movement energy that never took place. Synchrony of the pseudointeractions was then calculated the same way that synchrony was calculated above. To address hypothesis 1, we conducted a Welch's independent samples *t*-test in R using the R stats package (R Core Team, 2022) to statistically compare synchrony to pseudosynchrony and Cohen's *d* was calculated to quantify the size of the difference using the R package lsr (Navarro, 2015), and is interpreted according to Cohen's (1988) benchmarks.

Question 2: Does Greater Friendship Satisfaction (CSI-16) Predict Greater NVS During the Conversation?

To examine study questions related to the degree of NVS as an outcome variable, we conducted linear regression models with the predictor variables averaged within dyads due to NVS being a shared variable within dyads (i.e., both dyad members have the same composite score for their degree of synchrony during the conversation). Furthermore, we ran the linear regression models separately for each conversation completed.

Across these analyses, when outliers were detected on boxplots as falling above the third quartile + 1.5*interquartile range or below the first quartile – 1.5*interquartile range, we performed a 90% winsorization on the relevant predictor variables. For examining NVS as an outcome, two variables were winsorized. Furthermore, standardized regression coefficients

are reported. All subsequent analyses were conducted in RStudio using the R Stats package (R Core Team, 2022).

Finally, in the interest of preserving our sample size, we opted to include all dyads with at least partial data (i.e., synchrony data for at least one conversation and corresponding self-report for that conversation) rather than only including dyads with full datasets. As dyads differed in their missing data, the sample sizes for the below analyses differed depending on the data available. Thus, for all analyses below, we report analysis-specific *Ns*.

To examine if CSI-16 scores measured prior to the conversation significantly predicted NVS during each conversation, we conducted two linear regressions for each conversation. The primary model regressed average NVS scores for the relevant conversation on dyad-averaged CSI-16 scores measured at baseline. The second model examined the same association and included task condition as a covariate to examine if the association between friendship satisfaction and synchrony changed when controlling for this covariate.

Question 3: Does Greater Friendship Support Predict Greater NVS During the Conversation?

To examine if the friendship support measured prior to the conversation significantly predicted NVS during the conversation, we conducted two linear regressions according to the above steps for each conversation. Again, as NVS was shared between dyad members, the scores were the average of the two dyad partners' friendship support principal component scores.

Question 4: Does Greater NVS During the Conversation Predict Greater Ratings of Friendship Support Post-Conversation?

To examine NVS as a predictor, we conducted linear mixed effects models to account for the dependency in the data structure with individual participants (level 1) nested within dyads (level 2). Similar to the models examining NVS as an outcome, we conducted the models separately for each conversation, included dyads with partial data (i.e., self-report data and NVS data for at least one conversation), and winsorized the relevant variables according to the same procedure as when we examined NVS an outcome. Altogether, for examining NVS as a predictor, three variables were winsorized. For models examining NVS as a predictor, we utilized the nlme package (*Linear and Nonlinear Mixed Effects Models [R Package Nlme Version 3.1–152]*, 2021) in RStudio.

To examine if greater NVS predicted greater friendship support scores collected post-conversation, we conducted two-level multilevel models (random intercepts linear-mixed effects models). In the first two steps, we calculated an intercept only model and a random intercept only model and compared the AIC values in the chi-square deviance test of -2 loglikelihood to determine whether the random intercepts model was a better fit for the data. For all models, the random intercepts model was a better fit for the data and thus we report findings from the random intercepts model for all results. In the third step, we added NVS, the main predictor of interest, to the model. Following this step, we entered level-1 variables into the model, which included the covariates of *relationship seriousness* and *problem understanding*. Next, we entered the level-2 covariate of *task condition* into the model.

In addition to the above steps, we also examined exploratory moderators. Specifically, we included interaction terms of 'NVS × task condition', 'NVS × relationship seriousness', and 'NVS × problem understanding', in separate models with the levels 1 and 2 covariates included in the models. We took the same steps for conversations 1 and 2 separately.

