Physiology and Physiological Covariation in Close Relationships in Schizophrenia

By

Amy Harrison Sanchez

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Psychology

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Ann Kring, Chair
Professor Sheri L. Johnson
Professor Dana Carney
Professor Wendy Berry Mendes

Summer 2020

Abstract

Physiology and Physiological Covariation in Close Relationships in Schizophrenia

By

Amy Sanchez

Doctor of Philosophy in Psychology

University of California, Berkeley

Professor Ann Kring, Chair

Critical, intrusive family environments are a predictor of relapse and poor functional outcome in schizophrenia. Reactivity in the autonomic nervous system (ANS) has been proposed as a potential mechanism underlying this link, but little research has examined ANS physiological reactivity in schizophrenia in the context of family interactions. Further, physiological covariation – physiological interdependence between individuals – predicts important relationship and mental health outcomes, yet no work has examined physiological covariation between people with schizophrenia and their family members. The current study investigated physiological reactivity and physiological covariation during a conflict conversation between young adults with schizophrenia (n = 20) and without schizophrenia (n = 29) and their parents. Respiratory sinus arrhythmia (RSA) and inter-beat interval (IBI) were recorded during a 10-minute conversation about an area of conflict in the participants' relationship. Participants rated relationship qualities and affect, and participants with schizophrenia were rated on symptom severity. Results indicated that young adults with schizophrenia reported higher negative affect after a conflict conversation and had lower average RSA relative to baseline during the conflict conversation compared to young adults without schizophrenia. IBI and RSA covariation were associated with lower parental caring, with the effect of caring on RSA covariation driven by the control group. Within the schizophrenia group, weaker RSA covariation was related to higher negative symptoms. Together, these findings provide novel support for the importance of ANS, particularly PNS, reactivity and covariation in family relationships in people with and without schizophrenia.

Physiology and Physiological Covariation in Close Relationships in Schizophrenia

The quality of our close relationships can have a major impact on our wellbeing. This is particularly true for people with schizophrenia. Decades of cross-sectional and longitudinal research have shown that when the close family members of people with schizophrenia express critical, hostile, or intrusive attitudes toward them in interactions and during clinician interviews, people with schizophrenia are at greater risk for relapse, have more severe symptoms, and have worse functioning, while positive family environments are associated with improved symptoms and functioning (e.g., Brown et al., 1972; Butzlaff & Hooley, 1998; Cechnicki et al., 2013; Doane et al., 1981; O'Brien et al., 2006; see Hooley, 2007; Hooley & Gotlib, 2000 for reviews).

What might influence the link between difficult social relationships and poor outcomes? One theory suggests that the biological effects of negative emotions and stress resulting from negative family interactions, particularly reflected in the autonomic nervous system (ANS), may heighten vulnerability to worse symptoms and poor functioning (Tarrier & Turpin, 1992). A small body of early research supports this theory, finding that people with schizophrenia have heightened ANS arousal when they are with family members who display criticism and hostility (Altorfer et al., 1998; Leff et al., 1982; Sturgeon et al., 1981; Sturgeon et al., 1984; Tarrier, Vaughn et al., 1979; Tarrier et al., 1988). As we will discuss below, this research is promising but limited, particularly as it does not examine the parasympathetic branch of the ANS during family interactions in schizophrenia.

Further, emotion in the context of close relationships is interdependent and dynamic. To obtain a deeper understanding of how emotions and the associated autonomic arousal are manifested and transmitted during family interactions involving individuals with schizophrenia, research must attend to the processes occurring within and between interactants. There has been almost no work to our knowledge to characterize the physiology of close family members during interactions with their relative with schizophrenia. Moreover, work examining physiology in family and romantic relationships among healthy people has demonstrated that the degree to which members of a close relationship share each other's physiology – termed "physiological synchrony" – predicts important relationship and mental health outcomes beyond that of individual physiology (see Davis et al., 2018; Palumbo et al., 2017; Timmons et al., 2015 for reviews).

Considering that the quality of close family relationships is an important psychosocial predictor of relapse (Butzlaff & Hooley, 1998), it is critical to understand how ANS physiology is shared in the close relationships of people with schizophrenia. Thus, the current study had four aims: a) to characterize the similarities and differences in physiology during an emotional conversation with parents in young people with and without schizophrenia; b) to examine group differences in physiological synchrony during these conversations; c) to determine whether relationship variables or emotional reactions predict individual physiology and physiological synchrony; and d) to examine whether symptom severity predicts physiology and physiological synchrony in people with schizophrenia.

Family environment in schizophrenia

The association between the quality of close relationships and outcome was first investigated over 40 years ago using semi-structured interviews assessing "expressed emotion"

(EE), defined as hostility, criticism, and emotional intrusiveness expressed by relatives about the family member with schizophrenia (e.g., Brown et al. 1972, Vaughn & Leff, 1976, Vaughn et al., 1984). Having a relative high in EE explains nearly 10% of the variance in the probability of relapse in schizophrenia (Butzlaff & Hooley, 1998) and is related to rehospitalization and symptom severity (Cechnicki et al., 2013). By contrast, relatives expressing positive statements in clinical interviews is associated with improved symptoms and social functioning (O'Brien et al., 2006) and a supportive family environment moderates the relationship between psychosis symptoms and outcome in young people with clinical high risk for psychosis (Thompson et al., 2019). More evidence of the influence of close relationships on outcomes comes from studies of in-lab interactions between people with schizophrenia and their relatives, typically discussing a conflict in their relationship or other stress-inducing topics (e.g., Doane et al., 1985; Halford et al., 1999; Tarrier et al., 1988). When these conversations happen with a high EE relative, they show patterns of heightened negative reciprocity (Hahlweg et al., 1989) meaning that negative interactions are prolonged by the interactants rather than deescalated. In line with the EE findings, in-lab conversations high in these negative attributes are also related to higher relapse rates, worse symptoms, and poor outcome (Doane et al., 1985; Halford et al., 1999). A recent experience sampling study has found that relatives' intrusive, controlling behaviors in daily life predict patient reports of concurrent symptoms and time lagged negative emotion, supporting the ecological validity of these findings (Vasconselos e Sa et al., 2016).

Physiology during interactions in schizophrenia

By what processes do familial interactions contribute to outcome in schizophrenia? Theory suggests that the biological effects of the high negative emotion and stress associated with negative interactions may contribute to vulnerability to relapse. In particular, ANS arousal has been positioned as a biological index of the effects of the family interactions on people with schizophrenia (Tarrier & Turpin, 1992). The ANS is composed of two branches – the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). Very broadly, the SNS is associated with the "fight or flight" response, while the PNS is generally associated with rest and restoration, and may be important for social engagement (Porges, 2007). The studies of ANS in family interactions in schizophrenia have typically occurred during conversations meant to elicit criticism and conflict, thus ANS arousal has been interpreted as a measure of stress.

ANS in Schizophrenia. The handful of studies that have investigated ANS arousal in family interactions in schizophrenia have supported the hypothesis that exposure to negative family interactions is associated with heightened physiological arousal and that positive family interactions are associated with physiological soothing (Altofer et al., 1998; Leff et al., 1982; Stugeon et al., 1981; Sturgeon et al., 1984; Tarrier et al., 1979; Tarrier et al., 1988; see Hooley, 2007 for review). An early study found that participants with schizophrenia showed a decrease in SNS activity in the presence of low EE relatives compared to a baseline (Tarrier et al., 1979), a finding that was later replicated (Sturgeon et al., 1981; Tarrier et al., 1988). By contrast, study participants in the presence of a high EE relative failed to show this decrease and instead exhibited heightened physiological signs of stress compared to baseline. People with schizophrenia and bipolar disorder demonstrated elevated SNS arousal in response to critical, guilt-inducing, or intrusive statements by a close family member as compared to the participant's mean physiological arousal during the conversation (Altofer et al., 1998). Overall, these findings suggest relationships that are not critical or intrusive may have a physiological soothing effect on

individuals with schizophrenia, while those that are more negative may have an arousing effect. This heightened physiological arousal during interactions with critical or intrusive relatives has been related to higher risk of later relapse (Sturgeon et al.,1984).

These studies provide intriguing evidence for the significant role of physiology in predicting qualities of family interactions in schizophrenia, but several questions remain. For example, it is not clear if people with and without schizophrenia would have similar physiological responses during negative conversations with close others. One possibility is that people with schizophrenia will exhibit elevated physiological reactivity to stressful interactions compared to people without schizophrenia. Higher baseline SNS arousal is associated with schizophrenia independent of medication effects (e.g., Hazlett et al., 1997; Ohman, 1981; but see Clamour et al., 2014), and in daily life, people with schizophrenia report higher subjective stress reactivity compared to people without the diagnosis (see Myin-Germeys & van Os, 2007). Yet a recent review of the literature concluded that participants with and without schizophrenia did not demonstrate differences in subjective ratings of stress or in heart rate reactivity in response to laboratory social stress inductions (Lange et al., 2017). More work is needed to clarify whether schizophrenia is associated with elevated physiological arousal during stressful interactions with close others.

PNS in Schizophrenia. PNS arousal may be particularly salient to social interactions. Yet, no studies have examined PNS arousal in family interactions in schizophrenia. The actions of the vagus nerve at the heart, which have been related to adaptive social and emotional engagement and may be especially important for understanding physiology in close relationships in schizophrenia. Vagal influence over the heart is measured through variability in the heart rate caused by respiration --called respiratory sinus arrhythmia (RSA). Higher RSA indicates higher PNS arousal. Porges (2007) suggests that higher vagal influence over the heart creates a calm state that facilitates social engagement. Research findings support this claim: cardiac vagal tone is associated with empathy, social competence, and the use adaptive social coping strategies in the lab and in daily life, (e.g., Beffara et al., 2016; Geisler et al., 2013; Quintana et al., 2016). Vagal influence on the heart may also change in relation to the environment. For example, in a study of parent and teen conflict conversations, teen RSA was higher during more positive conversations and lower during more negative conversations (Cui et al., 2015).

