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RESEARCH ARTICLE

Respiratory sinus arrhythmia as a within-session biomarker in depression psychotherapy: integrrefereating resting RSA and RSA reactivity

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Abstract
Objective: Enhancing affective regulation is a key focus in psychotherapy for depression, yet within-session markers that capture the dynamics of regulation remain limited. Respiratory Sinus Arrhythmia (RSA), a biomarker of vagal mediation of the parasympathetic nervous system, is well-known for its role in affective regulation. This nonrandomized observational psychotherapy process study examined (1) whether resting RSA can serve as a biomarker for depression severity, and (2) whether RSA reactivity and its interaction with resting RSA can serve as a within-session therapeutic biomarker linked to session quality. **Method:** Twenty-eight clients with MDD underwent Supportive-Expressive short-term psychodynamic therapy. Resting RSA and RSA reactivity were measured during five pre-scheduled sessions throughout treatment. Session quality was assessed using the self-report Session Evaluation Scale questionnaire. The data were analyzed using multi-level modeling. **Results:** Higher resting RSA was associated with lower pre-session depression and was only significant at the within-client level. The interaction between resting RSA and RSA reactivity was linked to session quality, with higher resting RSA predicting a positive association between RSA reactivity and session evaluation. **Conclusion:** The findings underscore the value of physiological measures such as RSA as a biomarker for assessing depression severity that can capture affective regulation dynamics during therapy sessions.

Keywords: affect regulation; depression; parasympathetic nervous system; respiratory sinus arrhythmia (RSA)

Clinical or methodological significance of this article: This study highlights the value of incorporating implicit physiological markers to better understand affect dynamics in depression treatment. The findings suggest that RSA may serve as both a monitoring and a therapeutic biomarker that can contribute to the assessment of depression severity and the prediction of session quality.

Affective regulation is considered one of the main factors underpinning major depressive disorder (MDD; Joormann & Stanton, 2016; Rottenberg, 2017), a highly disabling and prevalent condition worldwide. Affect regulation in depression psychotherapy studies has primarily been based on clients' self-reports at discrete time intervals (e.g., Bar-Kalifa & Atzil-Slonim, 2020). Although these data provide valuable insights into clients' subjective experiences of regulatory dynamics, they rely heavily on clients' ability and willingness to articulate their experiences (Cummins et al., 2015; Rottenberg, 2017). They can often fall short of fully and objectively capturing the more implicit aspects of affect; namely, the automatic and pre-reflective components of the affective experience (Weil et al., 2019). Recently, researchers have suggested that focusing on these more implicit physiological

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markers as a complement to existing measures could provide a better understanding of the affective dynamics of depression (Rottenberg, 2017; Slonim et al., 2022; Zilcha-Mano et al., 2020).

The current study examined Respiratory Sinus Arrhythmia (RSA), a well-established index of the Parasympathetic Nervous System (PNS) that is known to reflect physiological affective regulation dynamics (Balzarotti et al., 2017; Barrett Feldman et al., 2016) to explore its potential as a biomarker for tracking changes in the treatment of depression, and as a representative marker of the implicit aspects of affect. Recent studies have provided evidence for an association between impaired PNS functioning and difficulties in affective regulation in cases of depression (Beauchaine, 2015; Holzman & Bridgett, 2017; Stange et al., 2017). Polyvagal Theory posits that the vagus nerve, also known as the "vagal brake", mediates the role of the PNS by modulating the heart's pacemaker (i.e., the sinoatrial node), thereby influencing heart rate through inhibitory control (Porges, 2007). At rest, the vagal brake enables increased PNS regulation, enabling resource conservation. This brake is released during situations that are perceived to be emotional, threatening, or physically taxing which then allows the Sympathetic Nervous System (SNS) to respond and adapt (Porges, 2007; Stange et al., 2017). Although the PNS and SNS often exhibit reciprocal temporal coordination (i.e., an increase in SNS activation is accompanied by a decrease in PNS activation), other patterns of activity may also occur in complex social or emotional contexts, including instances of co-activation where both systems increase simultaneously (e.g., Berntson et al., 1991; Gatzke-Kopp & Ram, 2018; Gatzke-Kopp et al., 2020; Piper et al., 2015).

RSA is a reliable peripheral biomarker of PNS activity and is mediated by the myelinated vagal innervation of cardiac activity (Berntson et al., 1997; Porges, 2007). RSA is calculated by applying a frequency power analysis to isolate high-frequency fluctuations from Heart Rate Variability (HRV) signals. This is necessary because HRV signals comprise components from the PNS, the SNS, and other non-neural components. By filtering out low- and mid-frequency bands, this analysis isolates PNS functioning (Beauchaine, 2015; Porges, 2007). Studies have suggested that differences in RSA levels could be used as an index of individuals' capacity for affective regulation in complex social environments, and more particularly as an autonomic, transdiagnostic biomarker of psychopathology (Beauchaine & Thayer, 2015; Hartmann et al., 2019; Holzman & Bridgett, 2017). Meta-analyses have shown that RSA levels were lower in MDD than in healthy controls (Kemp et al., 2010; Koch et al., 2019), and that depression severity was negatively correlated with RSA levels (Kemp et al., 2010).