Results

NVS Compared to Pseudosynchrony

Question 1: Is Synchrony Significantly Greater than Pseudosynchrony During the Conversation?

Comparing synchrony during conversation 1 to pseudosynchrony, we found that NVS (M=0.1635, SD=0.0172, N_{dyads} = 135) was significantly greater than pseudosynchrony (M=0.1550, SD=0.0174, N_{dyads} = 135), $t(268)$=4.04, p<.001, with a medium effect size of d=0.49, demonstrating a degree of NVS among the dyads above chance (Hypothesis 1).

Similarly, comparing synchrony during conversation 2 to pseudosynchrony, we found that NVS (M=0.1681, SD=0.0205, N_{dyads} = 116) was significantly greater than pseudosynchrony (M=0.1563, SD=0.0166, N_{dyads} = 116), $t(221)$=4.84, p<.001, with a medium effect size of d=0.64, again, demonstrating a degree of NVS among the dyads above chance. Thus, across both analyses, the amount of NVS exceeded the levels that one would expect if the coordination was only due to chance, suggesting that problem-focused discussions among friends can be characterized by the presence of NVS.

NVS as an Outcome

Question 2: Does Greater Friendship Satisfaction (CSI-16) Predict Greater NVS During the Conversation?

We conducted linear regressions examining if greater friendship satisfaction—CSI-16 scores taken at baseline prior to either conversation—was predictive of greater NVS during conversation (1) In these models, the CSI-16 scores reflected the average scores of both dyad members. Contrary to our hypothesis, we found that greater friendship satisfaction alone (M=70.31, SD=7.92, N_{dyads} = 130) did not predict greater NVS during conversation 1, $\beta = -0.11$, 95% CI [-0.28, 0.05], $t(128)$ = -1.35, p=.181, $adjR^2$=0.006. When task condition was added to the model, greater friendship satisfaction still did not predict greater NVS during the first conversation, $\beta = -0.11$, 95% CI [-0.28, 0.06], $t(127)$ = -1.32, p=.191, $adjR^2$=0.007. An exploratory analysis examining if task condition moderated the effect of friendship satisfaction on NVS (i.e., friendship satisfaction × task condition) was not significant, p=.830. We also conducted linear regressions examining if greater friendship satisfaction at baseline was predictive of greater NVS during conversation 2. We again found that contrary to our hypothesis, greater friendship satisfaction (M=70.47, SD=7.65, N_{dyads} = 111) did not predict greater NVS during conversation 2, $\beta = -0.13$, 95% CI [-0.32, 0.07], $t(109)$ = -1.30, p=.195, $adjR^2$=0.006. When the covariate of task condition was added to the model, greater friendship satisfaction still did not predict greater NVS during the second

conversation, $\beta = -0.13$, 95% CI [-0.33, 0.06], $t(108) = -1.39$, $p = .166$, $adjR^2 = 0.028$. An exploratory analysis examining if task condition moderated the effect of friendship satisfaction on NVS during conversation 2 (i.e., friendship satisfaction × task condition) was not significant, $p = .415$.

Question 3: Does Greater Friendship Support Predict Greater NVS During the Conversations?

We conducted linear regressions examining if greater ratings of how close or supported the dyad partners felt toward each other prior to the conversation were predictive of greater NVS during the first and second conversations. In these models, friendship support was represented as the average of the two dyad partners' weighted standardized pre-conversation friendship support principal component scores.

For conversation 1, we found that contrary to our hypothesis, greater friendship support ($M = 0.03$, $SD = 0.77$, $N_{dyads} = 130$) did not predict greater NVS during this conversation, $\beta = -0.04$, 95% CI [-0.21, 0.14], $t(128) = -0.44$, $p = .664$, $adjR^2 = -0.006$. When task condition was added to the model, greater friendship support still did not predict greater NVS during the first conversation, $\beta = -0.03$, 95% CI [-0.21, 0.14], $t(127) = -0.37$, $p = .716$, $adjR^2 = -0.005$.