Meta-analyses indicate that people with schizophrenia tend to have lower RSA compared to people without schizophrenia and that this effect cannot be accounted for by medication effects (Alvares et al., 2016; Clamor et al., 2016). Other evidence indicates that people with schizophrenia may have delayed parasympathetic recovery after a stressor compared to people without schizophrenia (Castro et al., 2008). Tonic RSA has been negatively related to symptom severity (see Montaquila et al., 2015 for review) and positively related to functional outcome (Hamilton et al., 2015). After the first psychotic episode, reductions in RSA during a social stressor compared to baseline has been related to better functional outcomes and mediates the relationship between social cognition and independent living (Reed et al., 2020). Lower RSA may leave people with schizophrenia vulnerable to “fight or flight” reactions in stressful contexts, potentially leading to higher chronic stress and worse outcome. To date, no study has investigated whether this lower RSA in schizophrenia occurs during social interactions. A goal of this study is to consider the how autonomic arousal broadly, and PNS arousal specifically, differ between people with and without schizophrenia during a stressful family interaction, and how autonomic arousal relates to relationship quality, affect, and symptoms.

Physiology of family members and physiological synchrony

Only one study to our knowledge examined the physiology of close family members during interactions with adolescents at high risk for schizophrenia. In this study both high EE parents and their children exhibited heightened skin conductance during conflict conversations (Valone et al., 1984). Yet other research has illustrated the importance of psychophysiological processes between family members for target outcomes. For example, Waters, West, and Mendes (2014) found that babies who were reunited with their mothers after their mothers experienced a laboratory stress induction showed physiological signs of stress coordinated with their mother's physiology and were more behaviorally avoidant during an interaction with the experimenter. This result was replicated in a follow-up study and extended to show that maternal exposure to a relaxation condition led to coordination in PNS arousal between mothers and babies (Waters et al., 2017). These findings demonstrate that the psychophysiological processes of one member of a dyad can affect the target member of the dyad through the "sharing" of physiological states with the target. This physiological synchrony – physiological interdependence between two or more individuals (Palumbo et al., 2017; Thorson et al., 2018) – predicts individual differences such as empathy and psychiatric diagnosis (e.g., Baker et al., 2015; Chatel-Goldman et al., 2014; Ferrer & Helm, 2013; Lunkenheimer et al., 2017; Woody et al., 2016;) and relationship variables such as relationship satisfaction, attachment style, responsiveness, and time spent together (e.g., Levenson & Gottman, 1983, Moore et al., 2009; Paap et al., 2009). Physiological synchrony occurs in a number of contexts but may be most salient between family members and during emotional and cooperative tasks (e.g., Sbarra & Hazan, 2008; Ghafar-Tabrizi et al., 2008; Valdesolo et al., 2010).

In social contexts, individuals may vary on the degree to which they are able to convey and perceive physiological cues. For instance, more expressive individuals paired with more sensitive or attentive individuals may have the capacity for higher synchrony. This principle may be particularly relevant for interactions in schizophrenia. The finding that people with schizophrenia exhibit elevated SNS arousal in response to critical or overinvolved family members suggests that they are responsive to the social environment (Altofer et al., 1998; Leff et al., 1982; Stugeon et al., 1981; Sturgeon et al., 1984; Tarrier et al., 1979; Tarrier et al., 1988). That family members are experiencing physiological arousal during these conversations (Valone et al., 1984) may be suggestive of physiological synchrony. Yet we cannot infer from these findings whether this arousal is sensitive to subtle fluctuations in their interactant's affect and physiology. Individuals with schizophrenia often have impaired facial affect perception (for review see Green et al., 2015) and may be less able to pick up on cues from their interaction partner that would influence their physiology. Further, people with schizophrenia may have the negative symptom of flat affect, or diminished affect expression, even in the presence of experienced affect and physiological arousal (Kring & Neale, 1996). It may be more difficult for people interacting with those with schizophrenia to detect changes in affect related physiology and, in turn, coordinate their own psychophysiological responses. Thus, there may be weaker physiological synchrony during interactions with people with schizophrenia compared to people without. Potentially, lower synchrony may be related to specific symptom profiles such as negative symptoms.

Evidence from healthy samples demonstrates that the meaning of physiological synchrony and whether or not it is related to adaptive outcomes is dependent on what the index of psychophysiological arousal being measured and the context in which it occurs (see Davis et al., 2018; Palumbo et al., 2017; Timmons et al., 2015 for reviews). Overall, research suggests

that physiological synchrony may be maladaptive in the context of stress. For example, classic work by Levenson and Gottman (1983) found that positive synchrony in a physiological composite in couples during a conflict conversation explained 60% of the variance in marital dissatisfaction. Here synchrony may be an indicator of negative affect contagion during conflict topics. Newer research findings have indicated that physiological synchrony occurs during the maladaptive "demand-withdrawal" pattern during romantic couples' conversations (Reed et al., 2013). Other work has demonstrated that "background" stress such as lower socio-economic status or being in a high conflict relationship enhances physiological synchrony during stressful lab interactions (Ghafar-Tabrizi, 2008; Suveg, Shaffer, & Davis, 2016).

In more positive contexts, however, high synchrony may be associated with more positive outcomes. For example, in a study of physiology in maltreating and non-maltreating mothers and their children while they watched a low-arousal cartoon together, maltreating mothers and their children had elevated baseline heart rate (HR), whereas only non-maltreating mothers demonstrated HR synchrony with their children (Creaven et al., 2014). Here, synchrony is potentially indicative of sensitivity to social and environmental cues in an adaptive way, while elevated baseline HR may be a sign of chronic autonomic hyperarousal, contributing to less sensitivity to changes in the environment.

PNS synchrony may be more generally adaptive. For example, stronger RSA synchrony in couples across neutral, positive, and conflict conversations was positively related to relationship quality (Helm et al., 2014; but see Smith et al., 2016). Stronger RSA synchrony between parents and children was related to lower risk for psychopathology play (Lunkenheimer et al., 2017) and less childhood PTSD (Gray et al., 2018) (but see Smith et al., 2016). Negative synchrony (that is RSA that is significantly but negatively correlated) may also be adaptive with negative synchrony between spouses while playing with their children was related to fewer marital conflicts – perhaps related to turn taking during the interaction (Gates et al., 2015). Together these findings indicate that the meaning of physiological synchrony is highly context dependent, but typically related to the level of engagement with the environment and the valence of the interaction.

Given the complex and context dependent findings of the correlates of physiological synchrony in past research, there are a few possibilities regarding how physiological synchrony during interactions with family may be relevant to outcomes in schizophrenia. In past studies, physiological synchrony during conflict has been associated with poor relationship outcomes, with the interpretation that the interactants "catch" the other's negative affect (e.g., Levenson & Gottman, 1983). Indications of higher autonomic arousal during conflict conversations and the findings of reciprocal negativity in high EE interactions may suggest a pattern of physiology and behavior like the dissatisfied married couples in Levenson and Gottman (1983). Given this, people with schizophrenia and their family members may also display high physiological arousal and synchrony during high arousal conflict, and this too may be related to poor relationship quality. If instead lower synchrony during conflict conversations reflects a miscommunication of social cues in schizophrenia, low physiological synchrony, even during conflict conversations, may be associated with negative relationship characteristics in schizophrenia.

Current study

The current study sought to examine group differences in physiological reactivity and physiological synchrony during an emotional interaction between dyads of parents and

adolescent/young adult children (hereafter: "young adults") who either did or did not have a schizophrenia diagnosis. We examined how relationship qualities related to EE such as criticism, warmth, intrusiveness, and caring were related to physiological reactivity and synchrony during the conversation, and whether group differences moderated these relationships. Finally, we examined how schizophrenia symptom severity predicted physiological reactivity and synchrony.

To address these aims, we recorded electrocardiogram (ECG) of family members and young adults as they participated in a conflict conversation. From the ECG recording we extracted inter-beat interval (IBI) a measure of the time between heart beats that represents the combined influence of the SNS and PNS on the heart, and RSA a more specific measure of PNS activation. We calculated both physiological reactivity-- physiological change during the conflict conversation compared to a baseline, and "physiological covariation," a measure of simultaneous (as opposed to time-lagged) physiological synchrony. Dyad members also reported on parental caring and overprotectiveness, how warm and critical the parent member of the dyad was, and their own emotional state. Additionally, participants with schizophrenia completed a clinical interview to assess symptom severity.

Question 1: Do people with and without schizophrenia differ in their physiological reactivity to interactions with parents?

In line with research finding elevated stress reactivity in schizophrenia, we expected that people with schizophrenia would have higher SNS and lower PNS activation evidenced by shorter IBI and lower RSA during conflict conversations compared to the control group.

Question 2: Do parent-young adult dyads in the schizophrenia and control dyads differ in their physiological covariation during emotional in-lab interactions?

Because of affect perception and expressive deficits in schizophrenia, we predicted that schizophrenia dyads would have weaker physiological covariation compared to control dyads.

Question 3: Are physiological reactivity and physiological covariation related to relationship qualities and emotions post-interaction? Does this differ by group?

In line with the idea that lower physiological covariation in the schizophrenia group might reflect disrupted psychophysiological communication between the young adult and parent, we hypothesized that weaker physiological covariation would be related to more intrusiveness and criticism, and lower warmth and parental caring within the schizophrenia group.

Question 4: Are physiological reactivity and physiological covariation during a conflict conversation related to symptom profile and symptom severity in schizophrenia dyads?

In line with past studies, we hypothesized that shorter IBI and lower RSA during the conflict conversation, would predict symptom severity in the schizophrenia group. By contrast, we expected that low physiological covariation, would be related to negative symptoms in schizophrenia.

Method

Participants. As part of a larger study investigating the effects of intranasal oxytocin on family interactions, 63 dyads composed of young adults (ages 14-45) and their parents

participated in the study. Due to equipment malfunction and experimenter error, physiology data for 13 dyads was either lost or unusable. There were two dyads in the control group that had the same caregiver participant, so the second of those dyads was dropped from the study. After exclusions, 29 dyads in the control group and 20 dyads in the schizophrenia group provided useable physiological data and were included in these analyses.