The literature on RSA differentiates between tonic RSA and phasic RSA in analyses of regulation dynamics (Balzarotti et al., 2017; Bar-Kalifa et al., 2021; Beauchaine, 2015; Yaroslavsky, Rottenberg, & Kovacs, 2014). Tonic RSA corresponds to RSA levels during periods of baseline relaxation; i.e., *resting RSA*, which is known to reflect the capacity for affect regulation (Balzarotti et al., 2017; Bar-Kalifa et al., 2021; Porges, 2007). While resting RSA is typically examined as a trait-like characteristic that varies between individuals (i.e., between-client; Balzarotti et al., 2017), it can also fluctuate within the same individual across different time points (i.e., within-client), thus potentially reflecting a more state-like regulatory capacity. Phasic RSA is measured by comparing RSA during demanding situations to RSA during resting periods; i.e., *RSA reactivity* (Bar-Kalifa et al., 2021; Beauchaine, 2015; Stange et al., 2017).[1] A decrease in RSA relative to baseline (i.e., RSA withdrawal) has been associated with stress responses (e.g., Balzarotti et al., 2017; Stange et al., 2017), whereas an increase in RSA relative to baseline (i.e., RSA augmentation) has been linked to self-regulatory efforts and more adaptive emotional and affiliative functioning in social contexts, such as enhanced compassion, improved emotion regulation, and greater prosocial engagement (Balzarotti et al., 2017; Bar-Kalifa et al., 2021; Stange et al., 2017).

The findings on potential associations between RSA reactivity and depression are inconsistent (Schiweck et al., 2019; Yaroslavsky, Bylsma, et al., 2013). RSA withdrawal has been associated with greater severity of depression in some studies (e.g., Bylsma et al., 2014), whereas others have linked RSA augmentation to greater severity of depression (e.g., Rottenberg et al., 2007). To address these inconsistencies, Yaroslavsky, Bylsma, et al. (2013) found that combining resting RSA and RSA reactivity constituted a more comprehensive approach to assessing affective regulation dynamics in depression than each index alone (e.g., Yaroslavsky et al., 2014; Yaroslavsky, Bylsma, et al., 2013). This underscores the complexity of the PNS system, which undergoes constant changes in activity before and during exposure to environmental stimuli to support adaptive physiological functioning (El-Sheikh & Erath, 2011; Porges, 2007). An individual can have a similar baseline level at different times (i.e., within-client resting RSA) but exhibit varying degrees of reactivity to environmental interactions (i.e., RSA reactivity) leading to different physiological and behavioral adaptations. Other studies across

developmental stages and treatment settings have also emphasized the importance of examining the interaction between resting RSA and RSA reactivity when evaluating trajectories of internalizing symptoms, including depression (Battaglini et al., 2024; Hinnant & El-Sheikh, 2013; Susman et al., 2025).

In psychotherapy, the few studies conducted on RSA have reported mixed results. While some found that increases in within-client levels of resting RSA from pre- to post-treatment were associated with improvement in depressive symptoms (e.g., Kim et al., 2009), others failed to do so (e.g., Susman et al., 2025, which did not find an association with resting RSA when considered alone). One possible explanation for the mixed findings is that depressive symptoms often fluctuate throughout the course of treatment. Because prior studies assessed depression severity and resting RSA only at pre- and post-treatment, they were unable to examine whether changes in resting RSA corresponded to these session-to-session fluctuations in depression. As a result, meaningful associations between within-treatment changes in depressive symptoms and resting RSA may have been obscured in designs that measured both variables only at two time points. Only one study that we are aware of has examined the association between within-client RSA levels and depression severity session by session throughout treatment (Blanck et al., 2019). However, no association was found between resting RSA as measured at the start of the session and depression outcome as measured at the end of the session. This lack of association may stem from the temporal gap in that study between the assessment of resting RSA at the beginning of the session and the evaluation of depressive symptoms at the end of the same session. Thus, to better evaluate the potential utility of within-client resting RSA as a biomarker for monitoring fluctuations in depression severity over the treatment, more fine-grained temporal alignment between RSA and depression measurements is needed.

Although some studies have argued that physiological reactivity may serve as a crucial biomarker for assessing the quality of therapeutic sessions (e.g., Slonim et al., 2022), we are not aware of any previous work that has evaluated RSA reactivity in individuals with depression during psychotherapy. Previous studies have typically examined RSA reactivity in controlled laboratory settings using structured tasks designed to elicit emotional or cognitive stress (e.g., Schiweck et al., 2019; Yaroslavsky, Bylsma, et al., 2013). In addition, RSA reactivity has been investigated in more naturalistic interpersonal contexts, such as dyadic couple interactions, where it has been assessed in relation to affiliative processes (e.g., Bar-Kalifa et al., 2021). However, to the best of our knowledge, RSA reactivity, and the extent to which it is associated with session quality, has not been examined within the naturalistic context of psychotherapy sessions.

In the context of physiological reactivity as a potential biomarker of within-session therapeutic processes, session quality refers to immediate, proximal therapeutic outcomes (often termed "small o" outcomes), which have been theorized to contribute cumulatively to longer-term therapeutic change ("big O" outcomes) such as symptom reduction or client retention (Greenberg & Pinsof, 1986). Research has demonstrated that clients' self-reported session quality is predictive of important distal outcomes, including a lower dropout rate and symptom improvement (e.g., Stiles et al., 1990; Watson & Greenberg, 1996). For these reasons, recent studies have adopted session quality as a primary outcome when evaluating dynamic in-session processes (e.g., Bar-Kalifa et al., 2023; Li & Kivlighan Jr, 2020). Overall, it remains unknown whether client-reported session quality at the end of naturalistic psychotherapy sessions might be reflected in within-session RSA reactivity, and specifically whether RSA augmentation or withdrawal is more strongly associated with higher evaluations of session quality.

The Present Study

Aim 1: Resting RSA as a pre-session Biomarker of Depression Severity

The first aim of the present study was to examine resting RSA as a potential pre-session biomarker of clients' depression severity at the beginning of each session. Specifically, we sought to determine whether session-by-session fluctuations in pre-session depressive symptoms would be reflected in corresponding changes in resting RSA.

Hypothesis 1

Drawing on previous findings linking higher depression severity with reduced PNS regulatory capacity (Kemp et al., 2010; Koch et al., 2019), we hypothesized that clients who exhibited higher levels of pre-session depression would exhibit lower levels of resting RSA at the beginning of the session. We also explored whether within-client or between-client differences would contribute more substantially to this association.