Lastly, the exploratory analysis examining if task condition moderated the effect of friendship support on NVS (i.e., friendship support × task condition) was not significant, $p = .150$.

Similarly, for conversation 2, we found that contrary to our hypothesis, greater friendship support ($M = 0.05$, $SD = 0.75$, $N_{dyads} = 111$) did not predict greater NVS during this conversation, $\beta = -0.07$, 95% CI [-0.27, 0.12], $t(109) = -0.73$, $p = .470$, $adjR^2 = -0.004$. When task condition was added to the model, friendship support still did not predict NVS during the second conversation, $\beta = -0.07$, 95% CI [-0.27, 0.12], $t(108) = -0.77$, $p = .446$, $adjR^2 = 0.016$.

Lastly, the exploratory analysis examining if task condition moderated the effect of friendship support on NVS during conversation 2 (i.e., friendship support × task condition) was not significant, $p = .92$. Thus, greater ratings of friendship support did not predict greater NVS scores across conversation 1 and 2. Furthermore, task condition did not moderate this association.

NVS as a Predictor

Question 4: Does Greater NVS During the Conversations Predict Greater Ratings of Friendship Support Post-Conversation?

We conducted linear mixed effects models examining if greater NVS during conversations 1 and 2 was predictive of greater ratings of how close or supported participants felt about their dyad partner after each conversation. We found that when NVS for conversation 1 was entered into the model alone as a predictor, greater NVS during this conversation was not predictive of greater individual friendship support scores measured post-conversation, $\beta = 0.05$, 95% CI [-0.09, 0.20], $t(130) = 0.70$, $p = .486$, $N_{\text{dyads}} = 132$. When the level-1 covariates of relationship seriousness and problem understanding were entered into the model

as covariates, the results did not substantially change, $\beta = 0.08$, 95% CI [-0.05, 0.20], $t(130) = 1.24$, $p = .218$. Similarly, when the level-2 covariate of task condition was entered in the model with the level-1 covariates and NVS, greater NVS was still not predictive of greater friendship support measured post-conversation, $\beta = 0.08$, 95% CI [-0.04, 0.21], $t(129) = 1.31$, $p = .194$, $N_{\text{dyads}} = 132$.

Lastly, the exploratory analyses examining if task condition, relationship seriousness, and/or problem understanding moderated the effect of NVS during the first conversation on the friendship support principal component scores (i.e., synchrony × task condition, synchrony × relationship seriousness, synchrony × problem understanding) were not significant ($ps > 0.05$).

Similarly, we found that when NVS for conversation 2 was entered into the model alone as a predictor, greater NVS during this conversation was not predictive of greater friendship support measured post-conversation, $\beta = -0.04$, 95% CI [-0.19, 0.11], $t(111) = -0.49$, $p = .625$, $N_{\text{dyads}} = 113$. When the level-1 covariates of relationship seriousness and problem understanding were entered into the model as covariates, the results did not substantially change, $\beta = 0.01$, *95% CI* [-0.12, 0.14], $t(111) = 0.11$, $p = .915$. Similarly, when the level-2 covariate of task condition was entered in the model with the level-1 covariates and NVS, greater NVS was still not predictive of greater friendship support measured post-conversation, $\beta = 0.01$, 95% CI [-0.12, 0.14], $t(110) = 0.12$, $p = .903$, $N_{\text{dyads}} = 113$.

Lastly, the exploratory analysis examining if the perception of relationship seriousness moderated the effects of NVS during the second conversation on friendship support (i.e., synchrony × relationship seriousness) was significant. Specifically, in a model with no covariates added, there was a significant difference in the simple slopes for the association between the degree of NVS during conversation 2 and friendship support measured post-conversation when comparing individuals who identified their relationship with their partner as friends as opposed to close friends, $\beta = 0.37$, $t(109) = 2.06$, $p = .042$. Furthermore, there was a trend in the simple slopes for the association between the degree of synchrony during this conversation and friendship support when comparing individuals who identified their relationship with their partner as friends as opposed to best friends, $\beta = 0.34$, $t(109) = 1.77$, $p = .080$. When the level 1 and level 2 covariates were included, a similar pattern of findings were found.