Parent inclusion criteria specified that the parent had to be between the ages of 18-75 years, have at least 4 hours of contact with the young adult per week, and had to be considered a "significant caregiver" by the young adult. Due to intranasal oxytocin administration in the larger study, parent participants had to have a lack of significant nasal pathology, and female parents could not be pregnant at the time of the study.

Participants with schizophrenia had to have a diagnosis of schizophrenia, schizophreniform disorder, schizoaffective disorder, or psychosis NOS; be clinically stable at the time of the study; have no changes in medication in the past week; and have no history of severe brain trauma. The young adult participant had a diagnosis of a schizophrenia spectrum disorder in 20 of the dyads. All young adults with schizophrenia were clinically stable, with no changes in medication in the past week. We obtained current medication data for 11 participants. See Table 1 for chlorpromazine equivalents. Control participants had no reported history of psychiatric or neurological illness.

Young adult participants in the schizophrenia and control group differed by gender (more women in the control group) and by age (participants with schizophrenia were older). See Table 1 for demographic information by group.

Procedure. Participants completed informed consent/assent at the start of the study. Participants came to the lab for an initial study session during which diagnosis was confirmed by research assistants trained by a trained, PhD-level psychologists using the Structured Clinical Interview for DSM-IV-TR (SCID, First et al., 2002). Young adults with schizophrenia were also administered the Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987) to assess current symptom severity including positive symptoms, negative symptoms, and general psychopathology symptoms. Participants then attended two visits, one week apart. During one visit, the parent was administered intranasal oxytocin and during the other he or she was administered a placebo. For the current study, only data from the placebo visit were analyzed.

Upon arrival, participants completed questionnaires assessing parental criticism, warmth, caring, and overprotection (see below for a description of self-report measures). Participants were outfitted with electrodes to measure electrocardiogram (ECG). Participants sat for a five-minute baseline and then the parent was administered a nasal spray. Participants then watched a 45-minute neutral film clip. After the film, participants engaged in three interactions. The first two of these, a neutral and a positive conversation, will not be included in these analyses. The final interaction was a 10-minute conversation with the aim of finding a resolution to a conflict in their relationship. Specifically, participants were asked to write down areas of conflict in their relationship at the beginning of the study session. Using primarily the young adult's responses, the research assistant identified a conflict topic and asked the participants directly before the conflict conversation task if the topic was indeed a source of conflict in their relationship. If the parent and young adult agreed, then they proceeded to discuss the topic. If they did not, then the research assistant helped them identify a source of conflict in their relationship to discuss. Participants were free to choose any conflict topic, including topics related to schizophrenia. Only two dyads included in these analyses discussed topics specifically related to schizophrenia. After the interactions, the participants completed measures to assess their current affect.

Participants then completed a cooperative task that will not be included in these analyses. Finally, participants repeated questionnaires measuring parental warmth and criticism. Participants were compensated for their time.

Measures. *The Parental Bonding Instrument* (PBI; Parker et al., 1979) is a retrospective questionnaire measuring parents' caregiving style during the first 16 years of the child's life as reported by their child. Participants were asked to rate 25-items on a four-point scale measuring how likely certain attitudes and behaviors were of their parents. The measure has two subscales: caring and overprotection/control. The caring subscale measures parental warmth, with items such as "[My parent] spoke to me in a warm and friendly voice." The overprotection/control subscale measures how restrictive the parent was, with items such as "[My parent] tried to control everything I did." The PBI has good internal consistency and test-retest reliability (twenty-year retest stability coefficients ranged from .74-.79) (Wilhelm et al., 2004). Young adult participants and their parents both completed this questionnaire about their respective parents; only the young adult reports are included in these analyses.

The Perceived Warmth Perceived Criticism Survey was administered at the beginning and end of the study session. Parental criticism was measured using the Perceived Criticism Scale (PC; Hooley & Teasdale, 1989), a single item to rate how critical the parent was toward the young adult from 1 (not at all critical) to 10 (very critical indeed). The PC scale has acceptable test retest reliability (r = .75) and has demonstrated acceptable convergent and discriminant validity (Riso et al., 1996). Schlosser et al. (2010) adapted the PC scale to measure perceived parental warmth, with a single item to rate how warm the parent was toward the young adult from 1 (not at all warm) to 10 (very warm indeed). These researchers found that perceived warmth measured by the adapted self-report was significantly correlated with interviewer ratings of parental warmth (r =.52). Both young adults and parents completed these questions before and after the conflict conversation.

The Self-Assessment Manikin (SAM; Bradley & Lang, 1994) is a pictorial assessment of current feelings of negative to positive affect and low to high arousal. For each item, participants viewed a continuum of pictures depicting a cartoon figure with expressions that varied from positively valanced to negatively valanced for affect and that varied from calm to excited for arousal. Participants selected their current emotional valence and arousal from a 9-point scale underlying the cartoon figures. All participants completed the SAM ratings immediately after the conflict conversation. The SAM ratings demonstrate excellent convergent validity with other measures of affective valence and arousal (r's range from .94-.97).

Physiological measurement. Electrocardiography (ECG) was collected throughout the two study sessions to measure ANS activity. Physiological arousal was indexed by inter-beat interval (IBI). IBI represents the time interval in milliseconds between one heartbeat and the next (Mendes, 2009). PNS arousal was estimated using RSA. RSA is high frequency heart rate variability in line with respiration rate, with higher RSA representing higher PNS arousal. ECG waveforms were visually inspected and artifacts were manually edited. MindWare software (Heart Rate Variability 2.6; Gahanna, OH) was used to calculate IBI and RSA. IBI and RSA were calculated in 20 second bins to maximize granularity in the physiological covariation analyses without sacrificing signal integrity.

Data analytic plan. For each inferential analysis we set our alpha level at p = .05 and examined trend-level non-significant effects if p < .1. We examined the assumptions of linear regression for all regression equations in the following ways: scatterplots of continuous predictor variables against outcome variables were constructed to examine the assumption of linearity;

multicollinearity was examined using the VIF and tolerance statistics; Durbin-Watson test was examined to test the assumption of independent errors; homoscedasticity was examined by plotting the standardized residuals against the predicted value of the standardized values predicted by the model; the distribution of errors examined using normal probability plots. We conducted a power analysis to determine the percent chance we had of detecting a small effect size ($\rho = .2$) given our sample size of N = 49. Power analysis indicated that we had a 29% chance of detecting a small effect size.

Preliminary analyses. Mean IBI and RSA during the baseline period were calculated. One participant was missing all baseline physiology, so baseline was calculated using physiology during the movie watching task. Descriptive statistics and intercorrelations of the self-report variables were examined to evaluate their psychometric viability.

Regression models assessed differences in self-report measures, and baseline IBI and RSA arousal between participants with and without schizophrenia. Body mass index (BMI), smoking, caffeine exposure on study day, and study session (lab visit 1 versus lab visit 2) were considered as possible covariates. Because of missing data, smoking and caffeine data were not included as a covariates. There was also substantial missing BMI data (schizophrenia dyad N=14; control dyad N = 26). Preliminary analyses reveal no correlation of BMI with baseline IBI or RSA, IBI or RSA reactivity or covariation and no group differences in BMI. To preserve power, BMI was not included as a covariate in these analyses. We did, however, include study visit (visit 1 versus visit 2 for the placebo visit) as a covariate in all analyses. In analyses examining physiological reactivity, we included baseline physiology as a covariate.

In our examination of the self-report variables, we found that parent ratings of warmth had restricted range, with baseline warmth ranging from 3-10 and post-conversation warmth ranging from 5-10 on a 1-10 scale. Neither parent nor young adult ratings of parental warmth were normally distributed. Due to these psychometric problems, warmth ratings were excluded from further analyses.

Parent and young adult ratings of parental criticalness at baseline and post-conversation were highly correlated (parent $r = .80$; young adult $r = .83$) and violated the assumption of no multicollinearity (VIFs > 1) in regression models. Thus, regression models included baseline parental criticism only as a predictor and post-conversation parental criticism was excluded from further analyses.

Question 1) Do people with and without schizophrenia or their parents differ in physiological reactivity during a conflict interaction?

The last segment of baseline physiology was subtracted from each subsequent segment of physiology (e.g., IBI conflict – IBI baseline) to form a reactivity score, such that positive scores reflect higher values during the conflict conversation and negative values represent lower values during the conversation. If the last segment of baseline physiology was missing for a participant, the last segment of interpretable baseline physiology was used to form the reactivity score. Mean IBI and RSA reactivity scores during the conflict conversations were calculated, and regression models examined whether diagnosis predicts mean IBI or RSA reactivity during conflict conversations, including study session as a covariate.

Question 2: Do dyads in the schizophrenia and control groups differ in their physiological covariation during the conflict conversation?

Physiological covariation was quantified by the zero-order correlation between the participants' and their parents' physiological reactivity during the conflict conversation. Thus, each dyad has correlation coefficients that represents the strength of the covariation between their IBI reactivity and RSA reactivity respectively, measured in 20 second bins during the 10-minute conversations (30 observations per participant). These correlation coefficients were used as the outcome variable in regression equations that included group as the predictor variable, controlling for study session.

Question 3: Are physiology and physiological covariation predicted by relationship qualities and emotions post-interaction? Does this differ by group?

We used regression models to examine how self-report variables predict mean physiological reactivity during the conflict conversation. For each outcome (parent or young adult IBI or RSA reactivity), three regression models were constructed with the following predictor variables respectively: 1) parent caring and overprotection measured by the PBI, 2) parent criticism at baseline measured by parent and child reports, and 3) participant affective valence and arousal. Each model included placebo day and baseline physiology as covariates. As an exploratory analysis, the interaction of self-report and group (schizophrenia versus control) was included in each regression equation using forward entry. Six models including the predictors above (save baseline physiology) were constructed with IBI and RSA covariation as the outcome variables.