Aim 2: RSA Reactivity as a Within-session Therapeutic Biomarker

A second, exploratory aim was to examine RSA reactivity as a potential within-session therapeutic biomarker of clients' affect regulation efforts. Specifically, we focused on whether increases or decreases in RSA relative to baseline (i.e., RSA augmentation or RSA withdrawal) were differentially associated with client-reported session quality.

Exploratory research question. Based on previous recommendations to jointly consider resting RSA and RSA reactivity when examining physiologically related processes in depression (Laborde et al., 2017; Yaroslavsky, Bylsma, et al., 2013; Yaroslavsky, Rottenberg, & Kovacs, 2014), we explored whether within-client resting RSA at the beginning of a session would interact with within-session RSA reactivity in predicting self-reported session evaluation. In addition, given the inconsistent findings in the literature regarding the directionality of RSA reactivity effects, we explored whether increases or decreases in RSA relative to baseline (i.e., RSA augmentation or RSA withdrawal) would be more closely associated with session evaluation.

Method

The data utilized in this study were extracted from a broader psychotherapeutic program on clients with MDD. This study was conducted at the community clinic of the Bar-Ilan University Psychology Department and received ethical approval from its associated IRB. This study was not pre-registered. Although data from this sample have been included in previous publications (Bar-Kalifa et al., 2023; Goren et al., 2025; Paz et al., 2024; Slonim et al., 2022; Slonim et al., 2023), these studies addressed different research questions related to the interpersonal dynamics of RSA and session quality, or employed completely different variables (i.e., that did not incorporate RSA indices or client-reported session quality measures).

Participants

The sample was composed of 28 individuals diagnosed with MDD who fulfilled the criteria for a primary diagnosis of MDD on the Mini-International Neuropsychiatric Interview version 5.0 (MINI; Sheehan et al., 1998). Potential participants also needed to score 17 or above on the self-report Beck Depression Inventory-II (21 items, BDI-II; Beck et al., 1996; M = 27.13, SD = 6.55, BDI range 18-43). All the participants were aged 18 or older (M = 35.64 years, SD = 6.70, age range 25–48 years). The exclusion criteria were: active suicidality, psychosis, addictions, bipolar disorder, brain damage, currently pregnant, or heart problems. Table I presents the participants' demographic characteristics.

Table I. Participant demographic characteristics.

Characteristic	Category	*n*
Gender	Female	21
	Male	7
Relationship Status	Single	13
	Married/Committed	13
	Divorced	2
Education	Secondary education	3
	Post-secondary	4
	Academic degree	21
Employment status	Full position	12
	Part position	10
	Not working	6
Birth location	Israel	24
	Ukraine	2
	Soviet Union	2
Native language	Hebrew	24
	Russian	3
	Other	1

Procedure

For purposes of recruitment, ads were posted on social network platforms offering short-term psychodynamic therapy for depression-related symptoms. All potential participants were evaluated by MA-level clinical trainees under the direction of senior clinicians. The 58 applicants with BDI-II scores ≥17 were called for an intake interview, during which the inclusion and exclusion criteria were assessed (the BDI-II was administered once again during the intake session, which became the actual BDI score). The sample size was determined based on the number of eligible clients who enrolled during the defined recruitment period (July 2018 - May 2020); no a priori power analysis was conducted.

The 47 clients who met the inclusion criteria were invited to start manualized short-term (16-session) Supportive Expressive Therapy (SET) for the treatment of depression (Luborsky et al., 1995). SET integrates supportive techniques such as affirmation and empathic validation with expressive techniques including interpretation, confrontation, and clarification. The treatment followed the SET protocol specifically designed for depression, which targets core psychodynamic themes commonly seen in individuals with MDD, such as a sense of helplessness, anger turned inward, vulnerability of self-esteem, suicidal ideation, and pessimistic explanatory styles (Luborsky et al.,

1995). Within this framework, the supportive dimension of SET provides clients with empathic, emotionally attuned interactions that foster coregulation and help them manage intense affective states, while the expressive dimension encourages clients to explore and understand their characteristic experiential patterns, thereby broadening their agency and capacity to regulate their experience in more adaptive ways. Each therapy session lasted approximately 50 min and was held once a week over the course of treatment. No financial or material incentives were provided for participation in the study. All participants received the same psychotherapy intervention, and no comparison or control condition was included.

Eleven therapists (6 women and 5 men), all of whom were advanced trainees at the university clinic with 2–6 years of experience, received supervision by senior supervisors with specializations in the SET approach. All sessions were recorded; thus, the supervision sessions included individual and group settings during which the therapists and supervisor viewed video-recorded sessions together. The therapists received specific guidance on how to adhere to the principles of SET throughout the course of treatment.

Six therapists treated 3–4 clients, three treated 2 clients, and two therapists treated 1 client. This number varied as a function of therapist case load availability at the clinic, rather than random allocation. The therapists ranged in age from 28 to 41 with a mean age of 32.4. Clients completed questionnaires before and after each session. Physiological activity was recorded in 5 pre-selected sessions (2, 5, 8, 11, and 14) over the course of treatment, using electrocardiography (ECG).

Two clients dropped out of therapy, and data from three clients were excluded after they required psychopharmacological treatment during therapy. Two clients had to be excluded due to persistent excessive signal noise that could not be analyzed, and data from two clients were excluded as outliers (more than 2 SDs from the group means for BDI or RSA). Due to technical problems (e.g., Wi-Fi signal interruptions, electrode detachment, or excessive signal issues), 63 measurements were unusable, representing 31% of the total potential measurements. Note however that most of these unusable recordings occurred during the early stages of data collection, and the frequency of technical failures decreased substantially as procedures and equipment handling were stabilized. Clients with fewer than three measurements throughout the therapy were also dropped, resulting in the loss of 10 more clients.