Simple slopes analysis revealed that for individuals who identified their relationship as friends, greater NVS trended toward predicting *lower* friendship support ($\beta = -0.30$, 95% CI [-0.61, 0.01]). The trend between these variables was not present for individuals who identified their relationship as close friends ($\beta = 0.07$, 95% CI [-0.13, 0.27] or as best friends ($\beta = 0.04$, 95% CI [-0.18, 0.26]). Additionally, there was a trend difference in the simple slopes between those who identified their relationship with their partners as friends as opposed to close friends, $\beta = -0.37$, $t(109) = -2.06$, $p = .103$. The other exploratory moderators of task condition and problem understanding (i.e., synchrony × task condition, synchrony × problem understanding) were not significant, $ps > 0.05$.

Greater NVS did not directly predict greater friendship support measured post-conversation. However, the exploratory analyses revealed that relationship seriousness moderated the association between NVS during conversation 2 and post-conversation friendship support scores in an unexpected direction. Namely, among individuals who identified their partners as friends, greater NVS during the second conversation predicted lower friendship support scores measured after this conversation. The same findings did not hold for conver-

sation 1 and the other exploratory variables of task condition and problem understanding did not moderate the association between NVS and friendship support for either conversation.

Discussion

The present study explored NVS among friend dyads as they engaged in two problem-focused discussions and its association with friendship satisfaction, closeness and support. To quantify NVS, we used Motion Energy Analysis (MEA), an objective and computerized analysis of video recordings (Ramseyer, 2020b). Consistent with the first hypothesis, we found that in these social interactions, synchrony among friends was present at a level significantly above chance, suggesting that NVS accompanies problem-focused conversations. In this study, the mean fisher's Z synchrony value for a single conversation among friends was around 0.16, similar to previous work (Tschacher et al., 2014). Furthermore, using similar data collection and analysis methods as others (Tschacher et al., 2014), we found that NVS was present with small-to-medium effect sizes of $d=0.49$ for conversation 1 and $d=0.64$ for conversation 2; an effect similar to that found in previous work. Specifically, effect sizes between $d=0.50$–0.59 were reported in psychotherapy dyads (Ramseyer & Tschacher, 2011) and effect sizes between 0.56 and 1.11 were reported in unacquainted dyads engaging in social tasks (Tschacher et al., 2014). Thus, in this study, we found objective evidence for the presence of genuine NVS collected inconspicuously in dyadic interactions among friends.

However, inconsistent with our second hypothesis, we found that friendship satisfaction was not predictive of the degree of NVS. This finding was unexpected as previous work has found a significant and positive association between the degree of NVS and relationship quality among therapist-client relations in psychotherapy settings (Ramseyer & Tschacher, 2011). While a well-validated self-report measure of relationship satisfaction was administered to individuals, the measure has only been validated for use in measuring relationship satisfaction in romantic partner dyads and has not been validated for use in friendship dyads. Thus, it may be possible that a well-validated friendship relationship satisfaction measure might better capture friendship satisfaction in future work.

Inconsistent with our third and fourth hypotheses, we did not find that greater ratings of perceived friendship support were predictive of or predicted by greater NVS. While we conducted a principal components analysis here to identify underlying components represented by the individual items across the *Closeness to the Partner* and *Social Support* scales, it might be that NVS is specifically related to a particular form of support or social bonding that should be examined in future studies. Another potential explanation for why we did not find that synchrony was significantly predictive of or predicted by various aspects of the quality of the friendship could surround the different roles that synchrony might play in close relationships compared to unacquainted relationships. There has been research to suggest that synchrony can work as a type of "social glue" to create strong social bonds (Vacharkulksemsuk & Fredrickson, 2012) rather than maintain these bonds. From this view, unacquainted individuals, rather than individuals in already established close relationships with each other, might benefit from the bonding effects of synchrony.