Question 4: Are physiology and physiological covariation during emotional conversations predicted by symptom profile and symptom severity in schizophrenia dyads?

Regression equations using data from schizophrenia participants only were computed to examine whether symptom severity measured by the PANSS predicts IBI and RSA reactivity and covariation during the conflict conversation.

Results

See Table 1 for demographic information, descriptive statistics of self-report measures, and symptom ratings. There were significantly more men, χ^2 (1) = 6.06, p =.01, and older participants, t (47) = -2.47, p = .02, in the schizophrenia group compared to the control group. There were no significant race/ethnicity differences between the groups χ^2 (4) = 5.52, p =.24. Physiology at baseline, reactivity, and covariation was not significantly related to young adult gender or age (all p's >.05). Parent participants did not significantly differ in age, gender or race/ethnicity by group (all p's >.05).

Group Differences: Self-Report Data.

Young adult self-report. Regression models were conducted to examine group differences on self-report measures controlling for study day and results are shown in Table 2. At baseline, people in the schizophrenia group rated their parents as less caring at a nonsignificant trend-level (p = .06) People with schizophrenia reported feeling significantly more negative affect after conversations compared to the control group.

Parent self-report. Parents of young adults with schizophrenia reported significantly less arousal after conversations compared to parents of people without schizophrenia Study day did

not significantly predict young adult or parent self-reports. See Table 2 for group standardized betas predicting young adult and parent self-report.

Group Differences: Baseline IBI and RSA.

Regression models demonstrated no significant differences between young adults with and without schizophrenia on baseline IBI, model R^2 =.006, group β < .001, p = .99. Contrary to past research, RSA at baseline did not differ between young adults with and without schizophrenia, model R^2 =.04, group β = -.18, p = .22. Parents of people with and without schizophrenia also did not differ on baseline IBI, model R^2 =.09, group β = .10, p = .48, or baseline RSA, model R^2 =.02, group β = -.03, p = .85.

Question 1: Group Differences in IBI and RSA reactivity

There was one young adult outlier with high RSA reactivity in the schizophrenia group (3.47 standard deviations above the mean) who was excluded from the RSA reactivity analyses. Regression models controlling for baseline physiology showed no significant difference between groups in IBI reactivity during the conflict conversation for either young adults, β = -.15, p = .21, or their parents, β = .02, p = .90. Consistent with expectation, young adults with schizophrenia had significantly lower RSA reactivity during the conflict conversation compared to young adults without schizophrenia, β = -.18, p = .04. Parents of young adults with and without schizophrenia did not differ on RSA reactivity during the conflict conversation, β = -.12, p = .32.

Question 2: Group Differences in Physiological covariation

Contrary to our hypothesis, we found no group differences in physiological covariation for either IBI, model R^2=.04, β = .20, p = .20; or RSA, model R^2= .04, β = -.09, p = .55.

Question 3: Relationship and emotion variables predicting physiological reactivity and synchrony.

See Table 3, Table 4, and Table 5 for model R^2 and standardized beta coefficients for models predicting physiological reactivity and covariation from parental caregiving style, parental criticalness, and affect, and their interaction with group.

Physiological Reactivity. Regression models examining mean physiological reactivity in the young adult participants from group, self-report of parenting caring, overprotection, and criticalness, and current affect, and their interaction controlling for baseline physiology and study day indicated that RSA reactivity was predicted by more positive affect rated on the SAM scale. Self-report measures and their interactions with group did not predict IBI among the young adults. Thus, contrary to expectations, only positive affect predicted RSA reactivity (and not IBI reactivity), and this was true for young adults with and without schizophrenia.

Neither IBI nor RSA reactivity in the parent participants was predicted by self-reported relationship quality or affect, or their interaction with group.

Physiological Covariation. Models predicting IBI covariation from group, self-report, and their interaction found that lower young adult ratings of how caring their parent had been for the first 16 years of their life was related to lower IBI covariation. That is, higher caring ratings predicted lower IBI covariation. Similarly, models predicting RSA covariation from group, self-report, and their interaction found that lower parental caring negatively predicted RSA covariation during the conflict conversation. A significant interaction with group revealed that

this relationship was driven by the control group (See Table 5 and Figure 1). All other models predicting IBI and RSA covariation from self-report did not reach statistical significance.

In sum, more positive affect in young adults predicted higher RSA during the conflict conversation; no self-report measure we collected predicted IBI reactivity. Young adult ratings of higher parental caring in the first 16 years of the young adult's life predicted lower IBI and RSA covariation, with the effect on RSA covariation driven by the control group.

Question 4: Symptoms predicting physiological reactivity and synchrony.

Physiological reactivity. Due to missing symptom data, only 16 participants were included in regression models examining physiological reactivity predicted by positive symptoms, negative symptoms and general psychopathology symptoms controlling for study day and baseline physiology. Negative symptoms predicted higher IBI reactivity during the conflict conversation at a nonsignificant trend level, $\beta = .47$, $p = .07$. RSA reactivity was predicted at a nonsignificant trend level by general symptoms of psychopathology $\beta = -.36$, $p = .06$, with higher symptoms related to lower RSA during the conflict conversation. Parent physiological reactivity was not related to their young adult child's symptoms.

Physiological covariation. Due to missing symptom and physiology data, regression models predicting IBI and RSA covariation from schizophrenia symptoms included only 15 participants' data. Positive, negative, and general psychopathology did not predict IBI covariation, model $R^2 = .21$, $p = .64$. RSA covariation was significantly predicted by symptoms, model $R^2 = .62$, $p = .03$. As shown in Figure 3, negative symptoms emerged as the only significant predictor, with higher negative symptoms predicting lower RSA covariation, $\beta = -.49$, $p = .05$.

Discussion

The current study examined how schizophrenia diagnosis and symptoms, as well as relationship qualities and affect, predict physiological reactivity and covariation measured during a conflict conversation between young adults and their parents. Our novel psychophysiological findings point to the importance of the PNS in the family context in schizophrenia. Specifically, we found that young adults with schizophrenia reported having higher negative affect after a conflict conversation with their parent, had lower average RSA reactivity during the conflict conversation relative to young adults without schizophrenia, and lower RSA was associated with general psychiatric symptom severity (e.g., depression and anxiety) measured by the PANSS at a nonsignificant, trend-level within those with schizophrenia. Further, we found preliminary evidence that young adults with negative symptoms had significantly lower RSA covariation with their parents. In addition to the group differences in young adult reports of affective valence, we also found that parents of people with schizophrenia reported significantly lower arousal following the conflict conversation. Parent reports of arousal were not related to any physiological outcome measure, and it is unclear what might account for this difference in self-report. Analysis of conversation content differences between dyad groups might provide some insight into this difference in affect.

We found no differences in baseline parasympathetic activation or overall physiological activation measured by IBI between people with and without schizophrenia. While many studies find baseline differences between people with and without schizophrenia in both heart rate and vagal tone (Alveres et al., 2016; Clamor et al., 2016; Hazlett et al., 1997), there is evidence that younger people with schizophrenia do not differ from those without schizophrenia on

parasympathetic activation (Reed et al., 2020). Further research is needed to characterize physiological differences between recently diagnosed, younger people with schizophrenia compared to those with chronic schizophrenia.

Our finding that lower parasympathetic activation during the conflict conversation in young adults with schizophrenia compared to those without schizophrenia partially supports our hypothesis that people with schizophrenia would show physiological signs of higher stress reactivity during conflict. Given the role of PNS in social engagement (e.g., Beffara et al., 2016; Geisler et al., 2013; Porges et al., 2007; Quintana et al., 2016) lower parasympathetic activation in schizophrenia may indicate more negative interactions and potentially less adaptive engagement with their parents. Past research has found that in parent-teen conflict conversations, more negative conversations were related to lower vagal activation during those conversations (Cui et al., 2015). We replicated that finding in our dataset – lower RSA was related to less positive/more negative affect across all young adult participants.

Taken together with our finding that people with schizophrenia reported more negative affect after the conflict conversation, affect might also account for the group difference in RSA reactivity. That is, people with schizophrenia may be experiencing lower positive affect/higher negative affect during conversations with their parents, which contributes to lower parasympathetic activation during those conversations. Although speculative, it is possible that repeated negative interactions with parents over time may be associated with lower parasympathetic activation chronically, in turn leaving people with schizophrenia vulnerable to chronic physiological and psychological stress. The non-significant trend-level finding that people with higher general psychiatric symptoms may have lower RSA reactivity during conflict should be further explored with a larger sample. Our findings underscore the potential role of the PNS may play in linking negative family environments to poor outcome in schizophrenia.

Contrary to our hypothesis predicting higher physiological stress reactivity during conflict in the schizophrenia group, IBI reactivity did not differ by group. Yet within the schizophrenia group, symptoms may account for some variability in IBI reactivity. In contrast our hypothesis that symptom severity would be related to higher physiological stress reactivity, people with schizophrenia with higher negative symptoms had *longer* IBI during the conflict conversation, albeit at a non-significant trend level. Longer IBI indicates lower SNS activation and/or higher PNS activation, potentially signaling lower engagement with the conflict conversation (e.g., McLaughlin et al., 2014). One possibility is that defeatist cognitions associated with negative symptoms (Campellone et al., 2016) may contribute to lower task engagement (e.g., Granholm et al., 2009). For example, those with negative symptoms may have had previous failure experiences with interactions with their parents and may develop generalized negative beliefs about their ability to engage successfully in such conversations, leading to lower task engagement. Yet because the result failed to meet statistical significance, we interpret this effect with caution: it should be replicated with a larger sample, and future work should examine cognitions about family relationships in those with negative symptoms to shed light on lower IBI reactivity.

We found no support for hypothesized group differences in physiological synchrony. We did, however, find that symptoms and individual differences predicted synchrony. Our findings support our prediction that negative symptoms of schizophrenia would be associated with lower PNS synchrony. Negative symptoms may disrupt dyadic processes as indexed by the PNS. Lower parasympathetic covariation between young adults with negative symptoms and their parents may be due to a missed communication of affective signals (see Thorson, West, &

Mendes, 2018). It is important to note that we did not assess this, so this interpretation is only conjecture. One possibility is that conversation partners of those with negative symptoms may not have adequate expressive cues to coordinate their physiological responses. Indeed, past research has shown that many people with schizophrenia have diminished outward expressions (Kring & Elis, 2013), and this may interfere with dyadic interactions.