Prior to treatment, clients were informed that physiological data would be collected during specific sessions. In each of these sessions, trained research assistants attached electrodes to both the client and the therapist (therapist data are not relevant for the current study and are reported elsewhere; Bar-Kalifa et al., 2023; Goren et al., 2025). At the outset of each physiological measurement session, clients were seated with their therapist in the therapy room and instructed to rest quietly in an armchair while breathing naturally for 2–3 min. Following this brief resting period, the therapy session commenced. As in Laborde et al. (2017), baseline data were obtained for a 1-min period. Two measurements lasting over 4 min were excluded from the sample. Overall, the final sample consisted of 28 clients with 115 sessions.

This manuscript was prepared with reference to the TREND reporting guidelines for nonrandomized evaluations (Des Jarlais et al., 2004), insofar as these guidelines are applicable to an observational psychotherapy process study. A completed TREND checklist is provided in the Supplementary Materials (i.e., Table S1).

Measures

Beck depression inventory-II (BDI-II). The BDI-II (Beck et al., 1996) is a 21-item self-report measure of depression that asks respondents to rate the severity of their symptoms during the previous week on a Likert scale (19 items use a 4-point scale, 2 items use a 7-point scale). The BDI-II assesses cognitive-affective and somatic symptoms of depression (Whisman et al., 2000). Individual item scores are summed to create a total severity score ranging from 0 to 63. Depressive severity is categorized using the following ranges: 0–10 (minimal), 11–16 (mild), 17–20 (borderline), 21–30 (moderate), 31–40 (severe), ≥ 40 (extreme). High internal consistency (.93) and significant ($p \leq .01$) inter-correlations have been reported between the total BDI-II scale and the Behavior and Symptom Identification Scale 24-item, Depression/Functioning scale (r .79) and the Overall (r .82) subscales (Subica et al., 2014). Clients completed the BDI-II at the beginning of each session. In the current sample, the levels of reliability for within-person and between-person measures were 0.61 and 0.98, respectively.

Session evaluation scale (SES). To assess session quality, at the end of each session, clients completed the four-item Session Evaluation Scale (SES) from the Helping Skill Measure (Hill & Kellems, 2002). The original version consists of four items (e.g., "I did not feel satisfied with what I got out of this session"). Clients rate each statement on a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scale correlates with post-

session measures of skills used in-session and the therapeutic relationship. The SES had adequate internal consistency reliability estimates in two different samples (α = .89). As in Lent et al., 2006, we added another item to the SES, asking clients to "rate the overall effectiveness of this session" on a scale from 1 (not effective) to 5 (highly effective). This item correlated strongly with the original SES items and somewhat increased the scale variance. In the current sample, the levels of reliability for the within-person and between-person measures were 0.68 and 0.90, respectively.

Respiratory sinus arrythmia (RSA). An integrated system and the Mindware Technology software package (Gahanna, OH) were used to obtain the ECG from clients at a sample rate of 1 kHz. Three disposable electrodes fitted with wireless mobile devices were attached to the clients' body: one on the right clavicle and two on either side of the lower thoracic bones. Signals were captured by a computer in an adjacent room using BioLab Software 3.3.1 (Mindware Technology Ltd.). The data were subjected to HRV Analysis 3.2.7 (Mindware Technology Ltd.) offline. For purposes of preprocessing, suspected artifacts were identified based on the overall R-R distribution using the Shannon Energy Envelope algorithm (Manikandan & Soman, 2012). Five trained research assistants deleted or located R-peaks in 45 s windows. The percentage of problematic R-peaks was negligible (range = 0-0.8%). RSA was calculated by applying a frequency-domain analysis to isolate the high-frequency band (0.15–0.4 Hz) from the HRV signal, thereby capturing PNS activity (Beauchaine, 2015; Porges, 2007).

In the current study, RSA was estimated separately from the baseline phase and the working phase of each therapy session. As defined above, baseline data were collected at the beginning of each session and were used to establish *resting RSA* values (the baseline phase ranged from 62 to 223 s).[2] The working phase for each session was defined by Auszra et al. (2013) as the 15-min period before the final 5 min of the session. This phase is considered to be the part of the session in which clients are most likely to be engaged in therapeutic work. The *RSA reactivity* variable was created by subtracting the RSA of the working phase from the RSA of the baseline phase, consistent with previous studies using similar calculation methods (e.g., Bar-Kalifa et al., 2021; Gentzler et al., 2009). Thus, an increase in RSA (i.e., RSA augmentation) indicates that the activity of the PNS in the working phase was higher than in the baseline phase, and vice-versa for a decrease in RSA (i.e., RSA withdrawal). While resting RSA and RSA reactivity are often measured in response to standardized stress-induction tasks (e.g., Schiweck et al., 2019; Yaroslavsky, Bylsma, et al., 2013), in this study they were assessed in the context of psychotherapy sessions. Resting RSA was measured during a baseline phase immediately preceding the session, during which clients were invited to sit quietly and breathe naturally. However, this period may still have been influenced to some extent by anticipatory responses. RSA reactivity was calculated based on RSA changes during actual therapeutic interactions, reflecting engagement in naturalistic, emotionally dynamic conditions. To the best of our knowledge, this is the first study to apply RSA reactivity within the context of ongoing psychotherapy sessions.