In support of this idea, there have been studies that have found that out-group members demonstrate more synchrony in performing repetitive actions than in-group members

(Miles et al., 2009). Furthermore, Fujiwara and colleagues (2020) found that while friend dyads demonstrated greater NVS compared to stranger dyads in an unstructured conversation task, the degree of NVS was only predictive of the motivation to develop/deepen the relationship with the dyad partner among stranger dyads and not among friend dyads. These prior findings align with the current findings and lend further support to the idea that because the dyads in this study were already in close relationships, they might not have benefitted from the bonding effects of synchrony. Ultimately, this may be a strong reason for why we failed to find a significant association between synchrony and various aspects of friendship quality.

Lastly, the exploratory analyses that examined task condition as a moderator in the models that examined the association between relationship variables (i.e., friendship satisfaction and closeness/support) and synchrony were not significant. Interestingly, relationship seriousness was a significant moderator between the degree of NVS predicting friendship support post-conversation scores but only for the latter of two conversations. Furthermore, when this interaction was probed, it was shown that for those who rated their relationship with their partners as friends specifically as opposed to close or best friends, greater NVS during this interaction only trended toward predicting lower friendship support scores in the second conversation. This finding was unexpected and is in need of replication.

However, some findings from the psychotherapy literature might lend some potential explanations of this finding. Rasting and Beutel, (2005) measured reciprocity in facial affect between patients and interviewers and found that greater reciprocity over the course of a baseline and discharge interview predicted unsuccessful treatment outcome. They theorized that in some cases, greater reciprocity of facial affect may demonstrate too much agreement between therapists and clients, which may impede the ability to work through certain conflicts in psychotherapy, and thus limit the helpfulness in correcting maladaptive behavior.

Along a similar vein, Ramseyer (2020a) measured NVS, clinical outcome measures of symptom distress, and interpersonal difficulties on a session-by-session basis. They found that patients with greater interpersonal problems at the end of treatment tended to show greater levels of synchrony throughout treatment. In examining time-varying effects of synchrony, they found that greater synchrony in the previous session predicted both greater interpersonal difficulties during that session and greater symptom distress in the next session. Thus, surprisingly, these findings demonstrated that greater synchrony was predictive of worse clinical outcomes. The researcher theorized that among dyads with fluctuating therapeutic alliance, greater NVS may represent increased effort on behalf of the therapist to coordinate their nonverbal behaviors to their clients, as opposed to a more balanced coordination between therapist and client, which may lead to worse clinical outcomes.

Thus, altogether, one interpretation of our finding of greater synchrony predicting lower friendship support scores for one conversation might be that among individuals who identified their partner as a friend, greater synchrony may not have been well-balanced in this conversation. Specifically, it might have represented too much agreement between two partners or too much attempted coordination or effort from one partner, perhaps the 'responder', that may have hampered the other partner's independent emotion-regulation abilities, which may then have predicted lower friendship ratings. For individuals who identified their partner as a close friend or best friend, it may be that the perceived strength of their friendship was able to buffer against this potentially negative effect of synchrony, though this was not directly examined.

While we may be able to offer some thoughts regarding the interpretation of this finding, it is important to again acknowledge that these results only held for one conversation. Furthermore, due to the exploratory nature of this analysis, we did not adjust the alpha for this analysis. Thus, these results should be viewed as tentative and replication is warranted before forming firm conclusions. However, these initial findings may suggest that greater NVS plays a different role depending on the perceived closeness of the friendship, particularly within problem-focused discussions and should be further explored in future studies.

Limitations

A known limitation regarding the use of MEA to quantify nonverbal behavior and synchrony is that it is not possible to assess the qualitative aspects of nonverbal behavior, such as smiling. While some work has found a moderate correlation between automated and manual coding methods for measuring NVS (Fujiwara et al., 2021), research in this area is still new. Thus, future studies that examine the utility of both observer-based methods and automated methods for measuring NVS would be helpful in furthering our understanding of the association between the qualitative and quantitative features of NVS and their association to the perception of important relationship variables, such as satisfaction and support.