RSA synchrony has been related to higher relationship quality and positive affect in non-clinical samples (e.g., Helm, Sbarra, & Ferrer, 2014) and may be protective against psychopathology (Gray et al., 2018). Over time, individuals with high negative symptoms may have repeated interactions characterized by missed affective signals, potentially leading to feelings of disconnect and loneliness (Human & Biesanz, 2013) and perhaps leaving people vulnerable to worse outcomes. Though intriguing, these ideas should be tested with a larger sample and extended to investigate PNS synchrony in people with negative symptoms in a variety of social interactions and environments.

Young adult reports of lower parental caring during their first 16 years of life correlated with higher IBI synchrony during the conflict conversation. In line with classic findings in married couples (e.g., Levenson & Gottman, 1983), heightened IBI synchrony during conflict may indicate higher negative affect contagion in the context of lower parental caring. It is possible that parents lower in caring fail to deescalate negative affect during contentious exchanges with their children. This may be particularly pernicious for children with psychiatric vulnerability. We found a non-significant tendency for young adults with schizophrenia (compared to those without schizophrenia) to report that their parent was less caring. Repeated exposure to exchanges with parents lower in caring may lead to contagion of autonomic stress responses, increasing the likelihood of worsening symptoms and functioning (Tarrier & Turpin, 1992). Treatments targeting parenting improves outcomes in schizophrenia (Girón et al., 2014, Kane et al., 2016), and our finding suggests that IBI synchrony during conflict may be a target of such treatments.

In contrast to our hypothesis and to past research relating RSA synchrony during conflict to positive relationship outcomes (Helm, Sbarra, & Ferrer, 2014), lower parental caring was also related to higher RSA synchrony during the conflict conversation, but only for young adults without schizophrenia. This finding is more in line with a result showing that preschool aged children and their mothers had higher RSA synchrony during a separation and reunion in the lab if they had an insecure attachment style (Smith et al., 2016). These researchers proposed that heightened RSA synchrony might indicate "overly attuned" parent and child, in a way that might predict maladaptive outcomes. Of course, findings for preschool children may not carry over to findings with young adults. It would be interesting to assess attachment style in young adults to more clearly test this idea. It is also unclear why this finding did not generalize to the schizophrenia group. It is possible that within-group variability in RSA synchrony due to schizophrenia symptoms may mask this effect. Larger samples could be sufficiently powered to examine the interaction of symptoms and parental caring on RSA synchrony.

The findings from this study should be interpreted in the context of several important limitations including a small sample size and missing data. Our power analysis indicated that we had insufficient power to detect small effects. Meta-analyses indicate that while the effect size of physiological differences between people with and without schizophrenia may typically be large in older samples, these effects are more subtle in younger people (e.g., Clamour et al., 2016). A larger sample would not only allow us to detect real but smaller between-group effects but would also allow for more complex statistical modeling including stability and influence models

(Kenny et al., 2006), the optimal approach to characterizing interdependence in dyadic data. Other limitations included age and gender imbalance between young adults in the schizophrenia and control group. Although gender was not related to any physiological indices in our sample, there may be important gender differences in the clinical presentation of schizophrenia (e.g., Leung & Chue, 2000), and future research should focus on recruiting a gender balanced study with enough power to model gender effects.

We did not analyze data from the neutral and positive conversations, as we were underpowered to include multiple additional variables and interaction terms into the regression models. Physiological synchrony in the PNS occurs in response to positive mood inductions (Waters et al., 2017), but even putatively positive contexts may elicit more complex emotional responses from those with schizophrenia (e.g., Mote & Kring, 2019; Sanchez et al., 2014). Future work should examine how physiological and physiological reactivity in positive contexts predict emotion, relationship quality, and outcome in schizophrenia.

This study also has notable strengths. To our knowledge, this is the first study to examine parasympathetic reactivity and physiological synchrony in the context of close relationships in schizophrenia. Further, taking physiological and self-report measurements from both young adults and their parents allowed us to examine dyadic processes. Further, recruiting young adults with their parents for live conversations about conflicts relevant to their relationship enhanced the ecological validity of our findings.

Theory has positioned physiological stress as a potential link between the quality of family relationships and poor outcome in schizophrenia. While preliminary, this study provides novel support for the importance of ANS – particularly PNS – reactivity and synchrony in family relationships in people with schizophrenia and may be especially relevant for those with negative symptoms. Future research should build on this work by replicating these findings and extending them through examining potential mechanisms such as reduced expressivity, defeatist beliefs, and social cognitive deficits in those with schizophrenia. In addition, ecological momentary assessments examining ANS reactivity and synchrony in daily life and through longitudinal treatment studies targeting the family would further shed light on the relationship between family environment, physiology, and outcome in schizophrenia.

References

Altorfer, A., Käsermann, M. L., & Hirsbrunner, H. (1998). Arousal and communication: l. The relationship between nonverbal, behavioral, and physiological indices of the. *Journal of Psychophysiology*, *12*, 40-59.

Alvares, G. A., Quintana, D. S., Hickie, I. B., & Guastella, A. J. (2016). Autonomic nervous system dysfunction in psychiatric disorders and the impact of psychotropic medications: a systematic review and meta-analysis. *Journal of Psychiatry & Neuroscience*. 89–104. https://doi.org/10.1503/jpn.140217

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of other in the self scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology*, *63*(4), 596-612. https://doi.org/10.1037/0022-3514.63.4.596

Baker, J. K., Fenning, R. M., Howland, M. A., Baucom, B. R., Moffitt, J., & Erath, S. A. (2015). Brief report: A pilot study of parent–child biobehavioral synchrony in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *45*(12), 4140-4146. https://doi.org/10.1007/s10803-015-2528-0

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: the self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49-59.

Brown, G. W., Birley, J. L., & Wing, J. K. (1972). Influence of family life on the course schizophrenic disorders: A replication. *The British Journal of Psychiatry*, *121*(562), 241-258. https://doi.org/10.1192/bjp.121.3.241

Beffara, B., Bret, A. G., Vermeulen, N., & Mermillod, M. (2016). Resting high frequency heart rate variability selectively predicts cooperative behavior. *Physiology & Behavior*, *164*, 417-428. https://doi.org/10.1016/j.physbeh.2016.06.011

Butzlaff, R. L., & Hooley, J. M. (1998). Expressed emotion and psychiatric relapse: a meta-analysis. *Archives of General Psychiatry*, *55*(6), 547-552. https://doi.org/10.1001/archpsyc.55.6.547

Campellone, T. R., Sanchez, A. H., & Kring, A. M. (2016). Defeatist performance beliefs, negative symptoms, and functional outcome in schizophrenia: A meta-analytic review. *Schizophrenia Bulletin*, *42*(6), 1343-1352. https://doi.org/10.1093/schbul/sbw026

Castro, M. N., Vigo, D. E., Weidema, H., Fahrer, R. D., Chu, E. M., De Achaval, D., Nogues, M., Leiguarda, R. C., Cardinali, D. P., & Guinjoan, S. M. (2008). Heart rate variability response to mental arithmetic stress in patients with schizophrenia: autonomic response to stress in schizophrenia. *Schizophrenia Research*, *99*(1-3), 294-303. https://doi.org/10.1016/j.schres.2007.08.025

Cechnicki, A., Bielańska, A., Hanuszkiewicz, I., & Daren, A. (2013). The predictive validity of expressed emotions (EE) in schizophrenia. A 20-year prospective study. *Journal of Psychiatric Research*, *47*(2), 208-214. https://doi.org/10.1016/j.jpsychires.2012.10.004

Chatel-Goldman, J., Congedo, M., Jutten, C., & Schwartz, J. L. (2014). Touch increases autonomic coupling between romantic partners. *Frontiers in Behavioral Neuroscience*, *8*. https://doi.org/10.3389/fnbeh.2014.00095

Clamor, A., Hartmann, M. M., Köther, U., Otte, C., Moritz, S., & Lincoln, T. M. (2014). Altered autonomic arousal in psychosis: an analysis of vulnerability and specificity. *Schizophrenia Research*, *154*(1-3), 73-78. https://doi.org/10.1016/j.schres.2014.02.006

Clamor, A., Lincoln, T. M., Thayer, J. F., & Koenig, J. (2016). Resting vagal activity in schizophrenia: meta-analysis of heart rate variability as a potential endophenotype. *The British Journal of Psychiatry*, *208*(1), 9-16. https://doi.org/10.1192/bjp.bp.114.160762

Creaven, A. M., Skowron, E. A., Hughes, B. M., Howard, S., & Loken, E. (2014). Dyadic concordance in mother and preschooler resting cardiovascular function varies by risk status. *Developmental Psychobiology*, *56*(1), 142-152. https://doi.org/10.1002/dev.21098

Cui, L., Morris, A. S., Harrist, A. W., Larzelere, R. E., & Criss, M. M. (2015). Dynamic changes in parent affect and adolescent cardiac vagal regulation: A real-time analysis. *Journal of Family Psychology*, *29*(2), 180-190. https://doi.org/ 10.1037/fam0000067

Davis, M., West, K., Bilms, J., Morelen, D., & Suveg, C. (2018). A systematic review of parent–child synchrony: It is more than skin deep. *Developmental Psychobiology*. *60*(6), 674 – 691. https://doi.org/10.1002/dev.21743

Doane, J. A., West, K. L., Goldstein, M. J., Rodnick, E. H., & Jones, J. E. (1981). Parental communication deviance and affective style: Predictors of subsequent schizophrenia spectrum disorders in vulnerable adolescents. *Archives of General Psychiatry*, *38*(6), 679-685. https://doi.org/10.1001/archpsyc.1981.01780310079008

Ferrer, E., & Helm, J. L. (2013). Dynamical systems modeling of physiological coregulation in dyadic interactions. *International Journal of Psychophysiology*, *88*(3), 296-308. https://doi.org/10.1016/j.ijpsycho.2012.10.013

First, M. B., Spitzer, R. L., Gibbon, M., & Williams, J. B. (2002). *Structured clinical interview for DSM-IV-TR axis I disorders, research version, patient edition*. SCID-I/P.