Data Analysis

Since the data were nested (session [S] nested within clients [C]), we tested the hypotheses using two-level multi-level models (Hoffman, 2015).[3] Missing data were not imputed; all analyses were conducted using available cases alone. Model 1 corresponded to Hypothesis 1 that examined whether higher depressive symptoms would be negatively associated with PNS regulation capacity at the between- and within- client levels. The variable $RSA^{resting}$ (operationalization of PNS regulation capacity) was client mean-centered around each client's mean (MC) for the within-client effect, as well as grand-mean-centered around the grand mean of all clients (GMC) for the between-client effect. The model 1 equation was as follows:

Level 1

$$BDI_{sc} = \beta_{0sc} + \beta_{1sc} * \mathrm{RSA}_{\mathrm{MC}_{sc}^{resting}} + e_{sc}$$

$$(\mathrm{e_{sc}}) \sim \mathrm{N}[0,\ \sigma^2]$$

Level 2

$$\beta_{0sc} = \gamma_{00} + \gamma_{01} * \mathrm{RSA}_{\mathrm{GMC}_{0c}^{resting}} + u_{0c}$$

$$\beta_{1sc} = \gamma_{10} + u_{1c}$$

$$(\mathrm{u_{0c}}) \sim \mathrm{N}[0,\ \tau_{00}^2]$$

$$\begin{pmatrix} u_{0c} \\ u_{1i} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \tau_{00} & \\ \tau_{01} & \tau_{11} \end{pmatrix}\right]$$

BDI was estimated using an intercept (γ_{00}) term and a slope term for session-level (i.e., level 1) $RSA^{resting}$ (γ_{10}). In addition, client level (i.e., level 2) $RSA^{resting}$ (γ_{01}) was included. The former (γ_{10}) served as a test of the within-client level and the latter served as a test of the between-client level (γ_{01}). Level 1 residuals (e_{sc}) and level 2 random

effects for the intercept as well as for the main-effect slope (u_{0c}, u_{1c}) were also estimated.

Model 2 corresponds to the exploratory research question (i.e., Study Aim 2), which examined whether in-session PNS regulation reactivity would be associated with the client's session evaluation and the interaction of this association with session's PNS regulation capacity. The variables $RSA^{resting}$ and $RSA^{reactivity}$ (operationalization of PNS regulation capacity and PNS regulation reactivity, respectively) were client mean-centered around each client's mean (MC). The model 2 equation was as follows:

Level 1

$$SES_{sc} = \beta_{0sc} + \beta_{1sc}*RSA_{MC_{sc}^{resting}} + \beta_{2sc}*RSA_{MC_{sc}^{reactivity}} + \beta_{3sc}*RSA_{MC_{sc}^{resting}}*RSA_{MC_{sc}^{reactivity}} + e_{sc}$$

$$(e_{sc}) \sim N[0,\ \sigma^2]$$

Level 2

$$\beta_{0sc} = \gamma_{00} + u_{0c}$$

$$\beta_{1sc} = \gamma_{10} + u_{1c}$$

$$\beta_{2sc} = \gamma_{20} + u_{2c}$$

$$\beta_{3sc} = \gamma_{30}$$

$$\begin{pmatrix} u_{0c} \\ u_{1i} \\ u_{2i} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \tau_{00} & & \\ \tau_{01} & \tau_{11} & \\ \tau_{02} & \tau_{12} & \tau_{22} \end{pmatrix}\right]$$

SES was estimated using an intercept (γ_{00}) term and two main-effect slope terms for session-level (i.e., level 1) $RSA^{resting}$ (γ_{10}) and $RSA^{reactivity}$ (γ_{20}). In addition, the interaction between $RSA^{resting}$ and $RSA^{reactivity}$ (γ_{30}) was included. Level 1 residuals (e_{sc}) and level 2 random effects for the intercept as well as for the two main-effect slopes (u_{0c}, u_{1c}, u_{2c}) were also estimated.[4]

Results

The descriptive statistics are presented in Tables II and III. A significant decrease in depressive severity was observed across the treatment, whereas changes over time in the remaining study variables were not statistically significant.

Table IV presents the Hypothesis 1 results. Consistent with Hypothesis 1, there was a negative association between BDI scores and RSA at the baseline phase of the session.[5] Specifically, higher PNS regulation capacity (i.e., higher $RSA^{resting}$) was associated with lower self-reported depressive severity at the beginning of a session (Est. = −2.015, SE = 0.795, $p < .05$). This association was only significant at the within-client level (as opposed to the between-client level; Est. = 0.069, SE = 1.409, $p = .961$). This suggests that when a given client's PNS regulation capacity was higher than their own average, they tended to report lower-than-usual depressive symptoms at the start of that session.

Table V presents the results of the Exploratory research question (i.e., Study Aim 2). $RSA^{resting}$ interacted with the association between $RSA^{reactivity}$ and SES (Est. = 0.252, SE = 0.092, $p < .01$). Neither $RSA^{resting}$ nor $RSA^{reactivity}$ demonstrated a significant main effect in relation to SES. This was further corroborated by two supplementary models in which each RSA component was examined separately as the sole predictor of SES, both of which yielded non-significant results. To further explore the interaction finding, we probed the interaction by computing the $RSA^{resting}$ parameter at 1 SD above and below the mean. As shown in Figure 1, when the $RSA^{resting}$ was higher (i.e., 1 SD above the mean), there was a positive association between RSA augmentation (i.e., increases in RSA relative to baseline) and SES

Table II. Means, SDs and correlations of the study's variables.

		Zero order correlations		
	Mean (SD)	2	3	4
1. Resting RSA	6.70 (1.28)	−0.491**	−0.038	0.086
2. RSA reactivity	−0.28 (0.78)		−0.119	0.199*
3. BDI	20.30 (9.87)			−0.095
4. SES	4.44 (0.60)			

*$p < .05$; **$p < .001$.

Table III. Means, SDs, and sample sizes of the study's variables at each measurement point.

	Measurement				
	1	2	3	4	5
Resting RSA	6.87 (1.05) [23]	6.63 (1.43) [21]	6.73 (1.24) [25]	6.66 (1.39) [25]	6.62 (1.38) [21]
RSA reactivity	–0.23 (0.75) [23]	–0.20 (0.81) [21]	–0.56 (0.77) [25]	–0.30 (0.78) [25]	–0.05 (0.74) [21]
BDI	22.70 (7.84) [23]	22.50 (9.57) [21]	19.90 (10.50) [25]	18.60 (10.30) [25]	18.00 (10.70) [21]
SES	4.38 (0.53) [22]	4.28 (0.88) [21]	4.45 (0.49) [24]	4.40 (0.61) [25]	4.69 (0.36) [21]

Values are means, with standard deviations in parentheses and sample sizes in square brackets.