Furthermore, because NVS was a shared value within dyads, all variables collected prior to the conversations (i.e., predictors) represented the average ratings of that variable within dyads. This poses as a limitation as there were instances where dyad partners had different ratings for the variables. Thus, by averaging ratings of that variable within dyads, some of the variance in the ratings may have been lost. Additionally, relationship seriousness was only examined as a moderator in the models with synchrony as a predictor and not in models with synchrony as an outcome given that there was some discrepancy between the seriousness of the relationship within dyads that made combining the ratings for this measure impossible.

Additionally, it should be mentioned that our sensitivity power analysis for examining the degree of NVS as an outcome revealed that at 80% power, we would only be able to detect medium-sized effects with our sample size of 111–130 dyads for those analyses. Thus, it is possible that we were underpowered to detect smaller effects of friendship support on the degree of NVS in conversations 1 and 2 in this study.

Lastly, there were some limitations regarding the video collection that, despite data quality and analytic controls we implemented (see Methods), should also be considered. Specifically, during some conversations, participants interacted with extraneous objects in the room that may have introduced noise to the quantification of movement and synchrony (e.g., picking up a piece of paper). As physiological data was also collected during the task, participants had certain wires that were connected to their chest and arms (e.g., blood pressure cuff) that may have also introduced noise to the quantification of movement and synchrony.

Future Directions

While we did not find that synchrony was significantly predicted by or predictive of various aspects of the quality of the friendship in this study, there have been several studies that have found synchrony to be related to various aspects of relationship quality in unacquainted dyads. Thus, it would be helpful for future work to explore the mechanisms by

which synchrony may or may not be associated with relationship quality among different types of dyads.

Additionally, as this was one of few studies that has examined synchrony in the context of friend dyads, future work should continue to explore the presence of synchrony among these close relationships and examine if there might be certain moderators or contexts that might contribute to the association between synchrony and various social and relational outcomes.

Thirdly, in this paper, we examined the degree of average NVS over an interaction and its association with friendship variables. We note that there exist other methods for measuring NVS in the field, including the examination of time-varying NVS (Cohen et al., 2021) and adjusting the synchrony value according to the corresponding degree of pseudosynchrony, producing a more conservative estimate of NVS (Ramseyer et al., 2020). In future work, it would be of interest to explore the association between time varying NVS and the average degree of NVS and whether one method is better able to explain variance in important relationship variables among friends.

Lastly, while in this study we defined a single ROI that contained the head and upper body of interacting participants, there have been other studies that have found that head and body movement were associated with different aspects of the conversation. For instance, one study found that head synchrony uniquely predicted global client outcome in psychotherapy while body synchrony uniquely predicted session outcome (Ramseyer & Tschacher, 2014). Thus, it would be interesting for future work to examine if head synchrony vs. body synchrony holds unique associations with various social measures in the context of dyads with existing close relationships.

Conclusions

Overall, this study found that while synchrony was present in problem-focused discussions among friend dyads, it was not significantly related to friendship satisfaction, closeness or support. The findings were unexpected given the existence of previous work that has found NVS to be significantly related to various aspects of relationship quality among unacquainted dyads (Tschacher et al., 2014) but appears to be in line with previous work that found NVS to not be predictive of the motivation to develop/deepen the dyadic relationship among friends (Fujiwara et al., 2020). As such, this study provides a methodological foundation for studying NVS with automated measures, but also raises questions about the role that NVS plays among these types of close relationships.

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Author Contributions B.P., A.M.G. and A.T. developed the original study and contributed to the original study design and data collection. L.L., M.J.F. and D.D.F. developed the secondary analysis research questions and contributed to the secondary data processing, data analytic plan, and data analysis. Data analysis and interpretation was mainly carried out by L.L. and D.D.F. with contributions from all other authors. L.L.

drafted the manuscript and all of the authors provided revisions. All of the authors approved of the final manuscript for submission.

Declarations

Conflicts of Interest The authors declared that there were no conflicts of interest with respect to the authorship of this publication.

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