Gates, K. M., Gatzke-Kopp, L. M., Sandsten, M., & Blandon, A. Y. (2015). Estimating time-varying RSA to examine psychophysiological linkage of marital dyads. *Psychophysiology*, *52*(8), 1059-1065. https://doi.org/10.1111/psyp.12428

Geisler, F., Kubiak, T., Siewert, K., & Weber, H. (2013). Cardiac vagal tone is associated with social engagement and self-regulation. *Biological Psychology*. *93*(2), 279-286. https://doi.org/10.1016/j.biopsycho.2013.02.013

Ghafar-Tabrizi, R. (2008). Reversal theory and physiological linkage in the low-conflict and high-conflict mother-daughter dyadic interactions. *Contemporary Psychology*, *3*, 62-75.

Girón, M., Nova-Fernández, F., Mañá-Alvarenga, S., Nolasco, A., Molina-Habas, A., Fernández-Yañez, A., ... & Gómez-Beneyto, M. (2015). How does family intervention improve the outcome of people with schizophrenia?. *Social Psychiatry and Psychiatric Epidemiology*, *50*(3), 379-387. https://doi.org/10.1007/s00127-014-0942-9

Granholm, E., Ruiz, I., Gallegos-Rodriguez, Y., Holden, J., & Link, P. C. (2016). Pupillary responses as a biomarker of diminished effort associated with defeatist attitudes and negative symptoms in schizophrenia. *Biological Psychiatry*, *80*(8), 581-588. https://doi.org/10.1016/j.biopsych.2015.08.037

Gray, S. A., Lipschutz, R. S., & Scheeringa, M. S. (2018). Young children's physiological reactivity during memory recall: associations with posttraumatic stress and parent physiological synchrony. *Journal of Abnormal Child Psychology*, *46*(4), 871-880. https://doi.org/10.1007/s10802-017-0326-1

Green, M. F., Horan, W. P., & Lee, J. (2015). Social cognition in schizophrenia. *Nature Reviews Neuroscience*, *16*(10), 620-631. https://doi.org/10.1038/nrn4005

Halford, W. K., Steindl, S., Varghese, F. N., & Schweitzer, R. D. (1999). Observed family interaction and outcome in patients with first-admission psychoses. *Behavior Therapy*, *30*(4), 555-580. https://doi.org/10.1016/S0005-7894(99)80025-2

Hahlweg, K., Goldstein, M. J., Nuechterlein, K. H., Magaña, A. B., Mintz, J., Doane, J. A., Miklowitz, D., & Snyder, K. S. (1989). Expressed emotion and patient-relative interaction in families of recent onset schizophrenics. *Journal of Consulting and Clinical Psychology*, *57*(1), 11-18. https://doi.org/10.1037/0022-006X.57.1.11

Hamilton, H. K., Sun, J. C., Green, M. F., Kee, K. S., Lee, J., Sergi, M., Shotly, G., Mathis, K., I., Jetton, C., Williams, T. J., Kern, R., Horan, W., Fiske, A., Subotnik, K. L., Ventura, J., Hellemann, G., Nuechterlein, K. H., & Yee, C. M. (2014). Social cognition and functional outcome in schizophrenia: The moderating role of cardiac vagal tone. *Journal of Abnormal Psychology*, *123*(4), 764-770. https://doi.org/ 10.1037/a0037813

Hazlett, H., Dawson, M. E., Schell, A. M., & Nuechterlein, K. H. (1997). Activity as a Prodromal Sign in Schizophrenia. *Biological Psychiatry*, *41*, 111-113.

Helm, J. L., Sbarra, D. A., & Ferrer, E. (2014). Coregulation of respiratory sinus arrhythmia in adult romantic partners. *Emotion*, *14*(3), 522-531. https://doi.org/10.1037/a0035960

Hooley, J. M. (2007). Expressed emotion and relapse of psychopathology. *Annual Review of Clinical Psychology*, *3*, 329-352. https://doi.org/10.1146/annurev.clinpsy.2.022305.095236

Hooley, J. M., & Gotlib, I. H. (2000). A diathesis-stress conceptualization of expressed emotion and clinical outcome. *Applied and Preventive Psychology*, *9*(3), 135-151. https://doi.org/10.1016/S0962-1849(05)80001-0

Hooley, J. M., & Teasdale, J. D. (1989). Predictors of relapse in unipolar depressives: Expressed emotion, marital distress, and perceived criticism. *Journal of Abnormal Psychology*, *98*(3), 229-235.

Human, L. J. & Biesanz, J. C. (2013). Targeting the good target: An integrative review of the characteristics of being accurately perceived. *Personality and Social Psychology Review*, *17*(3), 248-272. https://doi.org/10.1177/1088868313495593.

Kane, J. M., Robinson, D. G., Schooler, N. R., Mueser, K. T., Penn, D. L., Rosenheck, R. A., ... & Marcy, P. (2016). Comprehensive versus usual community care for first-episode psychosis: 2-year outcomes from the NIMH RAISE early treatment program. *American Journal of Psychiatry*, *173*(4), 362-372. https://doi.org/10.1176/appi.ajp.2015.15050632

Kay, S. R., Fiszbein, A., & Opler, L. A. (1987). The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophrenia Bulletin*, *13*(2), 261-276. https://doi.org/10.1093/schbul/13.2.261

Kring, A. M., & Elis, O. (2013). Emotion deficits in people with schizophrenia. *Annual Review of Clinical Psychology*, *9*, 409-433. https://doi.org/10.1146/annurev-clinpsy-050212-185538

Kring, A. M., & Neale, J. M. (1996). Do schizophrenic patients show a disjunctive relationship among expressive, experiential, and psychophysiological components of emotion?. *Journal of Abnormal Psychology*, *105*(2), 249-257.

Lange, C., Deutschenbaur, L., Borgwardt, S., Lang, U. E., Walter, M., & Huber, C. G. (2017). Experimentally induced psychosocial stress in schizophrenia spectrum disorders: A systematic review. *Schizophrenia Research*, *182*, 4-12. https://doi.org/10.1016/j.schres.2016.10.008

Leff, J., Kuipers, L., Berkowitz, R., Eberlein-Vries, R., & Sturgeon, D. (1982). A controlled trial of social intervention in the families of schizophrenic patients. *The British Journal of Psychiatry*, *141*(2), 121-134. https://doi.org/10.1192/bjp.141.2.121

Leung, A., & Chue P. (2000). Sex differences in schizophrenia, a review of the literature. *Acta Psychiatrica Scandinavica*, *101*(401), 3-38. https://doi.org/10.1111/j.0065-1591.2000.0a https://doi.org/10.1111/j.0065-1591.2000.0ap25.xp25.x

Levenson, R. W., & Gottman, J. M. (1983). Marital interaction: physiological linkage and affective exchange. *Journal of Personality and Social Psychology*, *45*(3), 587-597. https://doi.org/10.1037/0022-3514.45.3.587

Lunkenheimer, E., Tiberio, S. S., Skoranski, A. M., Buss, K. A., & Cole, P. M. (2018). Parent-child coregulation of parasympathetic processes varies by social context and risk for psychopathology. *Psychophysiology*, *55*(2), e12985. https://doi.org/10.1111/psyp.12985

McLaughlin, K. A., Sheridan, M. A., Alves, S., & Mendes, W. B. (2014). Child maltreatment and autonomic nervous system reactivity: Identifying dysregulated stress reactivity patterns using the biopsychosocial model of challenge and threat. *Psychosomatic Medicine*, *76*(7), 538-546. https://doi.org/10.1097/PSY.0000000000000098.

Mendes, W. B. (2009). Assessing the autonomic nervous system. In E. Harmon-Jones & J. S. Beer (Eds.) *Methods in Social Neuroscience* (pp. 118-147). Guilford Press.

Montaquila, J. M., Trachik, B. J., & Bedwell, J. S. (2015). Heart rate variability and vagal tone in schizophrenia: A review. *Journal of Psychiatric Research*, *69*, 57-66. https://doi.org/10.1016/j.jpsychires.2015.07.025

Moore, G. A., Hill-Soderlund, A. L., Propper, C. B., Calkins, S. D., Mills-Koonce, W. R., & Cox, M. J. (2009). Mother–infant vagal regulation in the face-to-face still-face paradigm is moderated by maternal sensitivity. *Child Development*, *80*(1), 209-223. https://doi.org/10.1111/j.1467-8624.2008.01255.x

Mote, J., & Kring, A. M. (2019). Toward an understanding of incongruent affect in people with schizophrenia. *The Journal of Nervous and Mental Disease*, *207*(5), 393-399. https://doi.org/ doi: 10.1097/NMD.0000000000000983

Myin-Germeys, I., & van Os, J. (2007). Stress-reactivity in psychosis: Evidence for an affective pathway to psychosis. *Clinical Psychology Review*, *27*(4), 409-424. https://doi.org/10.1016/j.cpr.2006.09.005

O'Brien, M. P., Gordon, J. L., Bearden, C. E., Lopez, S. R., Kopelowicz, A., & Cannon, T. D. (2006). Positive family environment predicts improvement in symptoms and social functioning among adolescents at imminent risk for onset of psychosis. *Schizophrenia Research*, *81*(2-3), 269-275. https://doi.org/10.1016/j.schres.2005.10.005

Ohman, A. (1981). Electrodermal activity and vulnerability to schizophrenia: a review. *Biological Psychology*, *12*(2-3), 87-145. https://doi.org/10.1016/0301-0511(81)90008-9

Papp, L. M., Pendry, P., & Adam, E. K. (2009). Mother-adolescent physiological synchrony in naturalistic settings: Within-family cortisol associations and moderators. *Journal of Family Psychology*, *23*(6), 882-894. https://doi.org/10.1037/a0017147

Parker, G. (1983) Parental Overprotection: A Risk Factor in Psychosocial Development, Grune & Stratton.