Table IV. Model 1 results for the association of resting RSA, at the within- and between- client levels, with pre-session BDI.

	Estimate (SE)	CI 95%	*p*	*Std. Est.*
Intercepts:	20.412 (1.664)	17.148, 23.676	0.000	–
$RSA^{resting}_{(GMC)}$:	0.069 (1.409)	−2.789, 2.927	0.961	0.008
$RSA^{resting}_{(MC)}$:	−2.015 (0.795)	−3.575, −0.454	0.013	−0.120

SE = Standard Error, CI = Confidence Interval, Std. Est = Standard Estimation. $RSA^{resting}$ stands for the estimated RSA of the pre-session baseline phase, where clients were requested to sit and rest for 2–3 min in an armchair while breathing calmly. GMC = Grand Mean-Centered; i.e., the between-client level. MC = Mean-Centered; i.e., the within-client level.

Table V. Model 2 results for the association between resting RSA, RSA reactivity and their interaction with post-session SES.

	Estimate (SE)	CI 95%	*p*	*Std. Est.*
Intercepts:	4.498 (0.095)	4.311, 4.684	0.000	–
$RSA^{resting}$:	0.046 (0.151)	−0.248, 0.340	0.760	0.045
$RSA^{reactivity}$:	0.025 (0.137)	−0.242, 0.292	0.855	0.022
$RSA^{resting}$ X $RSA^{reactivity}$:	0.252 (0.092)	0.072, 0.433	0.008	0.133

SE = Standard Error, CI = Confidence Interval, Std. Est = Standard Estimation. $RSA^{resting}$ stands for the estimated RSA from the pre-session baseline phase, where clients were requested to sit and rest for 2–3 min in an armchair while breathing calmly. $RSA^{reactivity}$ stands for the reactivity variable created by subtracting the estimated RSA from the working phase (i.e., the 15-min period before the final 5 min of the session) minus the estimated RSA from the baseline phase. $RSA^{resting}$ and $RSA^{reactivity}$ were mean-centered.

(Est. = 0.530, SE = 0.210, $p < 0.05$). However, no such association was found when the $RSA^{resting}$ was lower (i.e., 1 SD below the mean; Est. = −0.480, SE = 0.240, $p = 0.11$). This suggests that when a client entered a session with a higher-than-usual PNS regulation capacity, increases in their PNS activation during the session were associated with more positive evaluations of that session.

Discussion

The current study investigated RSA as a biomarker for PNS affective regulation dynamics on a session-by-session basis throughout the course of psychotherapy with depressed clients. Specifically, we examined whether changes in resting RSA were associated with changes in depression severity, given that they both fluctuate throughout treatment, and whether resting RSA could serve as a monitoring biomarker of clients' depression levels. In addition, we examined whether the combination of resting RSA and RSA reactivity was associated with clients' session evaluations and could serve as a within-session biomarker of session quality.

Consistent with Hypothesis 1, we found that lower pre-session self-reported depression severity was associated with higher resting RSA at the within-client level, but not at the between-client level. Notably, RSA was measured during a brief resting phase immediately following the depressive symptom assessment. While previous studies have typically observed such associations only over extended periods and in the context of adversity (e.g., Hinnant & El-Sheikh, 2009; McLaughlin et al., 2015; Susman et al., 2021; Zhang et al., 2017), our findings suggest that this link can also be detected over short timescales, within the natural flow of psychotherapy. This contribution may reflect specific features of the current study, including the clinical profile of participants (i.e., adults diagnosed with MDD) and the method of depression assessment (i.e., integrating pre-treatment clinician evaluation with session self-report ratings). Moreover, this finding aligns with a meta-analysis outside psychotherapy reporting a negative association between resting RSA and depression severity in MDD populations (Kemp et al., 2010)[6], as well as with studies linking depression severity to PNS regulation capacity in pre-to-post psychotherapy designs (e.g., Euteneuer et al., 2023; Kim et al., 2009). At the same time, other works in similar pre-to-post designs have reported null results (e.g., Susman et al., 2025), highlighting the importance of examining this association at higher temporal resolution during treatment.[7] One such attempt was made by Blanck et al. (2019), who conducted a session-by-session analysis but did not detect a significant link. Our findings suggest that this discrepancy may be related to differences in measurement timing: in our study, both PNS regulation capacity and depressive symptoms were assessed at the start of each session, enabling closer temporal alignment, whereas Blanck et al. measured RSA at the beginning and symptoms at the end of the same session. Moreover, examining the link between resting RSA and depression level at higher temporal resolution from session to session during treatment revealed that this association was only found at the within-client level. This suggests that the PNS regulation capacity may be viewed as a state-like biomarker of depression, rather than a stable trait-like characteristic. However, given that the literature traditionally views the PNS regulation capacity as a constant trait-like characteristic indicative of individual

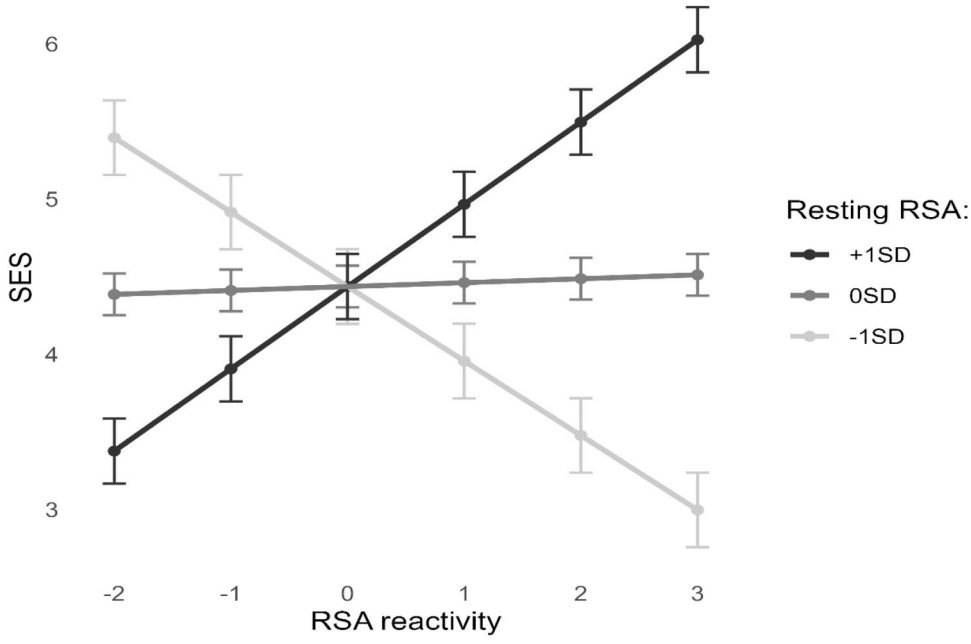

Figure 1. Association between RSA reactivity and SES at three different SDs of the resting RSA: + 1SD (dark gray), 0SD (medium gray) and −1SD (light gray). *SES* stands for the clients' self-report score on the Session Evaluation Scale. *Resting RSA* stands for the estimated RSA from the pre-session baseline phase, where clients were requested to sit and rest for 2-3 min in an armchair while breathing calmly. *RSA reactivity* stands for the reactivity variable created by subtracting the estimated RSA from the working phase (i.e., the 15-min period before the final 5 min of the session) minus the estimated RSA from the baseline phase. Error bars indicate ±1 SEM.

differences in affective regulation abilities (e.g., Balzarotti et al., 2017), and our relatively small sample size at the client level, these findings need replication to further confirm this result.

With respect to the Exploratory research question (i.e., Study Aim 2), the interaction between resting RSA at the beginning of a session and RSA reactivity during that session was associated with the self-reported session evaluation at the end of the session. In particular, neither resting RSA nor RSA reactivity alone were linked to clients' evaluations of the session's quality. Note that this conclusion is based on a model including both RSA components and their interaction; follow-up models testing each RSA component independently as a sole predictor yielded non-significant associations as well. These findings are concordant with research indicating that focusing on a single RSA index may not fully capture individual differences and that combining resting RSA with RSA reactivity provides a more comprehensive assessment (Battaglini et al., 2024; El-Sheikh & Erath, 2011; Hinnant & El-Sheikh, 2013; Laborde et al., 2017; Susman et al., 2025; Yaroslavsky et al., 2014; Yaroslavsky, Rottenberg, et al., 2013). Thus, our findings suggest that in the naturalistic environment of a psychotherapy session, integrating within-session PNS indices can serve as a biomarker of the session quality.

To further explore the nature of this interaction, we examined whether increases or decreases in RSA relative to baseline (i.e., RSA augmentation or RSA withdrawal) were more closely associated with session quality. The results indicated that when clients' resting RSA at the beginning of the session was higher (consistent with the hypothesized role of higher resting RSA as indicating greater regulatory capacity), within-session RSA augmentation was linked to clients' more positive evaluations of session quality; this interaction was not significant for lower clients' resting RSA. This finding echoes studies that have examined depressed individuals in laboratory settings and found that contrary to non-depressed individuals, depressed individuals tended to present RSA withdrawal (Schiweck et al., 2019; Yaroslavsky, Bylsma, et al., 2013). In other words, in depressed individuals who present higher levels of resting RSA, more productive dynamics are associated with an increase in PNS regulation efforts. The absence of a significant interaction at low levels of resting RSA may reflect the possibility that when clients enter a session with low resting RSA, indicating lower PNS regulatory capacity, session quality may be shaped less by clients' intrapersonal physiological changes and more by contextual or relational factors. For instance, interpersonal synchrony with the therapist might play a

compensatory role in promoting positive session quality (e.g., Bar-Kalifa et al., 2023).

Taken together, these findings are consistent with Porges' polyvagal theory (2007), which suggests that facing stress or affective challenges typically leads to decreased PNS control of the heart (i.e., a decrease in RSA relative to baseline, or RSA withdrawal), enabling SNS responses to allow the release of the metabolic requirements needed for mobilization responses, such as "fight or flight". In contrast, during safe interpersonal situations, PNS activity should increase (i.e., an increase in RSA relative to baseline, or RSA augmentation), to allow affiliative and safe social interactions (Porges, 2007). Such RSA augmentation has been found to be associated with adaptive interpersonal emotional functioning such as compassion, emotion regulation, and prosocial engagement (e.g., Butler et al., 2006; Schwerdtfeger & Friedrich-Mai, 2009; Stellar et al., 2015). Based on these theoretical ideas, one possible interpretation of our results is that when clients come to a session with a greater capacity for PNS regulation, the close interpersonal interaction with the therapist, ideally involving experiences such as emotional attunement and a sense of safety, may provide social cues that activate the vagal brake, facilitating more productive PNS efforts (as opposed to unproductive, stress-related SNS responses). This interpretation aligns with polyvagal theory, in that such socially cued increases in PNS activity could lead to more adaptive emotional functioning and to reports of better session quality. However, because the present study did not incorporate an examination of in-session interpersonal dynamics, more work is needed to test this interpretation.

Limitation, Future Directions and Clinical Implications

Overall, these findings suggest that resting RSA can serve as a biomarker of clients' fluctuating depression from session to session. They also suggest that the interaction between resting RSA and RSA reactivity can serve as a biomarker of the therapeutic process and that this biomarker may be associated with session quality. However, these findings should be considered in light of the study's limitations. One limitation is that we did not account for the contextual factors in which the physiological dynamics occurred. Recent research has underscored the importance of such factors, including clients' emotional experiences (e.g., Bar-Kalifa et al., 2023) and the quality of the therapeutic alliance (e.g., Blanck et al., 2019). Future studies should examine whether the RSA patterns identified here are moderated by these types of contextual variables. For instance, productive emotions (e.g., compassion, grief, or positive emotions) may be linked to RSA augmentation, whereas unproductive emotions (e.g., global distress or rejecting anger) may be linked to RSA withdrawal. In addition, consistent with the interpretation suggested above, higher levels of the therapeutic bond may be associated with RSA augmentation, compared to lower levels of this bond.