Parker, G., Tupling, H., & Brown, L. B. (1979). A parental bonding instrument. *British Journal of Medical Psychology, 52*, 1-10. https://doi.org/10.1111/j.2044-8341.1979.tb02487.x

Palumbo, R. V., Marraccini, M. E., Weyandt, L. L., Wilder-Smith, O., McGee, H. A., Liu, S., & Goodwin, M. S. (2017). Interpersonal autonomic physiology: A systematic review of the literature. *Personality and Social Psychology Review*, *21*(2), 99-141. https://doi.org/10.1177/1088868316628405

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology*, *74*(2), 116-143. https://doi.org/10.1016/j.biopsycho.2006.06.009

Reed, A. C., Lee, J., Green, M. F., Hamilton, H. K., Miller, G. A., Subotnik, K. L., Ventura, J., Nuechterlein, K. H. & Yee, C. M. (2020). Associations between physiological responses to social-evaluative stress and daily functioning in first-episode schizophrenia. *Schizophrenia Research.* https://doi.org/10.1016/j.schres.2019.12.040

Reed, R. G., Randall, A. K., Post, J. H., & Butler, E. A. (2013). Partner influence and in-phase versus anti-phase physiological linkage in romantic couples. *International Journal of Psychophysiology*, *88*(3), 309-316. https://doi.org/10.1016/j.ijpsycho.2012.08.009

Robin, A.L. & Foster, S.L. (1989) Negotiating parent–adolescent conflict: A behavioral-family systems approach. Guilford Press.

Sanchez, A. H., Lavaysse, L. M., Starr, J. N., & Gard, D. E. (2014). Daily life evidence of environment-incongruent emotion in schizophrenia. *Psychiatry Research*, *220*(1-2), 89-95. https://doi.org/10.1016/j.psychres.2014.07.041

Sbarra, D. A., & Hazan, C. (2008). Coregulation, dysregulation, self-regulation: An integrative analysis and empirical agenda for understanding adult attachment, separation, loss, and recovery. *Personality and Social Psychology Review*, *12*(2), 141-167. https://doi.org/10.1177/1088868308315702

Smith, J. D., Woodhouse, S. S., Clark, C. A., & Skowron, E. A. (2016). Attachment status and mother–preschooler parasympathetic response to the strange situation procedure. *Biological Psychology*, *114*, 39-48. https://doi.org/10.1016/j.biopsycho.2015.12.008

Sturgeon, D., Kuipers, L., Berkowitz, R., Turpin, G., & Leff, J. (1981). Psychophysiological responses of schizophrenic patients to high and low expressed emotion relatives. *The British Journal of Psychiatry*, *138*(1), 40-45. https://doi.org/10.1192/bjp.138.1.40

Sturgeon, D., Turpin, G., Kuipers, L., Berkowitz, R., & Leff, J. (1984). Psychophysiological responses of schizophrenic patients to high and low expressed emotion relatives: A follow-up study. *The British Journal of Psychiatry*, *145*(1), 62-69. https://doi.org/10.1192/bjp.145.1.62

Suveg, C., Shaffer, A., & Davis, M. (2016). Family stress moderates relations between physiological and behavioral synchrony and child self-regulation in mother–preschooler dyads. *Developmental Psychobiology*, *58*(1), 83-97. https://doi.org/10.1002/dev.21358

Tarrier, N., Barrowclough, C., Porceddu, K., & Watts, S. (1988). The assessment of psychophysiological reactivity to the expressed emotion of the relatives of schizophrenic patients. *The British Journal of Psychiatry*, *152*(5), 618-624. https://doi.org/10.1192/bjp.152.5.618

Tarrier, N., & Turpin, G. (1992). Psychosocial factors, arousal and schizophrenic relapse: The psychophysiological data. *The British Journal of Psychiatry*, *161*(1), 3-11. DOI: https://doi.org/10.1192/bjp.161.1.3

Tarrier, N., Vaughn, C., Lader, M. H., & Leff, J. P. (1979). Bodily reactions to people and events in schizophrenics. *Archives of General Psychiatry*, *36*(3), 311-315. https://doi.org/10.1001/archpsyc.1979.01780030077007

Thompson, E., Rakhshan, P., Pitts, S. C., Demro, C., Millman, Z. B., Bussell, K., DeVylder, J, Kline, E., Reeves, G., & Schiffman, J. (2019). Family functioning moderates the impact of psychosis-risk symptoms on social and role functioning. *Schizophrenia Research*, *204*, 337-342. https://doi.org/10.1016/j.schres.2018.08.035

Thorson, K. R., West, T. V., & Mendes, W. B. (2018). Measuring physiological influence in dyads: A guide to designing, implementing, and analyzing dyadic physiological studies. *Psychological Methods. 23*(4), 595-616. https://doi.org/10.1037/met0000166

Timmons, A. C., Margolin, G., & Saxbe, D. E. (2015). Physiological linkage in couples and its implications for individual and interpersonal functioning: A literature review. *Journal of Family Psychology*, *29*(5), 720. https://doi.org/10.1037/fam0000115

Waters, S. F., West, T. V., Karnilowicz, H. R., & Mendes, W. B. (2017). Affect contagion between mothers and infants: Examining valence and touch. *Journal of Experimental Psychology: General*, *146*(7), 1043-1051. https://doi.org/10.1037/xge0000322

Waters, S. F., West, T. V., & Mendes, W. B. (2014). Stress contagion: Physiological covariation between mothers and infants. *Psychological Science*, *25*(4), 934-942. https://doi.org/10.1177/0956797613518352

Valdesolo, P., Ouyang, J., & DeSteno, D. (2010). The rhythm of joint action: Synchrony promotes cooperative ability. *Journal of Experimental Social Psychology*, *46*(4), 693-695. https://doi.org/10.1016/j.jesp.2010.03.004

Valone, K., Goldstein, M. J., & Norton, J. P. (1984). Parental expressed emotion and psychophysiological reactivity in an adolescent sample at risk for schizophrenia spectrum disorders. *Journal of Abnormal Psychology*, *93*(4), 448-457. https://doi.org/10.1037/0021-843X.93.4.448

Vaughn, C., & Leff, J. (1976). The measurement of expressed emotion in the families of psychiatric patients. *British Journal of Social and Clinical Psychology*, *15*(2), 157-165. https://doi.org/10.1111/j.2044-8260.1976.tb00021.x

Vaughn, C. E., Snyder, K. S., Jones, S., Freeman, W. B., & Falloon, I. R. (1984). Family factors in schizophrenic relapse: Replication in California of British research on expressed emotion. *Archives of General Psychiatry*, *41*(12), 1169-1177. https://doi.org/10.1001/archpsyc.1984.01790230055009

Vasconcelos e Sa, D., Wearden, A., Hartley, S., Emsley, R., & Barrowclough, C. (2016). Expressed Emotion and behaviourally controlling interactions in the daily life of dyads experiencing psychosis. *Psychiatry Research*, *245*, 406-413. https://doi.org/10.1016/j.psychres.2016.08.060

Wilhelm, K. A. Y., Niven, H., Parker, G., & Hadzi-Pavlovic, D. (2005). The stability of the Parental Bonding Instrument over a 20-year period. *Psychological Medicine*, *35*(3), 387-393. https://doi.org/10.1017/S0033291704003538

Woody, M. L., Feurer, C., Sosoo, E. E., Hastings, P. D., & Gibb, B. E. (2016). Synchrony of physiological activity during mother–child interaction: Moderation by maternal history of major depressive disorder. *Journal of Child Psychology and Psychiatry*, *57*(7), 843-850. https://doi.org/10.1111/jcpp.12562

Table 1

Demographic Data, Symptom Measures, and Self-Report Descriptive Statistics

	Schizophrenia (dyad n= 20)		Control (dyad n= 29)	
	Young adult	Parents	Young adult	Parents
Age Mean (SD)	24.85 (7.14)	55 (11.41)	20.31 (5.71)	51.17 (7.91)
Gender -% male (n)	80% (16)	19% (4)	44.8% (13)	13.8% (4)
Race % (n)				
African American/Black	5% (1)	4.8% (1)	6.9% (2)	3.4% (1)
Asian American/Pacific Islander	5% (1)	14.3% (3)	17.2% (5)	17.2% (5)
Hispanic/Latino	15% (3)	14.3% (3)	20.7% (6)	27.6% (8)
White/Caucasian	60% (12)	57.1% (12)	31% (9)	41.4% (12)
Other	5% (1)	0%	17.2% (5)	6.9% (2)
Missing	10% (2)	9.5% (2)	6.9% (2)	3.4% (1)
BMI	25.29 (4.64), n = 14	26.28 (4.95), n= 14	24.38 (9.29), n = 26	27.22 (6.39), n = 26
Caffeine on study day (n missing)	7 (9 missing)	6 (9 missing)	12 (0 missing)	18 (0 missing)
Chlorpromazine equivalent (n=11)	48.96 (292.12)	--	--	--
Diagnosis				
Schizophrenia	55% (11)	--	--	--
Schizoaffective Disorder	25% (5)			
Missing*	20% (4)			
PANSS Positive	13.35 (5.61)	--	--	--
PANSS Negative	16.71 (5.69)	--	--	--
PANSS General	30.13 (9.49)	--	--	--
Baseline Warmth	8.00 (2.51)	8.29 (1.49)	9.00 (1.13)	8.55 (1.50)
Post-Conversation Warmth	7.53 (2.53)	8.40 (1.55)	8.86 (1.46)	8.73 (1.39)
Baseline Criticism	5.07 (2.89	4.71 (2.40)	5.34 (2.96)	5.00 (2.35)
Post-Conversation Criticism	4.87 (2.70)	3.93 (2.34)	4.76 (2.81)	4.66 (2.62)
PBI - Caring	27.18 (6.13)	--	30.24 (4.54)	--
PBI - Overprotection	14.71 (7.56)	--	11.55 (5.57)	--
SAM -Valence	5.87 (1.85)	6.64 (1.91)	6.92 (1.38)	6.89 (1.50)
SAM-Arousal	5.07 (2.09)	2.79 (1.71)	3.96 (1.99)	4.63 (1.90)

Note: *All young adults in the schizophrenia group were determined to meet criteria for a schizophrenia spectrum disorder diagnosis. Due to experimenter error, four participant's precise diagnosis was not entered in the data set.