Another limitation is that we focused solely on PNS biomarkers as indicative of affective regulation dynamics. Examining the combination of PNS and SNS activities simultaneously could potentially strengthen the validity of using physiological measures to identify therapeutic processes. Recent studies suggest that regulation dynamics occur across multiple modalities (e.g., Paz et al., 2024) and in both the client's intrapersonal as well as the client-therapist interpersonal space (e.g., Goren et al., 2025). Therefore, future studies should incorporate other modalities, such as clients' movement cues or vocal arousal, as well as parameters related to the ongoing interactions between clients and therapists, such as synchrony or coregulation. This would provide a more holistic view of the therapeutic processes and provide a better understanding of markers of intrapersonal and interpersonal dynamics associated with beneficial outcomes.

It is important to note that the data for this study were drawn from a broader project examining clients diagnosed with MDD undergoing supportive expressive therapy (SET). At the same time, the final analytic sample was reduced due to design- and data-related constraints (see Method section). This relatively small sample size may have limited our ability to detect between-client effects and should be considered when interpreting the findings. Future research with larger samples is therefore needed to replicate and extend our findings, particularly with respect to the conclusions drawn above regarding resting RSA as a potential state-like biomarker of depression. More broadly, to make our results more generalizable, future research should explore RSA and its association with outcomes in other populations and in other psychotherapy approaches. In addition, in this broader project, depressive symptoms were only assessed before the start of each session, which precluded examining depression as an outcome measure. Accordingly, future studies should assess depressive symptoms both before and after each session, thus allowing for the examination of session-level changes in depression and their potential associations with the interaction between resting RSA and RSA reactivity. Furthermore, since resting RSA was assessed in a naturalistic psychotherapy setting, the baseline measurement may

have been shaped to some extent by the clients' anticipatory responses. While this approach enhances ecological validity, future studies should further examine how the timing and context of assessment influences resting RSA when used as a biomarker of depression severity.

Nonetheless, the current findings have clinical implications that point to the value of integrating RSA indices as biomarkers for monitoring purposes and to gain insights into more implicit within-session therapeutic processes. The ongoing monitoring of clients' RSA patterns could provide therapists with valuable information about their clients' affective regulation dynamics and their interventions. For instance, if a client demonstrates a higher resting RSA at session outset, this may be indicative of a greater PNS regulation capacity and a potentially less depressive state, which may in turn prompt therapists to incorporate more expressive interventions within the session. Conversely, lower resting RSA levels, which may be indicative of lower PNS regulation capacity, might suggest the need for more supportive interventions.

Recent advances in non-invasive physiological monitoring, coupled with feedback-system technologies, offer practical tools that have yet to be fully integrated into psychotherapy clinics. Monitoring clients' (and therapists') physiological dynamics can be done with relatively simple, inexpensive devices (e.g., wearable heart rate monitors or finger-pulse oximeters) that require only a few seconds of setup before each session. These systems can feed data in real time to a tablet or computer dashboard in the therapy room, providing continuous recordings of clients' physiological dynamics.

Over time, accumulating session-by-session physiological profiles may help therapists and supervisors detect stable patterns (e.g., clients whose PNS activity consistently dips at mid-session) and fine-tune treatment plans. In routine practice, therapists might review a brief physiological summary at the start of each session to guide their in-session stance more sensitively. Such an approach could enhance therapist attunement to clients' affect regulation dynamics, ultimately improving therapeutic process and session quality.

Nevertheless, therapists can benefit from attending to clients' physiological regulation even when direct physiological monitoring is not available. By cultivating greater awareness of clients' affective regulation dynamics, therapists may more effectively spot nonverbal cues, understand how clients' emotional states influence the therapeutic relationship, and respond in a more attuned fashion. Importantly, the goal is not to modify the clients' regulation dynamics itself, but rather to utilize such understandings to enhance therapists' recognition of affective processes, such as physiological reactivity, and how these influence clinical quality.

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Notes

[1] Note that there are inconsistencies in the literature in the way RSA reactivity is calculated, with some studies computing it as subtracting RSA during demanding situations from baseline RSA (e.g., Bar-Kalifa et al., 2021; Gentzler et al., 2009), and others subtracting baseline RSA from RSA during demanding situations (e.g., McLaughlin et al., 2015; Susman et al., 2025). In this study, RSA reactivity was defined in consistent with the former approach.

[2] The association between baseline phase duration and baseline RSA score was -0.341.

[3] Although clients were nested within therapists, the distribution of clients per therapist was sparse, making it unfeasible to include therapist-level nesting in the multi-level models.

[4] All multi-level models included both unstandardized and standardized estimates; both are reported in the results tables, with the standardized estimates obtained by standardizing the variables prior to model estimation serving as the primary measure of effect size (Baldwin et al., 2014).

[5] To rule out the potential influence of baseline phase duration on the model 1 findings, we also ran the same model with the baseline duration as a covariant. The main effect for baseline duration was not significant, and the effects of resting RSA (i.e., GMC and MC) remained the same.

[6] Notably, Battaglini et al. (2024) did not find a significant association between resting RSA and depressive symptoms in a sample of adolescents.

[7] Although, another possible explanation for the null findings reported by Susman et al. (2025), in contrast to the current study, may lie in the heterogeneity of diagnostic groups and/or differences in participants' developmental stages.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Supplemental data

Supplemental data for this article can be accessed online at https://doi.org/10.1080/10503307.2026.2621741

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