Table 2

Standardized Beta Coefficients from Linear Regression Models Predicting Self-Report Data from Group

	Young Adult		Parent	
Outcome	Study Day β	Group β	Study Day β	Group β
PBI – Care	-.07	-.29†	--	--
PBI– Overprotection	.06	.24	--	--
Baseline perceived criticism from parent	-.27	-.05	.09	-.06
SAM – Valence (higher scores are more positive)	.01	-.31*	-.06	-.07
SAM – Arousal (higher scores indicate higher arousal)	.001	.26	.18	-.44*

Note: *Positive Group β values indicate a positive relationship with schizophrenia diagnosis.* $^{*}p <$ .05; $^{\dagger}p <$.10

Table 3

Standardized Beta Coefficients from Regression Models Predicting Physiological Reactivity and Covariation from Group and Parenting Style

Outcome	Model R^2	Study Day β	Baseline Phys-iology β	Group β	PBI-Caring β	PBI – Over-protection β	Caring x Group	Over-protection x Group
Young Adult IBI	.39*	.01	-.60*	-.13	-.07	-.07	--	--
Young Adult RSA	.72*	-.14	-.84*	-.18	-.05	-.03	--	--
Parent IBI	.20	-.02	-.44*	-.05	.05	.02	--	--
Parent RSA	.47*	.07	-.64*	-.09	-.03	-.21	--	--
IBI covariation	.20	-.001	--	.10	-.51*	-.28	--	--
RSA covariation	.28*	-.09	--	-.12	-.41*	-.06	.34*	--

Note: *Positive Group β values indicate a positive relationship with schizophrenia diagnosis.* $^{*}p <$ .05

Table 4

Standardized Beta Coefficients from Regression Models Predicting Physiological Reactivity and Covariation from Group and Perceived Parental Criticalness

Outcome	Model R^2	Study Day β	Baseline Phys-iology β	Group β	Parent Report β	Young Adult Report β	Young Adult Report x Group	Parent Report x Group
Young Adult IBI	.43*	.13	-.65*	-.06	.07	.19	--	--
Young Adult RSA	.77*	-.15	-.89*	-.10	.11	-.05	--	--
Parent IBI	.11	.08	-.33*	.06	-.06	.12	--	--
Parent RSA	.47*	.04	-.64*	-.13	.002	-.18	--	--
IBI covariation	.09	.21	--	.15	-.19	.22	--	--
RSA covariation	.06	-.07	--	-.06	-.18	.17	--	--

Note: *Positive Group β values indicate a positive relationship with schizophrenia diagnosis.* $^{*}p <$ .05

Table 5

Standardized Beta Coefficients from Regression Models Predicting Physiological Reactivity and Covariation from Group and Participant Affective Valence and Arousal

Outcome	Model R^2	Study Day β	Baseline Phys-iology β	Group β	Valence	Arousal	Valence x Group	Arousal x Group
Young Adult IBI	.37*	.14	-.59	-.02	.09	-.08	--	--
Young Adult RSA	.77*	-.14	-.91*	-.05	.20*	.05	--	--
Parent IBI	.21	.13	-.37*	.20	-.13	.08	--	--
Parent RSA	.29*	.05	-.46*	-.10	.03	.14	--	--
Predictor: Young Adult Affect								
IBI covariation	.09	.15	--	.16	-.07	.13	--	--
RSA covariation	.09	-.16	--	-.16	-.10	.22	--	--
Predictor: Parent Affect								
IBI covariation	.07	.10	--	.26	.02	.09	--	--
RSA covariation	.05	-.18	--	-.02	.00	.15	--	--

Note: *Positive Group β values indicate a positive relationship with schizophrenia diagnosis.* $^{*}p <$ .05

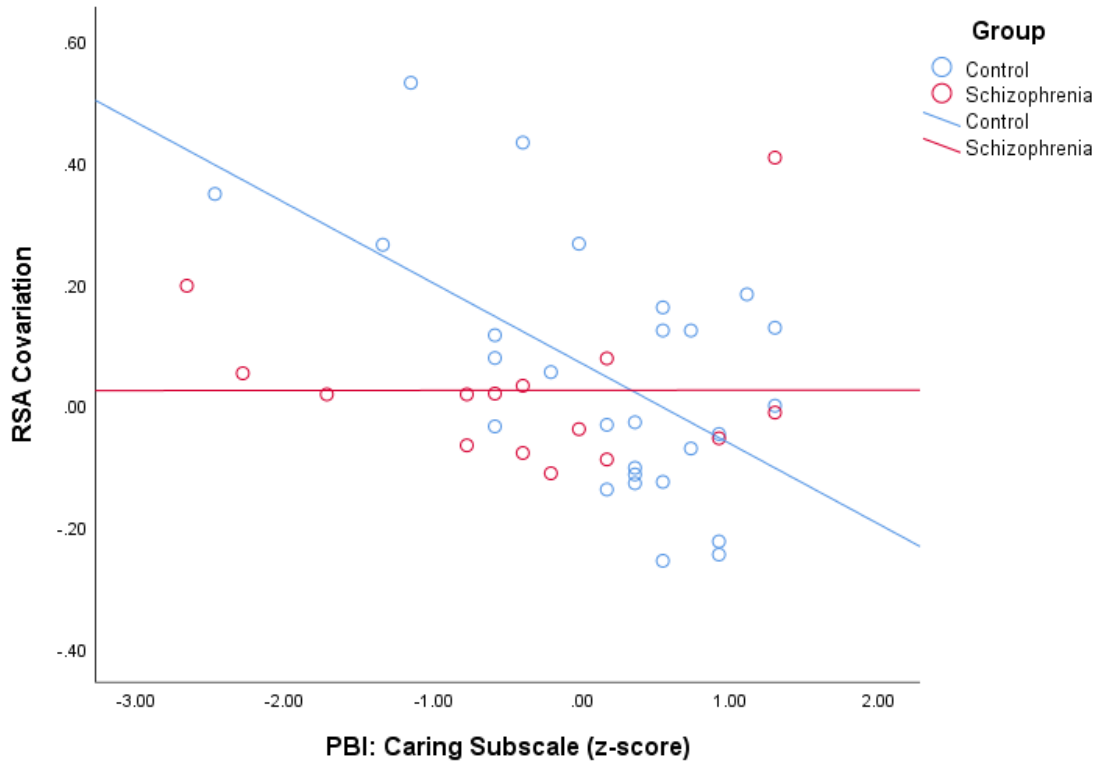

Figure 1. RSA covariation predicted by young adult report on the PBI caring subscale by group, controlling for study day.

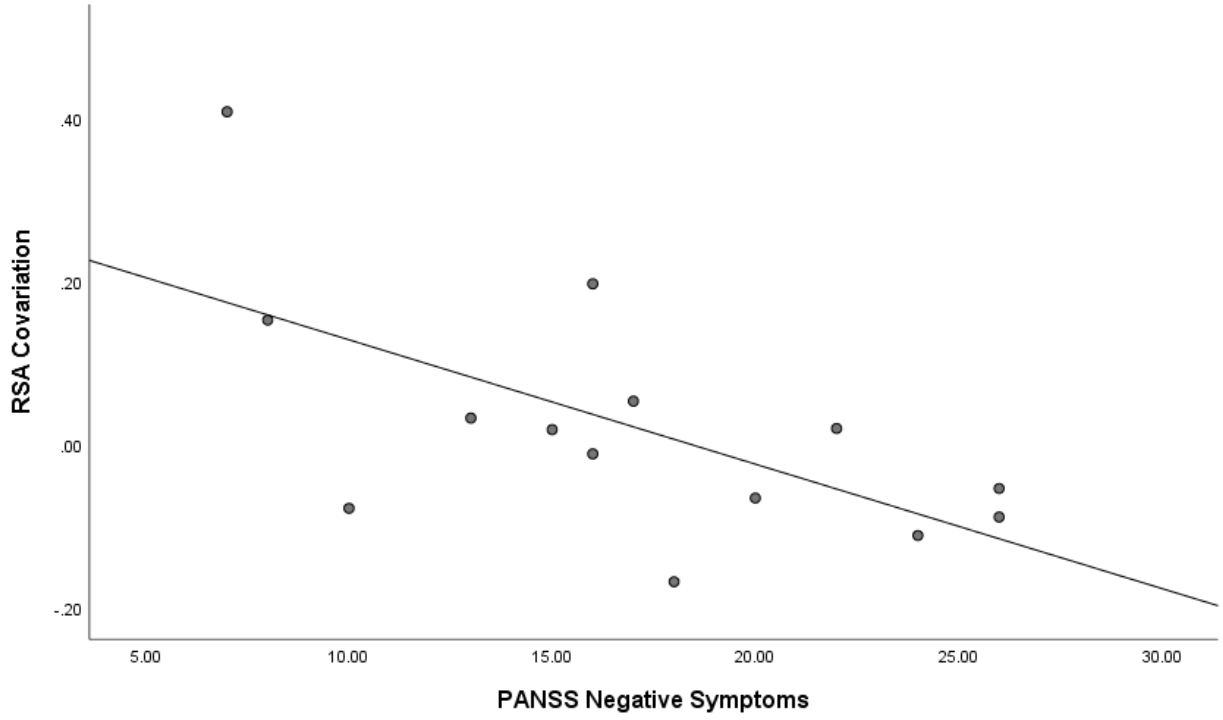

Figure 2. RSA covariation predicted by negative symptoms within the schizophrenia group.